

Email Dialogue Journals in a College Calculus Classroom: A Look at the Implementation and Benefits

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Teaching mathematics for understanding rather than rote learning has increased the number of college mathematics professors utilizing writing into their classrooms. These writing activities focus on student kept journals, writing papers, and answering essay questions. This paper discusses a particular writing activity, that is, dialogue journal writing, and its incorporation into a collegiate level Calculus 1 course. Dialogue journals involve students and instructors in timely bidirectional communications. The goal is to provide a forum for private interaction, devoid of censorship, retribution, or evaluation, where the concern is on content and not on prose. In particular, this essay identifies how (a) email dialogue journals provided a viable means of individualized, continual contact with students in a large class, (b) students benefited from asking questions and receiving timely explanations, and (c) the instructor received frequent feedback for course improvement.

The trend toward teaching mathematics for understanding rather than rote learning, according to Turner (1989), Sierrett (1990), and Meier and Rishel (1998), has increased the number of college mathematics professors utilizing writing into their classrooms. Sipka (1990) identified a variety of writing activities classifiable as either formal or informal in nature. The formal activities include the development of proofs, process papers, summaries, solutions to journal problems, research papers, and lecture notes. Informal activities include in-class writing whether it be focused or free, math

autobiographies, reading logs, journals, and letters. This article focuses on a particular type of journal writing activity, email dialogue journal writing, and how it fosters communication between calculus students and an instructor while minimizing the amount of additional work placed on the instructor. Additionally, the paper provides an example of the "inter-active" instruction, identifies the benefits of the email medium, and summarizes the information gathered from the journals.

A variety of researchers identified student journals to be a powerful methodology for aiding students in their learning of mathematical subject matter (Bell & Bell, 1985; Borasi & Rose, 1989; Carter, Ogle, & Royer, 1993; Davison & Pearce, 1990). Beyond impacting performance, student kept journals positively impact attitudes (Davison & Pearce, 1990; Shatzberg, 1989). Journals aid in fostering an atmosphere where the students and the teacher become a community of learners (Gordon & Macinnis, 1993; Britton, 1990) as well as enhance students' metacognitive abilities (Kreft, 1984; Nahrgang & Petersen, 1986; Stanton, 1984). These enhancements result from actively involving students in their own learning process, forcing students to synthesize information thereby inducing an awareness of what they do and do not know, and pointing students' attentions toward their own learning styles and strengths (Lim, 1987; Talman, 1990). Journals also benefit the instructor. In particular, they open the lines of communication between the teacher and the students while personalizing the learning environment (Lim, 1987). The instructor gains a wealth of student-generated information as to common error patterns, insights into instruction, and indications of misconceptions (Drake & Amspaugh, 1994). This diagnostic information arms the instructor with data for changing the scope and depth of the instruction prior to assessing students in a forum which may adversely impact their grades.

Even though considerable evidence for the inclusion of journal writing as an assessment tool in the mathematics classroom exists, some questions remain. For instance, Meier and Rishel (1998) identify a variety of reasons why they do not incorporate journal writing in their classes. These objections include: (a) spending time reading through a lot of "garbage," that is, ill-formed ideas and commentary, (b) diminishing the classroom dialogue, (c) presenting unfocused journal assignments such as "Keep a journal," (d) allowing students to define ideas which may be mathematically incorrect without them being addressed, and (e) shifting the focus from mathematics to students' feelings for assignments or other course aspects. In particular, Meier and Rishel (1998) point out that their major concern deals with the lack of focused direction for the journal writing activity. Additionally, considerable cost is incurred when reading and responding to student journal entries as well as addressing the various organizational issues identified.

They do believe that the effective use of journals is possible as long as one addresses the identified issues and formulates a means of providing reasonable feedback to students as well as evaluating the students' submissions. In particular, they express concern as to maintaining the focus of the journal assignments and submit that reasonable journal prompts could be similar to "Keep a journal...and such a journal should contain such things as transcripts of classroom discussions, questions you have, ideas you were mulling over on the way to class, points you still don't get and want to raise, notes as to what is and is not 'working' for you, and other topics as they occur" (Meier & Rishel, 1998, p. 23). In addition, Meier and Rishel point to issues concerning the maintenance of classroom discussion and the description of the scope, audience, procedures, and grading policies associated with the journal writing activity to the students. This paper describes how dialogue journals address the concerns raised while dynamically engaging the students with the mathematics they are learning.

WHAT ARE DIALOGUE JOURNALS?

Dialogue journals take the journal writing activity one step further and address the concerns raised by Meier and Rishel. The focus of dialogue journals is on establishing a bi-directional conversation between the students and the instructor whereas journal writing tends to be uni-directional communication from student to the instructor (Tieney, Readee, & Dishner, 1985). As a result, dialogue journals foster timely discourse between students and the teacher (Atwell, 1984; Calkins, 1983; Graves, 1983; Rose, 1990). Stanton (1980) indicated that the goal of using dialogue journals is to provide a forum for the student and teacher to interact in a private setting that eliminates any concern about censorship, retribution, or evaluation. At this level of interaction, the concern should be less about concisely formed prose and more on the interaction's content and the thinking underlying the conversation.

