Using "Seminaring" to Actively Engage Students in a Calculus Class

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Abstract: A seminar brings together a group of learners who have done some advance preparation to discuss their understandings of the topic. This paper includes a description of the implementation and evaluation of the seminar as a cornerstone of a college calculus class.

Introduction

In recent years, mathematics educators have increased the use of active learning strategies in mathematics classrooms as endorsed by Meyers and Jones (1993) who write: "A growing body of research today points to active learning strategies–in which students talk and listen, read, write, and reflect as they become directly involved in the instructional process– as a way to better engage students, cultivate critical thinking, and improve the overall quality of teaching and learning" (frontcover). *Crossroads In Mathematics: Standards for Introductory Mathematics Before Calculus* (AMATYC, 1995, p. 11) includes "Communication: Students will acquire the ability to read, write, listen to, and speak mathematics" as a Standard for Intellectual Development. Under Standards for Pedagogy, this document lists: "Interactive and Collaborative Learning: Mathematics faculty will foster interactive learning through student writing, reading speaking, and collaborative activities so that students can learn to work effectively in groups and communicate about mathematics orally and in writing" (ibid, p. 16).

Meyers and Jones (1993) suggest that active learning makes two assumptions: "(1) that learning by nature is an active endeavor and (2) that different people learn in different ways" (p. xi). They suggest that the key components of active learning include listening and talking to force clarity of thinking, writing, reading, and reflection

This paper discusses a technique called "seminaring" which is designed to promote each of these four components of active learning. Before listening to a lecture or doing problems, student concentrate on reading the text, writing answers to conceptual questions, meeting in groups to discuss their answers to the questions, and agreeing on a group answer to each of the questions. The details of this approach are the key points of this paper.

Theoretical Framework

Each component of active learning involves different ways of thinking and helps student create different mental structures. It is the development of these mental structures that leads to understanding. Hiebert and Carpenter (1992) define understanding as follows:

> A mathematical idea or procedure or fact is understood if it is part of an internal network. More specifically, the mathematics is understood if its mental representation is part of a network of representations. The degree of understanding is determined by the number and the strength of the connections. A mathematical idea, procedure, or fact is understood thoroughly if it is linked to existing networks with stronger and more numerous connections. (p. 67)

Active learning techniques are designed to increase the number of connections students develop among mathematical ideas. In the process, it is hoped that their understanding is relational, rather than instrumental, as described by Skemp (1976). Relational understanding is demonstrated by knowing what to do and why while instrumental understanding involves a multiplicity of rules rather than fewer principles of more general application. Skemp writes: "Instrumental understanding necessitates memorizing which problems a method works for and which not, and also learning a different method for each new class of problems" (ibid, p. 23). The advantages of relational understanding include improved adaptability to new tasks and less dependence on memory. Relational understanding promotes the building of effective connections internally. Active learning techniques are designed to promote just such understanding.

Hiebert and Lefevre (1986) make a similar distinction when they contrast conceptual knowledge which is "knowledge that is rich in relationships" (p. 3) with procedural knowledge which is "composed of the formal language, or symbol representation system ...[and] the algorithms, or rules, for completing mathematical tasks" (ibid, p. 6). They go on to assert that procedural knowledge is meaningful only if it is linked to a conceptual base. One focus of active learning strategies is to develop a firm understanding of concepts. In order to promote conceptual knowledge, Hiebert and Carpenter discuss what must be done instructionally: "Teaching environments should be designed to help students build internal representations of procedures that become part of larger conceptual networks before encouraging the repeated practice of procedures" (1992, p. 79). The use of a "seminaring" technique builds just such an environment in which students concentrate on the development of a conceptual network before focusing on problems.

What "seminaring" is

The seminar brings together a group of learners who have done some advance preparation, including reading, thinking about (reflection), writing about, and solving problems related to a specific topic. Prior to a seminar, students are given an assignment that includes reading and problems. They receive a series of conceptual questions on the assignment to write responses to prior to the next class session. During the seminar time

in class permanently assigned groups meet to discuss their written responses. Students refine their responses based on the group's discussion.

