The Impact of Peer Interaction Exercises in a Signals and Systems Course

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Abstract

This paper investigates the impact that peer interaction exercises have on student learning in the context of a Signals and Systems course. This junior-level course in the electrical engineering curriculum provides foundational material for several senior-level classes. The extent of the peer interaction activities varied from conceptual problems that required a few minutes of interaction between neighboring students to small group exercises requiring an extended amount of class time to complete. For the more challenging problems, such as those involving sampling theory, a scaffolding approach was utilized to direct the students to the solution. This involved the use of worksheets containing an outline of the key steps in the solution of the problem. Assessment of student learning gains was obtained through analysis of exam scores and results from a concept inventory test. Analysis of the assessment data does indicate a modest improvement in test scores compared to material not covered through peer interaction exercises. Student self-assessment surveys indicated the students generally perceived the value of the in-class peer interaction activities.

Introduction

Several studies have indicated the benefits of utilizing in-class peer interaction exercises to improve student learning and motivation. For example, the use of peer interaction activities centered around conceptual questions in an undergraduate genetics class was found to produce gains in conceptual understanding.[1] A similar study in computer architecture classes indicated the learning benefits associated with the active engagement of the students discussing problems with their peers.[2] This paper investigates the potential learning benefits from implementing active learning exercises centered around peer discussion groups in a Signals and Systems course. This junior-level course provides much of the foundational material in the electrical engineering curriculum for other courses such as Communications and Controls Theory.

The assessment instrument known as the Signals and Systems Concept Inventory (SSCI)[3] allows instructors to determine the conceptual understanding of the foundational material in a Signals and Systems course. The SSCI is a 25 question multiple choice test that can assist in uncovering common student misconceptions in the course and thus, can be used to improve the curriculum.

The SSCI was utilized in this study as a source of peer interaction questions as well as an assessment instrument to gauge student conceptual understanding of the course material. The use of in-class exercises to reinforce key concepts in a Signals and Systems course have been investigated by others.[4,5] Both studies report the positive impact of actively engaging the students in the classroom. The analysis of problems solved in-class was also used to better understand how students apply their mathematical background to understand key concepts in signals and systems with the ultimate goal of providing a framework for curriculum and assessment design.[6]

A study was undertaken in Spring 2012 at our institution to determine the impact of various types of peer interaction exercises on student learning in a Signals and Systems course. This is a junior-level course in the electrical engineering curriculum, which provides foundational material for several senior-level classes. This paper is outlined as follows. First, a general background of the Signals and Systems class is described followed by a description of the different types of peer interaction exercises utilized in this study. Second, the methods of assessment and an analysis of these results are given. The paper concludes with a summary and discussion of plans to further improve the use of peer interaction in-class exercises.

Implementation

The Signals and Systems course covers the analysis of linear time invariant (LTI) systems involving continuous-time and discrete-time signals. Several types of transforms, such as the Fourier transform, Laplace transform, and z-transform are used in this analysis. The students are also introduced to sampling theory as the bridge between the continuous-time and discrete-time domains. As such, the course draws upon a fair amount of mathematical theory that the students learn in their first two years of college. As a result, the students find many of the topics in this course, such as convolution and sampling theory, rather abstract and difficult to comprehend. Due to the importance of this course in laying a foundation for other senior-level classes and the challenging nature of the material, it is worthwhile to investigate the potential learning benefits associated with peer interaction exercises.

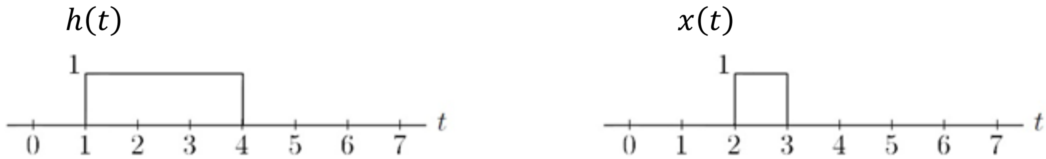
The extent and type of peer interaction activity varied depending on the conceptual difficulty of the topic. Table I lists the seven exercises administered in this course.