In 1964, Leslee Reed originated the idea of dialogue journals as a means of promoting genuine communication between herself and her 6th-grade students. Reed incorporated these journals to get to know the students, obtain feedback, improve classroom discipline, and involve students in a personalized reading and writing activity (Stanton, Shuy, Kreft, & Reed, 1987). This activity engaged the teacher and student in writing entries in a bound composition book. The resultant correspondence took place over time and in response to issues initiated by the student. In the process of correspondence, the teacher answered questions, introduced new topics, and

asked questions. Such an interaction engaged students in reading and writing about topics of their interest and provided students with support, insight, and feedback in a non-threatening manner.

Researchers have identified some additional benefits beyond those mentioned above. Dialogue journals provide opportunities for the student to reflect about experiences and examine, with an adult, choices, problems, and ideas (Stanton, 1984). The generated texts stimulate conversation at a deeper level than those generally produced in the classroom (McGrath, 1992, Rose, 1990). In addition, the exchange presents students with higher level explanations of concepts and techniques than would be normally read from textbooks (Gambrell, 1985; Stanton, 1986). Such interaction yields opportunities to tailor instruction to students' individual needs (Payton, 1993).

The implementation of dialogue journals in the collegiate mathematics classroom achieves many of these benefits. Specifically, dialogue journals aid in the acquisition of mathematical language and enhance mathematical writing skills while promoting students to examine mathematical ideas and communicate about the concepts and the processes involved (Linn, 1987, Rose, 1990). In addition, the particular implementation of dialogue journals discussed in this paper reveals benefits such as evoking reflection on the course by the students and the teacher, opening lines of communication in a large lecture class, answering student questions, guiding the development of student understanding, gathering relevant course-related information, and monitoring course aspects.

HOW DOES EMAIL FIT IN?

At the collegiate level and in such a technology-oriented age, most students have reasonable access to computers and email facilities. Email, however, is not the sole medium for journal transference since three other viable means of delivery exist: "chat" modes in online electronic environments, paper-based manuscripts, and electronic bulletin boards. Each of these competitors has advantageous as well as disadvantageous aspects. In order to compare the various methods of conveyance, it is essential to identify the components necessary for effectiveness. First, the medium must permit private and spontaneous communications between the student and the instructor. Beyond this, the byproducts from the agency of communication must be easily archived, resource-friendly, and supportive of the transmission of complex mathematical symbolization. Table 1 compares email with the three competitors on these required components for effective dialogue journal transference.

Table 1
Effectiveness Requirements Satisfied (✓) by various media.

Effectiveness requirement	email	"Chat"	Manuscripts	b-board
1. Private	✓	✓		
2. Spontaneous interaction	✓		✓	✓
3. Easily archived	✓			✓
4. Resource-friendly	✓	✓		✓
5. Math symbols	✓		✓	

One noteworthy reason that email, as a vehicle for transmission of the dialogue journals, is better than these other possible choices is due to its inherent privacy. Online "chat" modes maintain this privacy; however, bulletin board postings are in the public domain and paper-based manuscripts generally require a central repository for transference making it difficult to ensure complete privacy. With respect to spontaneity of the interaction, all the mediums with the exception of online "chat" modes permit the students and the instructor to engage in dialogue construction whenever they would like. The "chat" mode forces the conversation into a scheduled routine rather than a spontaneous interaction since both participants need to simultaneously be in front of their respective computer screens. Archival is another component where the "chat" mode and paper-based manuscripts are inferior as a means of conveyance. The online nature of the interaction hinders the capture of the dynamic conversation with the "chat" mode and written documents pose problems by requiring physical storage facilities. All the mediums, except for paper-based manuscripts, are resource-friendly in the sense of the consumption of natural resources. However, paper-based manuscripts, unlike the other mediums, directly support the use of complex mathematical symbolization. Of the email, "chat," and bulletin board modes of transference, only email, at present can include enclosures created in programs supportive of complex mathematical symbols.

As a result, email's inability to directly support mathematical notation is not necessarily detrimental. Initially, students need to focus on expressing their mathematical difficulties using informal language. As the sophistication of the students' mathematical lexicon grows, students can engage in technical writing using word processing programs, for example, *Text*, *Word*, or *WordPerfect*, or computer-algebra systems such as *Mathematica*™ or *Maple*™. Students can still maintain email as the means of conveyance but at the same time transcend the syntactically limited email platform. The resulting journals can include enclosures containing a rich blend of informal language and diverse mathematical representations.

HOW WERE THE JOURNALS USED?

For one semester, 85 students were participants in a Calculus 1 course taught at a mid-sized, nationally-recognized, private university in one of the Mid-Atlantic states. The course was part of a larger scheme in which three instructors, teaching a total of about 400 students, collaborated to organize lectures, design tests, and develop scoring criteria. The students met five days a week, three of which were in a large lecture with the professor. During the other two days of the week, smaller groups of approximately 30 students each met for recitation meetings with a graduate teaching assistant. In addition to incorporating journals in one of the instructor's sections, this course was the focus of a variety of innovations: (a) the requirement that students own and use a graphics calculator, (b) the incorporation of presentations utilizing the graphic calculator, (c) the usage of proficiency testing, and (d) for those scoring below 70% on any unit test, the implementation of error analysis of student responses to the unit test, remediation assignments, and allowance of retesting on the unit test's materials. These innovations were incorporated to reduce the failure rate and to ensure students developed reasonable understandings and skills thought necessary to excel in Calculus 2.