While students are "seminaring", the instructor visits each group identifying common areas of confusion. Subsequently, the instructor orchestrates a whole class discussion on the areas of confusion. At the end of the class, the instructor may collect seminar papers and assess them. Constructive comments encourage students to reconstruct certain aspects of their understanding.

Implementation of the seminar in calculus

The technique of "seminaring" was the primary mode of operation in two sections of Calculus I during the 1996–1997 academic year. On the first day of class, students were given a policy statement explaining the seminaring concept. Emphasis was placed on the goal of actively involving the students in their own learning. Critical to the process would be their willingness to read their textbook carefully and to write thoughtful answers to conceptual questions based on their reading. Students were informed that they would be assigned to permanent groups of size 3–4 for the purpose of discussing their written answers to the seminar questions. These groups also served as study groups in which students helped one another with homework problems and with exam preparation. The groups were assigned based on student input and on information collected by the instructor in order to assure each group had an appropriate mix of abilities. Space does not permit more detail here on group formation.

Each day, students were given a handout detailing the assignment for the next class. This handout contained seminar questions on the reading and a list of problems to try to test understanding. For example, on a section that introduces the concept of derivative, the seminar questions were as follows:

1. The derivative is a function in which the input is a function and the output is a new function. Your friend, Gordo, is confused about this. Describe to Gordo the meaning of the output function in terms of the input function.
2. Under what conditions will the derivative of a function fail to exist at a specific point?
3. Discuss the relationship between a function being differentiable at a point and a function being continuous at a point.

Each set of seminar questions included three questions asking students to reflect on their comfort level with the material, as follows:

1. What questions do you have after studying Section *n*?
2. Were you able to do the assigned problems? Which was the easiest? Why? Which was the hardest? Why?
3. What questions do you have about the assigned problems?

Once in groups students were asked to compare and contrast their answers to the conceptual questions. Once they had reached agreement, one person was designated as

the recorder and wrote a group response to each of the questions. Following this, each group could then discuss homework problems, as time permitted.

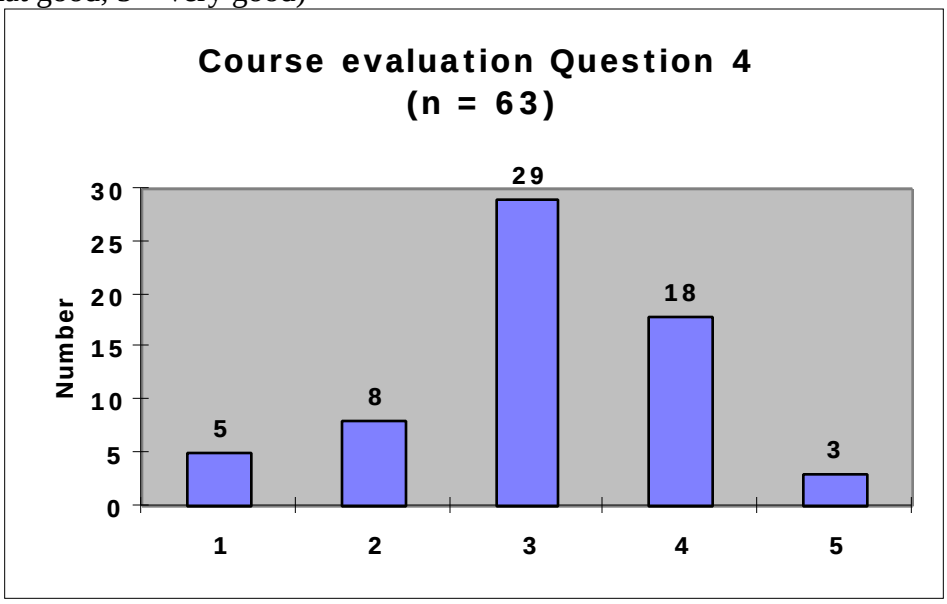
At the end of each seminar, the instructor collected the individual seminar papers and the group seminar response. The group response was graded based on how well the answers indicated understanding of the concepts. Individual papers were checked for completeness. Individual student responses to the "reflection" questions were noted.