Table I. Peer Interaction Exercises Implemented

Exercise	Type
1. Continuous-Time Convolution	Concept
2. Signal Transformation	Concept
3. Sampling Theorem	Worksheet
4. Discrete Fourier Transform	Worksheet
5. Discrete Time Convolution	Graphical
6. Discrete Linear Time Invariant System	Worksheet
7. Pole-zero Frequency Response	Graphical

Three types of peer interaction exercises were implemented, which we have categorized as concept, graphical, and worksheet exercises. The concept exercise presented the student with a conceptual problem and a multiple choice set of answers to choose from. The students were given a few minutes to discuss the question with a neighbor before selecting an answer. The problem was subsequently explained by the instructor. Conceptual problems in basic signal transformations and the characteristics of a linear time-invariant (LTI) system are representative problems of this type. Figure 1 illustrates the concept question that tests the student's understanding of continuous-time convolution. This example was taken from the SSCI.[3]

The impulse response $h(t)$ of an LTI system and the input $x(t)$ to the system are shown:



Select the signal below which best represents the output of the LTI system.

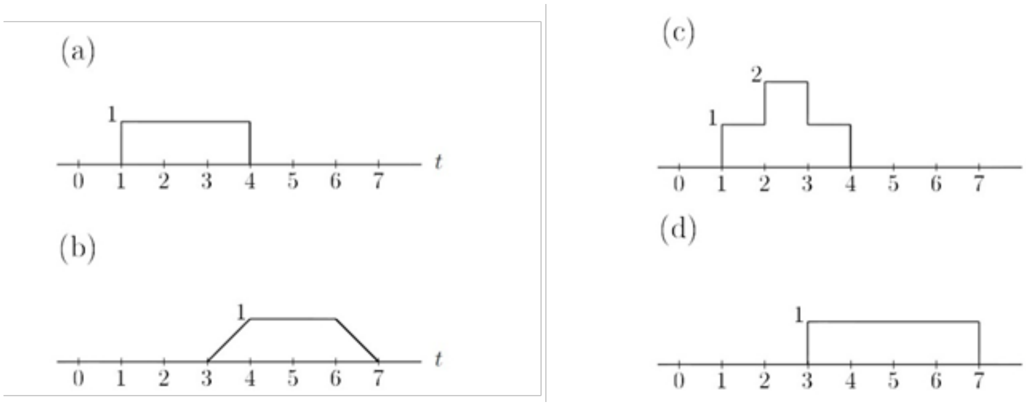


Figure 1. A conceptual question involving continuous-time convolution.

An intermediate type of problem involved the students working in small groups to produce a graphical solution to a given question, such as plotting the frequency response to a plot-zero plot, as shown in Figure 2.

Sketch the magnitude response for the following pole-zero plot

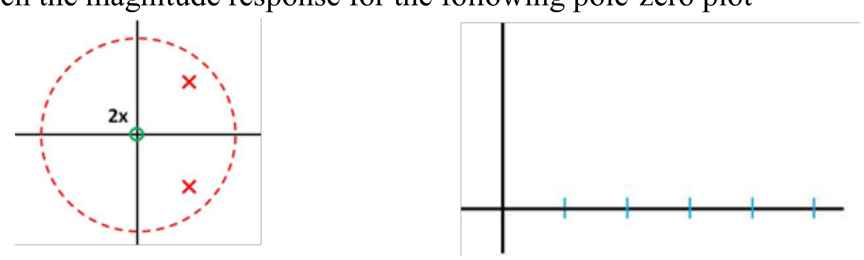


Figure 2. A graphical question involving a pole-zero plot.

For more challenging problems, such as those involving sampling theory, a scaffolding approach was utilized to direct the students to the solution. This involved the use of worksheets containing an outline of the key steps in the problem solution. The instructor worked with student groups in class to provide additional guidance where necessary. An excerpt from a Discrete Fourier Transform (DFT) worksheet is illustrated in Figure 3.

Given a signal $x(t) = \frac{2}{t^2+1}$, determine suitable values for T and T_0.

1. Find the Fourier Transform $X(\omega)$.

   Review the Duality Property from your textbook (p. 700).

   If $x(t) \quad \leftrightarrow \quad X(\omega)$ then

   $X(t) \quad \leftrightarrow$

   Find a suitable entry from Table 7.1 (p. 702)

   If $X_1(t) = \frac{2}{t^2+1}$ then

   Then $X(\omega) =$

2. Find the effective bandwidth B for $X(\omega)$. Use the criteria that $|X(\omega)|$ is equal to 1% of its peak value at $\omega = 2\pi B$.