It was of concern to establish regular interaction and have the students value the journals. As a result, the submission of a journal was part of the requirements of the course and accounted for 10% of the students' final grades. Journal entries were due every Monday of the semester and had to contain at least three sections. The first section summarized the previous week's lectures. The second section explicated the student's difficulties with any aspect of the course. The third section delineated the student's action plan to overcome the difficulties and indicated to the instructor the need for help or suggestions.

The students submitted their journals either electronically via email or in a written format. In particular, of the 82 students submitting at least one journal entry, 27 students exclusively used email, 6 students exclusively used paper-based mediums, and 49 others mixed both email and paper-based mediums. Collapsing this data into the displays of Figure 1 revealed detectable trends in the number of students submitting a journal each week and the percentage of those submissions being transferred via email or a paper-based medium, that is, hand-written or typed manuscripts.

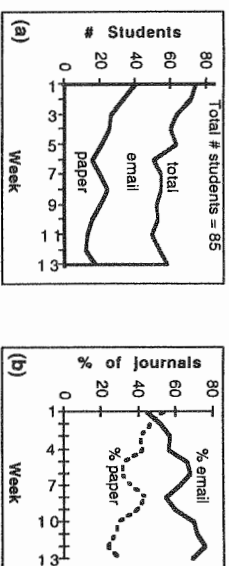


Figure 1. Journal submission rate and format over 13 weeks of the course. (a) Total journal submission divided by format. (b) Percent of journals submitted in each format.

As can be seen from Figure 1a, the submission rates fluctuated throughout the semester with the peak occurring for the first week and the valley occurring for journal 11 (Note: The week of Thanksgiving break). Interestingly, a significant positive correlation ($r(85) = .368, p < .001$) was found between the number of journals submitted and the students' combined averages on the unit tests, a proficiency exam, and the final. Even though this result does not have causal implications and may be attributable to conscientious students, the positive correlation could indicate that increased interaction addressed the students' difficulties prior to assessment. In addition to the fluctuation in the submission rates, Figure 1b also revealed fluctuations in the methodology of submission, that is, email or paper-based. In general, there was an increasing trend toward students' usage of email as their methodology of transference.

Even though students submitted their journals either via email or paper, the instructor's responses always came through email. The reason for this was that email was reasonably accessible to these college students and was more effective than the other possible transference choices. In addition, the use of email as an informal form of communication fostered an atmosphere less concerned about producing grammatically correct sentences and more attentive to conveying thoughts and meanings. As a result, the utilization of email as the primary vehicle of transmission of the dialogue journals appeared quite beneficial in maintaining personalization while keeping the focus on the mathematics of the course.

This personalization arose from the provision of a response to each student's journal entry. Accomplishing this took approximately three to four

A significant portion of the students (22% of the respondents) indicated that the limit concept was problematic. As a result, the limit concept was considered a *common* difficulty and this student along with the other students identifying this as a difficulty, was told (see part (A) in Figure 2) that the topic would be addressed in a hand-out and discussed in class. The discussion presented in part (B) of Figure 2 was in response to Bonnie's identified difficulty with continuity. The instructor sought to clarify the issues raised and present a reasonable discussion in language accessible to Bonnie.

Bonnie's Discussion of "Overcoming Difficulties"

At the conclusion of Bonnie's journal, she delineated the ways she was going to overcome her difficulties when she stated: "...To overcome my difficulties, I read chapter 1 thoroughly, but I still was confused. Therefore, I am going to go to the free calculus tutoring session, and if I still don't understand, I will email Professor Meel or my TA for an appointment." Having students verbalize an action plan forced them to actually consider what they need to do to address their difficulties. Rather than the focus being on what someone else should do for them, students received encouragement to consider what methodologies would allow them to overcome their difficulties.

Bonnie's journal provided a case study of many of the students' journals. For some of the dialogue journals, the interaction did not stop here but extended to address additional issues. Bonnie's continued journal interchange will provide an illustration of how the dialogue journal permitted students to extend the conversation.

Continuation of the Interaction

For many of the students, the interaction would end with the instructor's response; although for some, the acknowledgement of receipt brought an additional opportunity to ask questions or have concerns addressed. The following interaction with Bonnie exemplifies how the interaction extended resulting in discussion of additional difficulties. These concerns may have existed previously but were not articulated or they arose as a result of the instructor's response to her journal. In either case, the instructor's response provided an opportunity for her to continue her engagement in the personal dialogue.

Thank you for explaining continuity. I think that I understand now. Like you said, my previous Calculus books have always defined discontinuity as a break in the graph. I was wondering if I could still make an appointment with you because I am also having problems with a few of the other theorems (notably the sandwich theorem and the intermediate value theorem). Also, why does $|f(x) - L| < \epsilon$ whenever $0 < |x - a| < \delta$ prove limits? I have class during your office hours except on Friday, so perhaps I can make an appointment then. If you are not available then, is it possible to meet at another time? Thank you for your help. I really appreciate it.

In this message, it became apparent that Bonnie sought additional clarification concerning limit concept issues. The instructor, instead of providing a detailed response over the email medium, provided a cursory explanation which pointed out a problem in the student's thinking concerning limits, that is, her belief that " $|f(x) - L| < \epsilon$ whenever $0 < |x - a| < \delta$ " proves limits and arranged for a meeting to discuss the student's difficulties.