Seminars occurred in approximately ninety percent of the class meetings. Lecturing was restricted to those concepts and problems that proved difficult to several groups. While students were in groups, the instructor circulated answering individual group questions and supplying mini-lectures, as needed. A key role of the instructor after a seminar session included summarizing the key points of the seminar and helping students build connections among the various concepts.

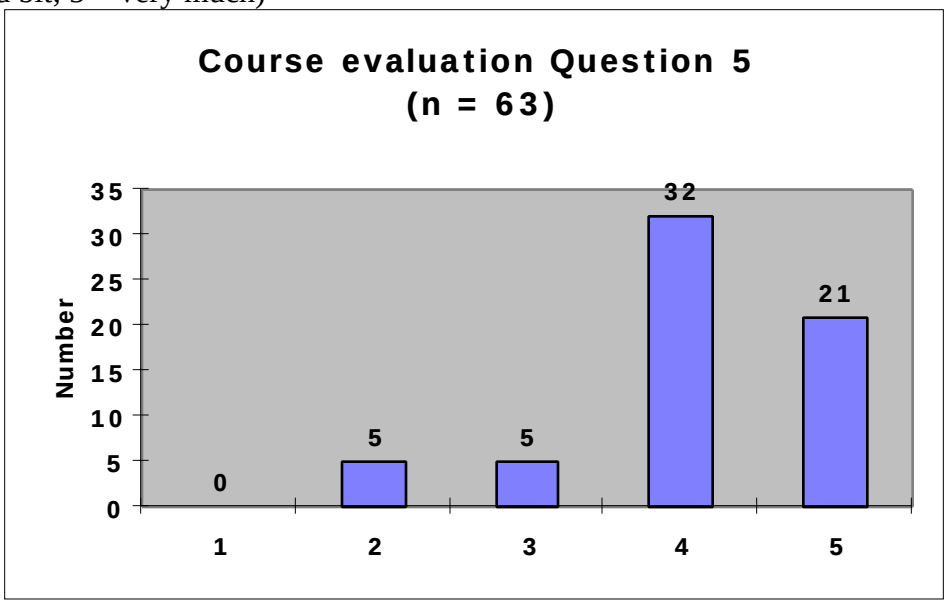
Student evaluation of the seminars

Students completed an extensive, specially-prepared course evaluation at the end of the semester. Included were statements that the student responded to on a Likert scale. In addition, students were encouraged to write comments on each major aspect of the course. The following collection of charts indicate student responses to various questions that relate to the use of the seminar technique.

Question 4: How would you rate **your ability to read and understand a mathematics text at the beginning of the semester**? (1 = very poor; 2 = somewhat poor; 3 = fair; 4 = somewhat good; 5 = very good)