   Observe: the peak value of $X(\omega)$ occurs at $\omega =$

   Solve for $\omega = 2\pi B$:

   Then: $B =$

   $T \leq \frac{1}{2B} =$

Figure 3. An excerpt of a worksheet exercise involving the Discrete Fourier Transform.

The first part of the worksheet guides the student to review some key points about the Fourier transform from their textbook, while the second part outlines the steps needed to solve the problem. The scaffolding approach is evident as suitable hints are given throughout the worksheet, with key equations given, and blanks requiring the student to complete an answer.

Assessment and Discussion

A variety of assessment methods were utilized. First, student self-assessment surveys were distributed at various points in the semester to gauge student reaction and attitudes to this teaching method. Second, student performance on the final exam was analyzed for evidence of learning gains. Third, a concept inventory test was administered to the students at the end of the semester to determine the impact on their conceptual understanding.

First, we present results for the first two peer interaction exercises involving the multiple choice concept questions. In these exercises, the students were asked to study the problems on their own and select an answer. Then they were directed to discuss the problem with a peer, and select an answer again. Table II summarizes the responses which are grouped into four categories, based upon whether the initial answer and second answer after peer interaction were correct or not.

Table II. Student Responses to the Concept Exercises

Question	Both Correct	Incorrect-Correct	Correct-Incorrect	Both Incorrect
1.	2	2	2	14
2 (a)	17	1	1	0
2 (b)	17	2	0	0
2 (c)	16	3	0	0

The first question covered continuous-time convolution, as illustrated in Figure 1. This was given in the third week of the semester before the topic was reviewed in class. Continuous-time convolution was covered in the previous semester. Most students favored answer (a) or (d) in Figure 1. The students apparently did not remember that convolution involves integrating the product of two signals, so the correct answer in this case must be (b). Also it appears that peer interaction did not help much since only two students changed their answer to the correct one after interacting. Questions 2 (a) to (c), covering signal transformations, was given a week later. This topic was covered at the beginning of the semester. It is evident from the results that the students understood this topic much better as it is conceptually easier than convolution and was reviewed in class prior to giving this assignment. It is interesting to look at the student attitudes towards peer interaction exercises at various points in the semester. After both concept questions, the students were surveyed, with their responses summarized in Table III.

Table III. Student Attitudes towards Peer Interaction Exercises
(*Scale*: 1= Strongly Disagree, 2= Disagree, 3 = Neutral, 4= Agree, 5 = Strongly Agree)

Statement: I was able to get a better grasp of this material by either explaining it to one of my peers or listening to an explanation from one of my peers	Rating	Sample Size
1. Continuous-time convolution problem.	3.50	20
2. Signal transformations.	4.20	19
3. Sampling Theory	3.95	21
4. Pole-zero Frequency Response	4.35	20
5. End of semester (Week 17)	4.33	21

The benefits of peer interaction were perceived as being more useful for the second set of problems even though most of them had the correct answer before discussing it with a peer. One student wrote a comment that the peer interaction helped clear up some confusion while another wrote that there was not much peer interaction since both concurred on the correct answer. For the pole-zero plot exercise, the instructor observed that the students were most engaged in this exercise. Select students were asked to present and explain their results in front of the class to the four graphical problems that were assigned. The survey of student attitudes given in the table above seem to concur with this observation as it is rated the highest. By the end of the semester, they had an overall positive attitude to the use the exercises.

In addition, the student attitudes in general towards the peer interaction exercises was sampled once before the second test (Week 13) and again at the end of the semester (Week 17). Overall, they viewed the exercises as a beneficial use of class time, as summarized in the table below.

Table IV. Student Attitudes towards Peer Interaction Exercises
(*Scale*: 1= Strongly Disagree, 2= Disagree, 3 = Neutral, 4= Agree, 5 = Strongly Agree)

Statement	Rating Week 13	Rating Week 17
1. Overall, I find interacting with my peers during an in-class exercise to be a beneficial use of class time.	4.10	4.43
2. We should have more peer-interaction exercises in this class	3.95	4.14
Sample Size	21	21

The final exam consisted of seven questions with four of the questions (3 to 6) covered by the peer interaction exercises. A summary of the student performance is given in Table V.