Glad I could help. As for a meeting, I can meet with you anyday [sic] except from 10:00 am to 12:00 on Tuesday's [sic] and Thursday's. I think it would be best to attempt to get together to talk about your difficulties sooner than later. I could meet with you tomorrow afternoon if you like; however, if Friday [sic] afternoon is the only time you have available then I'll write you into my calendar. Write me back one way or the other. Concerning " $|f(x) - L| < \epsilon$ whenever $0 < |x - a| < \delta$ " proving limits, it is not necessarily that this statement proves it but does so when coupled with the additional condition that this relationship holds for any ϵ . This requirement has been used as the formal definition of the limit because of the insidious [sic] nature of considering infinity. Rather than tackling infinity, mathematicians have chosen to show that for all practical purposes, the two values are equivalent.

Arrangements for a meeting then became finalized in an additional interchange of mail. In this final exchange, Bonnie made the following comments "Thanks again, email is [sic] really works well at CMU. Anyhow, tomorrow is fine. My last recitation ends at 11:20, so anytime after that is all right." Bonnie's comments illustrated how the use of email can work as a means of fostering communication between an instructor and a student. In addition, the interactions provided an example of how dialogue journals address many of the concerns raised by Meier and Rishel (1998) since they avoided the potential "garbage," provided focused instructions, addressed students' mathematical misconceptions, and focused the discussion on the mathematics.

RE-USING MATERIAL FOR EFFICIENCY IN WRITING RESPONSES

After examining the email dialogue journal interaction between Bonnie and the instructor, one might wonder how such protracted interactions did not require more time than three or four hours a week. In a word, the answer is replication. The above exchange of messages included a long missive, presented in Figure 2, responding to Bonnie's questions concerning continuity. As was the case with many of the student difficulties, she was not the only one with continuity concerns. For example, two additional students, Mark and Jennifer, indicated difficulty with continuity issues. The instructor responded to the two of them with individualized messages (see Figure 3) containing replicated material from the message to Bonnie shown in Figure 2.

Response to Mark	Response to Jennifer
I was reading your journal and it indicated that you were having difficulty with the concepts of continuity and discontinuity. Perhaps I can write a few things that would aid you in conceptualizing these two things:	I was reading your journal and it indicated that you were having difficulty with the concept of continuity. Perhaps I can write a few things that would aid you in conceptualizing continuity and discontinuity:
(A) same as Bonnie (see Figure 1) With respect to polynomial functions, new material...	
I am quite willing to speak with you further concerning these matters. Actually, I want to encourage you to set up an appointment with me.	I am quite willing to speak with you further concerning these matters. Actually, I encourage you to set up an appointment with me if you want.

Figure 3. Illustration of instructor's re-use of written explanations in responding to individual students insert Figure 3 about here

Such replication permitted the instructor to address the students' individual needs in a personalized manner while only developing a small set of general responses. As a result, the instructor could reduce time expenditures while showing concern for each individual.

These interactions exemplify how email dialogue journals engendered an atmosphere where the student and the instructor could communicate, in an informal manner, about calculus issues. Even though part of a class of 85, students knew they would have timely dialogues with the instructor rather than intermittent contact available during office hours. Such an opportunity allowed students to have their questions or concerns addressed prior to assessment. In particular, providing the opportunity to communicate

with the instructor through dialogue journals allowed each student to engage in diagnosing his or her potential problem areas and then to receive individualized instruction, which proactively addressed those problems prior to negative effects on performance. Beyond student-developed diagnoses, the requisite action plans forced students to consider how they would address their difficulties. This process cajoled students into thinking about mechanisms which would aid in overcoming their problems. However, students were not the only ones benefiting. The instructor received information about a variety of course aspects.

WHAT DID THE STUDENTS TELL THE INSTRUCTOR?

The journal directions, by design, encouraged students to look back at the ideas discussed in the previous week, reflect upon those, and consider their understandings of the material. In addition to accomplishing the feat of getting students to review the course notes and consider what problems they had when working on the homework, the students' responses in the journals informed the instructor of a variety of issues which were evident to students but unknown to the instructor.

The Students Summarized the Topics They Thought Were Important for the Week

The activity of having the student summarize the issues discussed in the previous week's lectures compelled the students to be reflective on the material. The provided summaries ranged from a mere recitation of the names of major topics to detailed summaries, which delineated the major topics and included explanations and commentaries. The two examples shown below illustrate the varying levels of summary provided by students for the thirteenth week of class.

Recitation of the names of major topics only. During the past week we covered the ways to find [sic] the Area between Curves, Exponential Growth and Decay, Hyperbolic Functions, and the Volume of Solid Revolution (Disk & Washer's methods).