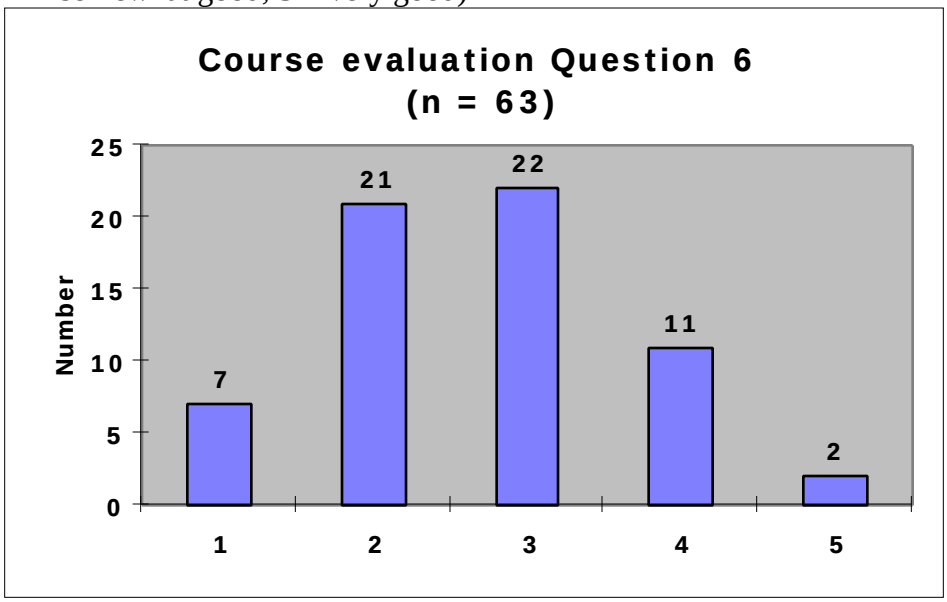


Question 5: To what degree do you think **this course has improved your ability to read and understand a mathematics text**? (1 = not at all; 2 = a little ; 3 = somewhat; 4 = a good bit; 5 = very much)

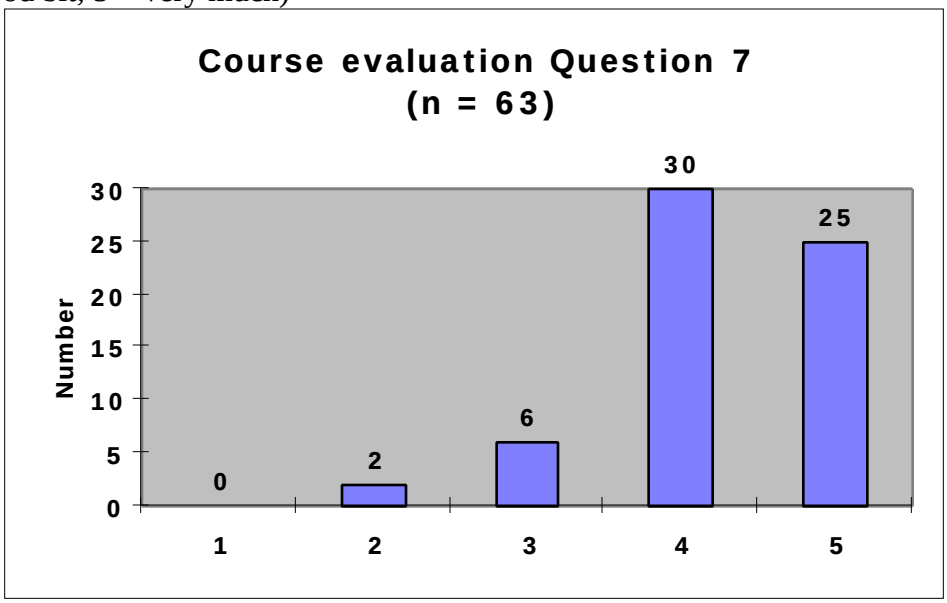


Notice that approximately 84 percent of the students indicated that their ability to read and understand a mathematics text had improved a good bit or very much.

Question 6: How would you rate your **ability to write about mathematical concepts at the beginning of the semester**? (1 = very poor; 2 = somewhat poor; 3 = fair; 4 = somewhat good; 5 = very good)

