AC 2007-1079: A PARADIGM FOR ASSESSING STUDENT LEARNING IN AN INTRODUCTORY DIGITAL SIGNAL PROCESSING COURSE

Shonda Bernadin, Georgia Southern University

Shonda L. Bernadin is an Assistant Professor of Engineering Studies in the Department of Mechanical & Electrical Engineering Technology at Georgia Southern University. Dr. Bernadin received her B.S. degree in Electrical Engineering from Florida A&M University in 1997, her M.S. degree in Electrical and Computer Engineering from University of Florida in 1999, and her Ph.D. degree from the Department of Electrical and Computer Engineering at Florida State University in 2003.

A Paradigm for Assessing Student Learning in an Introductory Digital Signal Processing Course

Abstract

This paper presents research on designing and incorporating assessment measures for evaluating student learning in an introductory digital signal-processing (DSP) course. We teach Electrical and Computer Engineering (ECE) students the first two years of their engineering curriculum in an engineering studies transfer program. One of their required courses is an introductory DSP course, which our students take during the second-year of their program. Due to the mathematical intensity of this course, traditional ECE programs offer the first signal-processing course during the third year of matriculation. There are many challenges that affect student learning of signal processing concepts by offering DSP in their second year, including less sophisticated mathematical foundation. Also, textbook selection becomes a challenge since the textbook for the course is not chosen by the instructor teaching this course, but by professors teaching the equivalent course at the degree-granting institution. One advantage to our university and ultimately, our engineering studies program, is the strong support to create a learning environment that fosters academic distinction, excellent teaching, and student success. Therefore, in our efforts to support and promote this objective, successful student learning must be a priority in the engineering studies transfer program. Data from several DSP courses has been collected, evaluated and used to create a paradigm for assessing student learning. This paper describes the paradigm, which is based on the reorganization of course content; and the incorporation of assessments that measure the effectiveness of student learning.

Introduction

It is becoming an inevitable notion that measuring how well students learn in the academic environment, i.e. assessing student performance is a significant and important part of the academic learning process, as well as, the institutional accreditation process. Educators and students are now held accountable for how well information is learned. Consequently, innovative teaching and learning strategies must be developed that incorporate measurable techniques for assessing the learning process. According to Bollag's article[1], learning is assessed through student performances on practical exercises that mimic real-world situations. Using this definition, the process of assessing student learning must involve challenging and realistic opportunities. Therefore, educators must devote more time to developing experiences for their students that involve issues they would face as a professional in their field of study.

Furthermore, collegiate students today were born into a technologically advanced society. Technology is integrated into almost every aspect of their daily lives. By the time they reach elementary school age, they know how to surf the Internet, talk on a cellular phone, play sophisticated video games using technically advanced 3D-graphics, and watch television on a high-definition plasma television set. We live in an age where technology demands attention, interaction, excitement and engagement. Educators have to be cognizant of this fact and find ways to create a learning environment that engages a student whose attention is no longer focused on traditional classroom learning, but rather on one that incorporates technology and actively engages the student in the learning process.

Engineering educators are faced with the challenge of not only staying current on the multitude of technological advancements in society, but also finding ways to teach students about the fundamentals of designing that technology, and not just using it. Our challenge is to actively engage our engineering students by building a learning environment using effective teaching and learning strategies. These strategies are designed to help create productive professional engineers, and to also provide measurable assessments to gauge student learning. Our engineering studies program seeks to provide this learning environment for our students through active learning and continual assessment. One method of assessment that had been incorporated into this work emphasizes students taking ownership of their learning and the learning process. In this introductory signal processing course, students are forced to evaluate their learning progress throughout the semester. This process was part of a learning paradigm that was created to provide effective teaching and learning strategies that produce active learners.

One advantage to our university and ultimately, our engineering studies program, is the strong support to create a learning environment that fosters academic distinction, excellent teaching, and student success. Therefore, in our efforts to support and promote this objective, successful student learning must be a priority in the engineering studies transfer program. Data from several DSP courses has been collected, evaluated and used to create a paradigm for assessing student learning. The next section describes this paradigm, which is based on the reorganization of course content; and the incorporation of assessments that measure the effectiveness of student learning. The results of implementing the model are presented, followed by future course enhancements and conclusions.

A Paradigm for Student Assessment

The paradigm that was developed for incorporating effective assessments in the introductory signal-processing course is defined as a three-step process. The underlined theme for creating appropriate assessments for increased student learning was self-reflection and correction.