Table V. Analysis of Final Exam Scores

Question	Score %	Vs. Avg
1. Exponential Fourier Series	68.2	
2. Frequency Shifting Property	66.9	
3. Frequency Spectrum and Signal Reconstruction	87.6	+11.7
4. Discrete Fourier Transform	79.5	+3.7
5. Discrete Linear Time Invariant System	65.7	-10.1
6. Frequency Domain Analysis – Pole/Zero Plots	78.1	+2.3
7. Implementing a Discrete System Transfer Function	79.5	

The overall average of the final exam was 75.6%. The last column shows how the four questions compared with the overall exam average. Modest improvements from 2.3% to 11.7% are observed for three of the questions. The discrete LTI system question was below average. This is a more challenging problem that was covered by a worksheet exercise. It is conjectured that without the benefit of scaffolding on the exam, the students were not able to do as well on this problem on the final exam.

A concept inventory test was given at the end of the semester to assess the conceptual understanding of the students. Twelve questions were selected from the standard SSCI, with seven of them (highlighted in blue) covered by the peer interaction exercises. The results are summarized in Table VI.

Table VI. Results of the Concept Inventory Test

Question	Number Correct	Percent Correct
1. Exponential Fourier Series	18	90%
2. Signal Transform $\rho(t-2)$	18	90%
3. Signal Transform $\rho(2-t)$	8	40%
4. Plot $r(t)-r(t-2)$	19	95%
5. Time Delay in Linear Time Invariant System	19	95%
6. Frequency Spectrum Plot Given $x(t)$	9	45%
7. Fourier Transform	9	45%
8. Convolution (continuous-time)	4	20%
9. Pole-zero plot for BIBO stability	19	95%
10. Convolution (frequency)	2	10%
11. Frequency response from Pole-zero plot	11	55%
12. Convolution (discrete)	1	5%

From these results, it is difficult to make any definitive conclusions on the impact of the peer interaction exercises on the conceptual understanding of the students. Some of the answers indicate a solid conceptual understanding while others, most noteworthy those involving convolution, appear to be still not well understood by the students. The notion of convolution is typically the most difficult concept for students to grasp in this course. The students, can generally work with the equations to solve a problem in convolution numerically, but the underlying concepts usually seem to elude them. The challenge of understanding convolution in our courses concurs with experience of other instructors.[5,7] Going forward, greater attention needs to be paid to teaching this concept although a significant amount of class time is already devoted to this topic, with several Matlab assignments given to illustrate this concept.

Finally, we present results from the end of semester survey that asked the students to rate the learning benefits associated with various teaching methods used in the Signals and Systems course. Table VII summarizes these results.

Table VII. Student Attitudes towards Teaching Methods
(1) Least Helpful (2) Not very helpful (3) Neutral (4) Somewhat helpful (5) Most helpful

Statement	Rating
1. Listening to a lecture/taking notes	4.1
2. Reading the textbook	3.3
3. In-class activity – working on a problem individually	3.4
4. In-class activity – peer interaction	4.1
5. Professor working out example in class	4.6
6. Doing the homework	4.3
7. Doing the Matlab assignments	2.9

The high value placed on professor-led activities (categories 1 and 5) are not surprising since these are components of a traditional lecture that the students would be most comfortable with. The in-class peer interaction activities, though, also scored highly in the student self-assessment.

Summary and Future Work

This paper has investigated the potential learning benefits that can be obtained from peer interaction activities in a Signals and Systems course. Various forms of peer learning activities were attempted. From an analysis of the tests and exams, there is some evidence for the positive impact of peer discussion on student learning. For example, on the final exam, on three of the four questions that were covered by peer discussion, the students scored above the exam average (ranging from 2 to 11% gains). Similarly, on the concept inventory test, some topics showed the majority of students had grasped the concept, while others indicated there was room for improvement. Of note is the student understanding of convolution, which is traditionally a difficult concept for students to grasp. The results do correlate with the student self-assessment of their conceptual understanding of the material. The assessment of student attitudes were positive overall as they felt on average that the peer interaction in class was beneficial in their understanding and was a good use of class time.

Future implementations will attempt to expand the use of peer interaction exercises in this course. The multiple choice concept questions only take a few minutes of class time and thus can be used more regularly. Concept inventory tests could be administered at several points during the semester to monitor student conceptual understanding and implement appropriate interventions to improve understanding where necessary.

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