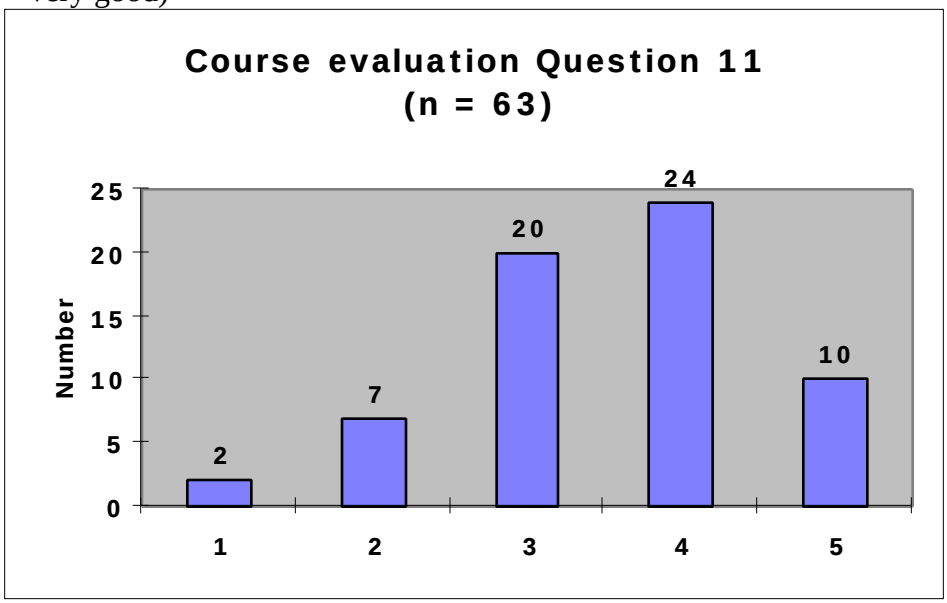


Question 7: To what degree do you think **this course has improved your ability to write about mathematical concepts**? (1 = not at all; 2 = a little ; 3 = somewhat; 4 = a good bit; 5 = very much)

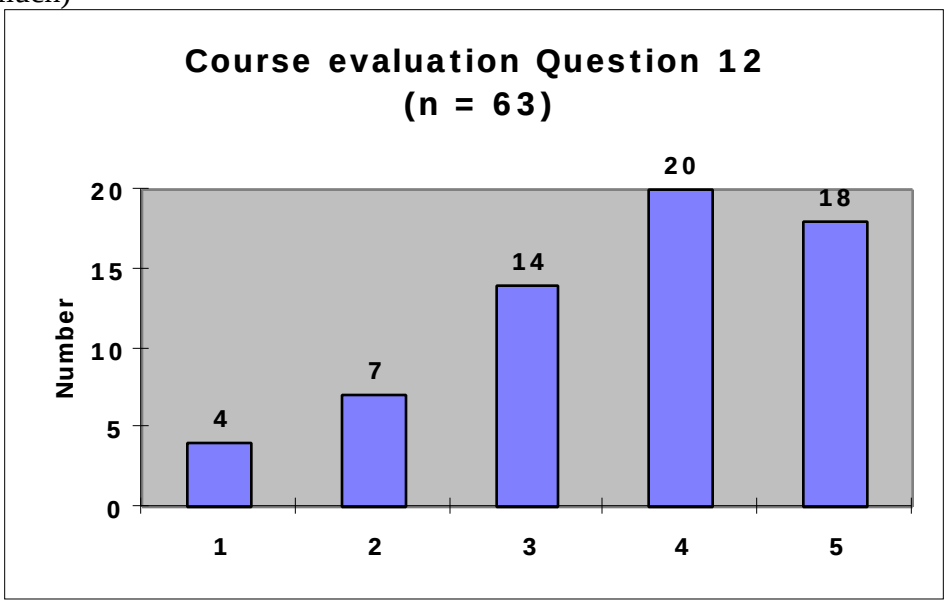


Again 87 percent of those responding suggest that their ability to write about mathematical concepts had improved a good bit or very much.

Question 11: How would you rate your **ability to work effectively in a group at the beginning of the semester**? (1 = very poor; 2 = somewhat poor; 3 = fair; 4 = somewhat good; 5 = very good)



Question 12: To what degree do you think **this course has improved your ability to work effectively in a group**? (1 = not at all; 2 = a little ; 3 = somewhat; 4 = a good bit; 5 = very much)



While approximately 86 percent said that they were at least fair at working in groups at the beginning of the semester, approximately 83 percent indicated that this ability improved at least somewhat as a result of the course.