Recitation of the names of major topics with both explanations and commentary. This past week, we covered the area between curves, hyperbolic

functions, growth and decay, and revolutions. By subtracting the area of one curve from the area under the curve above it, one can find the area between the two curves. The upper function must remain greater than the lower function over the entire interval. In general, when $f(x)$ is the upper function and $g(x)$ is the lower function, the area between $f(x)$ and $g(x)$, over the interval a to b can be expressed as the integral of $[f(x) - g(x)] dx$ from a to b . Trigonometric functions are based upon the unit circle, $x^2 + y^2 = 1$. Hyperbolic functions are based upon the "unit hyperbola," $x^2 - y^2 = 1$. A given point on the hyperbola is called (cosh t , sinh t). Knowing the derivatives and integrals of these functions can come in handy when solving integrals. Growth and decay problems are most often encountered when computing continually compounding interest, or the staggering growth of bacteria. The value (V) after growing or decaying at a rate of n can be expressed as $V = I$ (initial amt) e^{rt} . When computing interest, this equation can be modified to $V = P$ (principal) e^{rt} (r = interest rate * time). The last topic we covered last week was revolutions. The disk and washer methods of finding the volume of the solid formed by revolving the area under a curve around a given line. The basic formula for revolutions is that the volume is equal to the integral of the area (washer, disk, shell, etc.) from a to b . The area of a disk is $\pi * R^2$. The area of a washer is $\pi (R^2 - r^2)$. Then you have to determine whether you need to integrate [sic] along the x or y axis (dx or dy) and express your area accordingly. For instance, for a nonnegative function, $y = f(x)$, evaluated over the interval a to b , and revolved around the x axis, the volume of the resulting solid can be expressed as $\pi * \int_a^b [f(x)]^2 dx$ from a to b .

The variety of scope and depth provided in the students' summaries indicated that students reviewed their notes once a week at least at a cursory level and at best an extensive level which included the review and arrangement of understandings. Interestingly, a significant positive correlation ($r(85) = .295, p < .01$) existed between students' general summary types and their combined performances on course assessments, for example, unit tests, proficiency exam, and final exam. This journal summary type is a numerical value constructed by first identifying the level of detail provided in students' journal summaries and then averaging the weightings associated with the levels across the submitted journals. In particular, the students' summaries received codings in accordance to the following scheme: (a) no summary provided (0 points); (b) recitation of the names of major topics only (1 point); (c) recitation of the names of major topics with some explanation (2 points); and (d) recitation of the names of major topics with both explanations and commentary (3 points). From these weightings, each student received a generalized numeric characteristic score formed by summing the codings for each submitted journal and then dividing by the number of

submitted journal entries (Note: The journal for week #12 was omitted for the analysis since the journal directions did not require the inclusion of a summary). As a result, the characteristic score could range from 0 to 3 and the greater the characteristic value the more prevalent the use of explanation and commentary. Even though this result does not have causal implications, it was interesting to find that a positive correlation existed between the characteristic summary type and assessment average.

The required journal entries and their included summaries compelled students to look at their notes prior to a test. As a result, the journals forced students to stay current with the course material that tends to be a difficult task for many students without provided incentives. The student summaries identified the main topics discussed in class and these could be compared against the topics the instructor considered most essential. From this, the instructor was able to determine if the students were omitting a topic considered important to the instructor. In addition, the summaries carried information that provided clues as to the linkages the student had built and indicated the students' foci on the material, that is, whether it be on the conceptual components or the computational aspects. This information permitted the instructor to adjust his presentations, thereby better preparing students for assessments.

The Students Identified Difficulties with a Variety of Calculus Concepts and Techniques

The most dominant difficulties expressed by students dealt with the mathematical aspects of the course. Weekly analysis of students' statements of mathematical difficulty allowed the instructor to take a proactive role by addressing problems prior to assessment. In order to accomplish this, the instructor identified and compiled a listing of the difficulties students mentioned in their journals. From this index, the instructor classified the difficulties into two categories, *common* difficulty (a difficulty named in at least 10% of the entries) and *less common* difficulty (a difficulty named in less than 10% of the entries). These groupings proved useful to the instructor for gauging if a topic would need to be re-addressed or if only a handful of students needed further explanation. Depending on the pervasiveness of the difficulty, the instructor would address the students' needs through a personal message similar to the instructor response presented in Figure 1, a class discussion at the beginning of the next class meeting, or a hand out. As can be seen from Table 2, the difficulties mentioned by students generally pointed to issues and topics associated with each week's set of primary topics and techniques.

Table 2
Common and Less Common Difficulties Evident From
the Student Journals

Week	N	Common Difficulty ($\geq 10\%$)	#	Less common Difficulty ($< 10\%$)	#
1	75	Trigonometric Identities Exponential & Logarithmic Functions	19 8		
2	72	Concept of limit	16	Definition of limit Solving limit problems (algebra) Squeeze Theorem Continuity (domain vs. interval)	6 4 4 4
3	64	Chain rule	7	Implicit differentiation	5
4	61	Logarithmic differentiation	16	Implicit differentiation	6
5	64	Related rates Differentials	28 8	Approximations (Linear and Quadratic)	5 5
6	51	Maxima and minima	7	Mean Value Theorem Higher-order differentiation	4 3
7	51			Curve sketching Related rates	5 4
8	56	Applied extrema	10	Maxima and minima	4
9	56			Definite integrals	3
10	56	Riemann area method Summation notation Substitution method of integration	15 13 9	Fundamental Theorem of Calculus	4
11	54	Integration by parts	6	Choosing method of integration Substitution method of integration Riemann area method Complex integration	4 3 3 3
12					
				<i>Thanksgiving</i>	
13	50	Disk method Shell method Hyperbolic functions	9 6 12	Exponential growth and decay	4

Note: This table identifies the week, the number of students submitting a journal (N), the type of common difficulty and number of students indicating that difficulty (#), and the type of less common difficulty and number of students indicating that difficulty (#).