Students were asked to provide written comments on each aspect of the course on this evaluation. A few of the comments on seminars follow:

- They are a very different approach to mathematics from what I am used to. I feel they are a much better way of learning math. You're not just doing every other odd problem. You are learning to understand what you are actually doing.
- They were a good learning aid. It helped us learn each concept, and a good way to let you know of any questions we might have. A good push to get us to study each section to understand that section's concept.
- They really helped. By having to write about a concept, you really had to understand what you just read. Also, by writing about a concept, it helped me remember it.
- I enjoyed the seminar papers because they forced me to understand the concepts and be able to explain them in my own words and with the use of examples.
- Extremely helpful in learning and understanding the various sections of the chapters. Helps create a more intuitive understanding of the concepts discussed.
- The seminar papers are probably the best idea of the class. Compared to conventional methods of teaching, for me, this way is much more useful. I started doing something like a seminar in my chemistry class and it helped me understand there also. The seminars were a useful extension of the papers. It is also a whole lot more interesting than listening to a teacher lecture.

- I loved it. I actually got to learn concepts. From these, the homework was easy. In other courses I learned problems and when the problem would change I needed to be spoon fed again. But the seminar papers concentrate on what I should know to attack any problem.
- By participating in the seminars I was able to depend on myself more for learning. By reading each section carefully, answering questions, and doing some problems I think I was able to grasp the concepts a lot better than if someone were to tell me how to do it. I think seminars are a wonderful way to learn math. Of course they have to be accompanied by group discussions and teacher guidance. After I got used to doing them, I found that I learn more by reading the book, answering questions about what I read, and then discussing it with others.
- Seminars have helped me to form new independent study habits and self-reliance. But, most of all, they have forced me to take the time to thoroughly learn and understand a concept as best I can before class discussion.

The above testimonials indicate that the goals of active learning appear to be well served by the seminar technique.

Pros, cons, and modifications

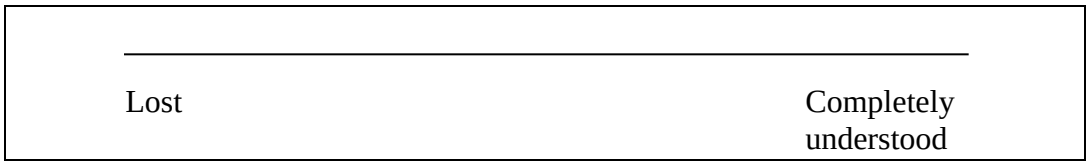
The pros of using the seminar approach are numerous. These include helping students become active and independent learners, improved group skills, improved ability to read and understand a mathematics textbook (ability to use resources), more focus on conceptual (relational) understanding as opposed to procedural (instrumental) understanding. Class time is used more efficiently by focusing on the confusing concepts rather than on all concepts.

Some cons to the approach include time commitment for both instructor and student, grading time, caution so as not to excessively punish poor writers, and time required to prepare the seminar questions. However, from student evaluations and instructor observation of student understanding, it appears that these problems are more than outweighed by the positive results.

Note that students need guidance on both how to read a mathematics text and clear instructions on how to write responses. It should be clear who they are writing to? Common seminar questions asked students to explain a concept to a confused friend. It is important for the instructor to be clear about the instructional objective. It is helpful to share the potential benefits and the theory behind this active learning approach with students.

Since the experience with seminars in these calculus classes, the instructor has gone on to incorporate the technique into other classes. One change in procedure has been instituted to give the instructor an instant measure of how well students understood the reading. Each seminar assignment includes the following task:

Place an X on the continuum below indicating how well you understood the section.



When students are directed to move into groups, they are first asked to place an X on the same continuum on the board matching where they located their X on the seminar paper. The instructor gets a quick summary of how well the class understood the assignment. At the end of the seminar or the class, students can mark the continuum again to indicate their understanding at that point in time. This technique is extremely helpful to instructor in orchestrating class discussion.

Conclusion

The use of the seminar has truly transformed the class into an active learning environment. Students actually read the text. They write about mathematics in a thoughtful way. They come to class prepared to discuss concepts as opposed to listen passively to a lecture or watch a problem being solved. They write and talk mathematics. They initially may resist this approach as "different" and not what they are "used to". Early seminar papers are quite poor as this is something students have never done before. With careful constructive criticism, they improve as they do more. Their confidence in their ability to read and understand mathematics independently grows.

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