The *common* difficulties generally focused on the global issues of the course such as precalculus, the limit concept, complex differentiation especially with embedded functions, applications of differentiation to extrema problems, Riemann integration, and methods associated with volumes by revolution. The *less common* difficulties tended to be less global than the expressed *common* difficulties for students mentioned more specific aspects of a concept. For example, difficulties with particular aspects of the limit concept (definition, techniques, and applications) were evident as were difficulties with differentiation of a function embedded within another function (implicit differentiation, approximations, and related rates). The students also reported particularities of integration (e.g., rules, techniques, and relationships) as problematic. The specificity of these *less common* difficulties permitted the instructor to compose short email responses which addressed the issues.

One might expect that the more difficulties students identify, the lower the performance on the combination of unit tests, proficiency exam, and final. Analysis revealed that there was no significant correlation between number of difficulties mentioned over the semester and the students' combined averages on the assessments ($r(85) = .126, p > .05$). The lack of significant correlation indicates that there is no relationship between the number of identified difficulties and performance. Since the dialogue journals, by design, proactively addressed students' difficulties, the effectiveness of the journals in addressing the students' needs prior to assessment conceivably contributed to this result.

The Students Identified Difficulties with a Variety of Course Aspects

Dialogue journals provided course-level feedback with comments and recommendations to the instructor concerning various aspects of the course: lectures, assessments, and recitations. For example, students used the journals as a forum to comment about the efficacy of the lectures.

...I think that there has been a really clear presentation of what can be a confusing and hard to visualize topic for some people. Revolutions can be hard because you have to be able to visualize the solid and then see which method would be best to use. The in-class examples have been good.

Students also supplied constructive criticism to the instructor concerning classroom behaviors of which he was not aware. For example, one student

mentioned the following: "...during class there are occasions that myself and other students have questions for you. Unfortunately, after you are done talking, you turn around and our hands go unseen and questions unanswered."

Such criticism permitted the instructor to adjust his classroom behaviors in the large lecture hall and made the instructor more aware of this hindrance to meaningful classroom interaction. The dialogue journals empowered the students to convey to the instructor some real problems that were largely invisible to the faculty. For example, one student made the following criticism:

...The graders should be taught that there is more than one solution and should be willing to give partial credit on the other methods, and they should be taught ethics, and that getting one part wrong doesn't constitute taking off points on the rest of the question....

Bringing this issue to the attention of the instructor resulted in an analysis of the departmental exams and the grading policies issued to the teaching assistants. This analysis resulted in the development of a clearer set of instructions provided to the graduate teaching assistants who were grading the student responses to the test items.

In addition, the journals provided invaluable information about what was going on in the recitation sections from the students' perspective. For example, students wrote the following early into the semester:

...In recitations, we went over L'Hospital's rule and did some practice limits ... I am having trouble with some of the new notation and symbols that my teaching assistant is using and also with some of the terminology, (i.e. "putative limit").

...As to the recitations, I honestly have stopped going. We don't go over anything that pertains to the lecture material. I understand everything that you do in the lecture since I have had calculus before, but the TA seems to think that we are in modern math and wants us to prove why numbers exist and other things like that.

...Oh, one thing, it doesn't seem like the recitations go along with the text. It seems like he's talking about different stuff than what is discussed in the lecture. What's up with that?

These excerpts revealed that the recitation instructor had been discussing limits using L'Hospital's rule, using different notation, and introducing the foreign concept "putative limit." Commentaries such as these permitted

the instructor to identify problematic areas in the teaching assistant's instruction as well as the TA's tendency to use methodologies and terminology inconsistent with the instructor's teaching. These comments then became the basis of discussion with the recitation leader. Through the conversation, it became evident that the recitation instructor considered the students more advanced than they were. The instructor informed the recitation leader to concentrate on answering the questions posed by the students and to remember that some of the students had never taken calculus before. As a result of these conversations, the recitation leader's presentations improved over the semester as can be seen in the following comments from students:

...At first, I did not find my recitation helpful at all. He was always teaching us exactly what we learned in class, but added all this theory which confused us. However after a while, we started going over a lot of the homework problems and I found that useful.

...Once [he] stopped with the theory crap and started churning out problems, my grade went up. Well, that and I started doing the homework.

Without hearing about these issues from the students, it would have been difficult to gather such information and affect a change in how the recitation leader conducted the recitations.

The Students Reflected on the Process of Learning the Calculus Material

The journal directions encouraged students to look back at the ideas discussed in the previous week, reflect upon those, and consider their understandings of the material. A few students took this opportunity to identify some of their reflections on their own learning processes. For example, one student mentioned the disparity between the requirements of high school calculus and collegiate calculus and concluded: "...the tests we took and the material we covered only had to do with practical applications....I have never dealt with theoretical applications which seems to be the bulk of what we are doing. I have been studying for the tests in a wrong direction."

Other students reflected upon how to improve their calculus grades and wrote about how study habits would need to improve. Such reflection, although sought, did not usually come without explicitly requesting it from the students. For example, one unique journal assignment, given for the week following the Thanksgiving break, was designed to have students reflect on the

course as a whole. The assignment asked students to discuss the most difficult aspect of the calculus course and why they felt it to be the most difficult. The most common responses to this assignment pointed to the courses' conceptual underpinnings. One student pointed to the presentation of theorems and theorems as a stumbling block in the following statement:

...understanding a theorem is more difficult for several reasons (I found). First of all, there are [sic] alot [sic] of unfamiliar symbols/signs within the statement, makes it even harder to analyze the theorem. Secondly, They [sic] are worded "weirdly," in a language that is not simply understood. Lastly, the solutions to the problems we are to solve, do not contain any explanation [sic], but simply an answer. That leaves us (or I) with doubts about the way or methods used in solving the problem if the answers found are not corresponding to the answers stated in the book.

Another student was taking, in addition to the calculus course, an overview course on cognitive psychology. Her discussion revealed she transferred concepts from the psychology course to clearly explicate the origin of difficulties in the calculus course.

...I think the hardest aspect of learning calculus is putting all the information together for tests and just combining it all in general in order to tackle any problem we encounter that involves concepts from calculus....Practice, I think, is probably the best solution to this problem, which is mainly a difficulty of novices. In a class I'm taking, we talked about the difference between experts' and beginners' approaches, and as it turns out, experts, who have a lot of experience, are able to solve problems faster because they recognize much more quickly what type of problem they're dealing with and are therefore able to develop a plan for solution almost at once out of a vast store of knowledge. However, novices could also benefit perhaps from seeing a variety of problems in each section, which focus on a certain concept but draw in other ideas at the same time. I think our calc. books and practice problems in lecture do that to some extent already. Other than that, it is largely a matter of gaining experience.

These two examples provide evidence that journal assignments can encourage students to reflect on the learning process. Assignments such as these, provide a wealth of information about student thinking while promoting analysis of course components and encouraging transfer within and across disciplines.

The Students Sought Clarification to Ideas and Submitted Requests to the Instructor

The nature of the dialogue journal permitted a rapid response that could poignantly address the student's individual need. For instance, one student asked the following: "...In class, I thought you said that absolute extrema can be end points, and that local extrema cannot be endpoints. However, my TA disagrees. So my question is, did I hear you wrong, or is the TA incorrect?" and received the following response:

According to the definition presented on the top of pg. 255 of our text, a local extrema must have an open interval about it which contains the point in question. For a closed interval $[a, b]$, there cannot be an open interval containing points from $[a, b]$ on both sides of an end-point. So, I reiterate [sic] that local extrema only can occur at critical numbers, that is, [sic] when $f'(x) = 0$, or $f'(x)$ does not exist. We do not include the end-points in the discussion of local extrema but do examine them when wondering about absolute extrema. That is, an absolute extrema could occur at a local extrema or at the end points; however, the local extrema can only occur in the open-interval between the end points. As a result, I believe either you misheard the TA or the TA was incorrect. I hope this clears things up.

This example of a student asking for clarification was typical of many of the requests initiated by students; however, many students did not bother to explicitly ask questions since they found that the mere mention of a calculus difficulty resulted in an instructor's response.

Questions about calculus were not the only questions received. Each week there would typically be a few students requesting information concerning study helps, make-up work, and scheduling issues. Thus, the dialogue journal format permitted students to gain clarification about topics and aspects of the course when they needed answers. Opening the lines of communication between the students and the instructor also promoted an atmosphere where students felt that they could contribute ideas, make requests, or provide opinions. For example, a student commented:

...One possible suggestion for the tests is that they are made to be one hour tests, but you can have as much time as you need. This would reduce the amount of rushing through the tests, which I believe, leads to so many careless errors. This would also give us time to make sure we got through the entire test. Since the test is given at night, after most classes are over, I think that everyone would appreciate knowing that

they don't have a time limit. After all, the point of the test is to see if you know the material, not how fast you can do it.

Even though the suggestion caused no changes in policy due to other external constraints imposed on the testing situation, the suggestion revealed that the student displayed concern about time pressures and developed a reasonable argument for the elimination of time-constraints on testing. Other students utilized the lines of communication to make suggestions that would also benefit the entire class. For example, another student showed concern for being tested on the substitution method of integration:

...Could you give us some more tips on how to choose *n*? Also, in class today you suggested that we mix up examples of the different types of integration. Could you give us a take home quiz or a sample quiz with examples like this? I think it would help us understand if we know what we're doing and what we might encounter on the test.

Here, the student was requesting further explanation on a specific integration technique. The dialogue forum became utilized to ask questions whenever they arose in students' minds. Instead of students simply feeling that the dialogue journals were a course requirement that was only due by Monday evening, they started to view them as a viable means of communicating with the instructor throughout the week. These unplanned interactions permitted students to share a variety of questions, concerns, and even jokes with the instructor while receiving timely feedback.

The Students Commented on the Use of Group Assignments and Assessments

For example, concerning the utilization of group exercises and assessment, students supported the continued use of these types of collaborative assessments when they commented:

...I liked the take home quiz we got this week. On the last quiz we had, I did poorly because I made careless errors. On the group work, the other students can catch my mistakes and then we can all learn from the exercise, and get good grades. I'd like to see more of these exercises.

...I liked Friday's quiz because it was challenging. I also liked the fact that we did some group work. It gave me a chance to meet some more of my classmates and share ideas with them.

...I found that working with a partner [sic] on the word problems was very helpful. My mind worked more clearly when I vocalized my thought processes.

Such feedback provided indication that at least a portion of the class was comfortable with the group activities and that they were amiable to a continuance of such activities. Such detailed feedback gave the instructor a viewpoint into the students' desires and permitted the instructor to evaluate the practicality of implementing suggested changes to accommodate the students' needs and desires.

CONCLUSION

The inclusion of dialogue journals where the initial discussion forced students to summarize the class discussions from the previous week, delineate any difficulties, and consider an action plan to address the difficulties was quite beneficial to the students and the instructor in a large calculus I class. The summary forced students to at least review their notes once a week. Many students tend to reflect very little on class discussions until right before an assessment but the journal compelled students to stay at least somewhat current. The section where students identified their difficulties concentrated student thinking on obstacles to their understanding and permitted the instructor to detect and address those difficulties. The action plan personalized the responsibility for addressing the students' difficulties and obliged students to identify what actions they would employ to alleviate their problems.

In addition to forcing students to reflect on the previous week's material, dialogue journals opened lines of communication between the instructor and the students which in turn promoted a sense of communality in the course. The utilization of email as the primary vehicle of transferring the dialogue journals retained the benefit of personalization while limiting both the instructor's and students' extra work. The journals served as private conversations where the student could clearly characterize problems and ask for timely feedback from the instructor. The instructor could then use the response portion of the dialogue journal to privately provide guidance to the student. This guidance extended beyond explanations of course materials to include discussions of methodologies to study, ways of solving problems, and techniques of time management when students brought up these issues.

The vast amount of information provided to the instructor through such a large number of sources yielded a conglomerate which generally was reflective of the entire class. Rather than having a few students providing feedback to the instructor, the journals yielded a wealth of information that was reflective of the entire course, reaching from instruction to all the other important related aspects. By listening to the students, the instructor was able to gather information about how the course discussions impacted students' understandings and attitudes. Information gleaned from the journal entries allowed the instructor to provide guidance at both individualized levels and class levels. The search for major and minor trends allowed the instructor to address student difficulties in manners that minimized time expenditures.

Thus, the dialogue journals aided students in their reflection on the course and provided them with a chance to obtain feedback on issues, which they found to be problematic. Just as importantly, the dialogue journals allowed the instructor to collect information on how students perceived instruction, assessments, and other integral aspects of the calculus course. All of this occurred as a result of sharing bidirectional conversations with each of the students. Conversations such as these humanized the course and made the instructor increasingly approachable and able to know more about the students in a large lecture class than would normally be possible.

IMPLICATIONS FOR MATH EDUCATORS AND OTHER CONSUMERS

The particular implementation of dialogue journals discussed in this paper provides evidence that large lecture mathematics courses also receive benefits from the incorporation of email dialogue journals. Specifically, the implementation yields a variety of benefits not only for the students but also for the instructor such as evoking reflection on the course by the students and the teacher, opening lines of communication in a large lecture class, answering student questions, guiding the development of student understanding, gathering relevant course-related information, and monitoring course aspects. Previous researchers identified many of these benefits from the use of dialogue journals such as reflecting on understandings and other issues (Stanton, 1984), generating insightful conversations (McGrath, 1992), exchanging ideas (Gambrell, 1985), gaining information on student thinking (Drake & Amsbaugh, 1994), and guiding instruction from this information (Payton, 1993).

However, none of these researchers examined the implementation of dialogue journals in large lecture classes with over eighty students. As a result,

this study provides evidence of the possibility and profitability of incorporating dialogue journal writing when managing large groups of students. Also seen from this study was the effectiveness of using email as a means of transferring the journal submissions. Using this medium, the students and teacher communicated in a timely manner and the instructor could reproduce various elements in multiple messages without spending exorbitant amounts of type rewriting or retyping the descriptions or discussions.

This paper has identified a host of benefits resulting from the inclusion of email dialogue journals in both large and small mathematics classes, though several questions arise surrounding the implementation. In particular, additional research needs to be conducted to examine if the dialogue journals are an efficient means of augmenting the course. Since dialogue journals require the expenditure of time, it would be profitable to examine if students receive significantly greater benefits in comparison to less invasive forms of communication. In particular, studies need to further document the effect of dialogue journal writing on students' attitudes, learning of content, and conceptual understanding.

In addition, studies need to address the effect dialogue journals have on the various components involved. In particular, a variety of additional questions deserve attention: What effect does dialogue journal writing activities have on teacher's preparations, thinking about the course, the use of language and examples in the class room, and so forth? How does the dialogue journal writing activity effect the tone and tenor of the classroom discourse? In other words, are students more likely to ask questions during class or are they more inclined to ask those questions in the less non-threatening email journal environment? Questions also arise regarding the level of structure needed in the prompts. Do excessively structured prompts negatively effect students' perceptions of the activity? These questions and others should be examined in order to clearly identify the impact of implementing dialogue journals. However, initial indications from both small and large courses indicate that dialogue journals provide an effective medium for promoting genuine communication, which in turn personalizes the learning environment and benefits both the students and teacher.

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