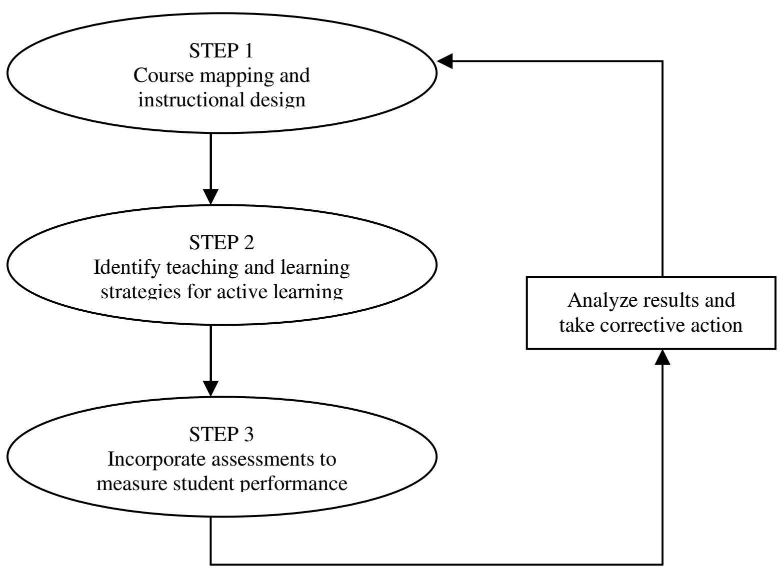

Figure 1- Paradigm for assessing student performance

Step 1: Signal-Processing Course Design

The first step, *course mapping and instructional design*, is the most significant and most valuable step in the assessment process. In this step the student outcomes, course objectives and instructional layout are defined in a clear and structured manner. Course assessments and teaching strategies can be readily identified as a result of the successful implementation of this step. The focus of this work is not on instructional design, however due to the significance of this step in the overall assessment process, it is given some emphasis in this paper.

In Figure 2, the design of the course using the required textbook is shown. The course is divided into two main directives: presentation of signal-processing (SP) fundamentals in the continuous-time domain (CT) and the discrete-time domain (DT), followed by a presentation of the advanced SP concepts in the CT and DT domains, respectively. Though this model is logical and provides a structured design, there are obvious challenges in its implementation. The complete coverage of necessary subject matter is difficult due to time constraints. Later course material, which forms the basis of digital signal processing (DSP) prerequisite knowledge, is presented in a rushed manner or omitted entirely. As a result students suffer in their subsequent courses.

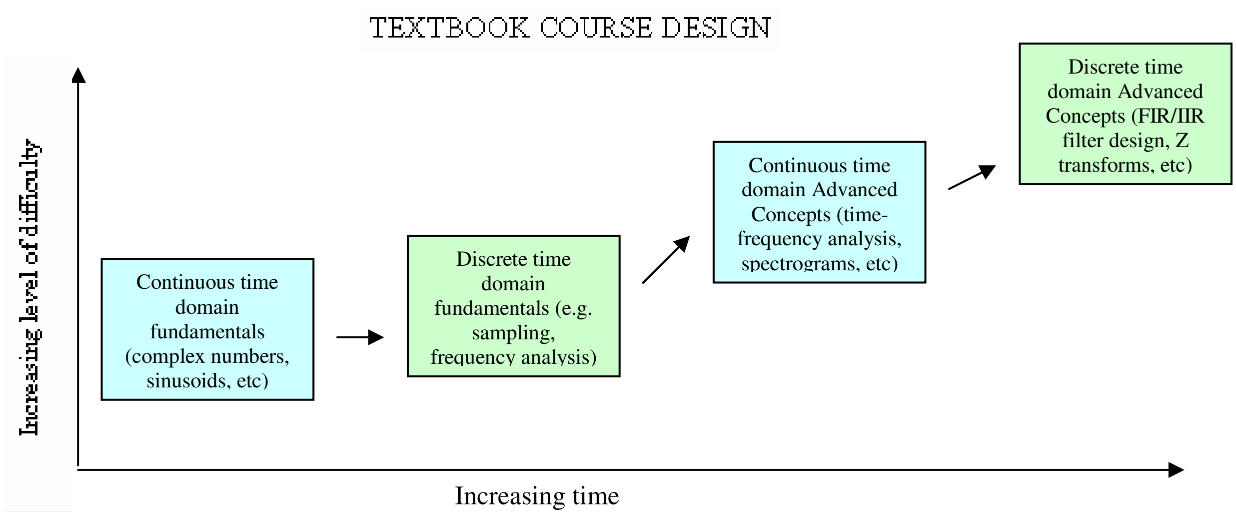

Figure 2 – Signal Processing Course Design from Textbook

Another challenge is the discontinuity between the presentation of CT and DT concepts, both fundamentals and advanced. Unless a clear and concise understanding of the duality between continuous and discrete is constantly emphasized, students with little or no SP knowledge will struggle to make the connection between the two domains. This issue creates a negative learning environment full of confusion and frustration for the student. To counter these challenges and create a classroom environment that facilitates learning, a new course design was created and implemented. Figure 3 illustrates this new model. The course was divided into units of instruction based on the course outcomes and objectives. In this course, seven units of instruction were identified (Unit 1- Complex Exponential Representation, Unit 2-Signals and Sequences, Unit 3-Sampling and Reconstruction, Unit 4-Filter Design, Unit 5-Spectrum Analysis, Unit 6- Z-Transform Method, Unit 7-Recursive Filter Design). A parallel presentation of CT and DT concepts was presented in each unit, where appropriate. As a result of this type of course design students were forced to understand the duality between CT and DT analysis. Additionally, more content coverage was achieved by rearranging the course topics using a parallel approach to SP analysis.

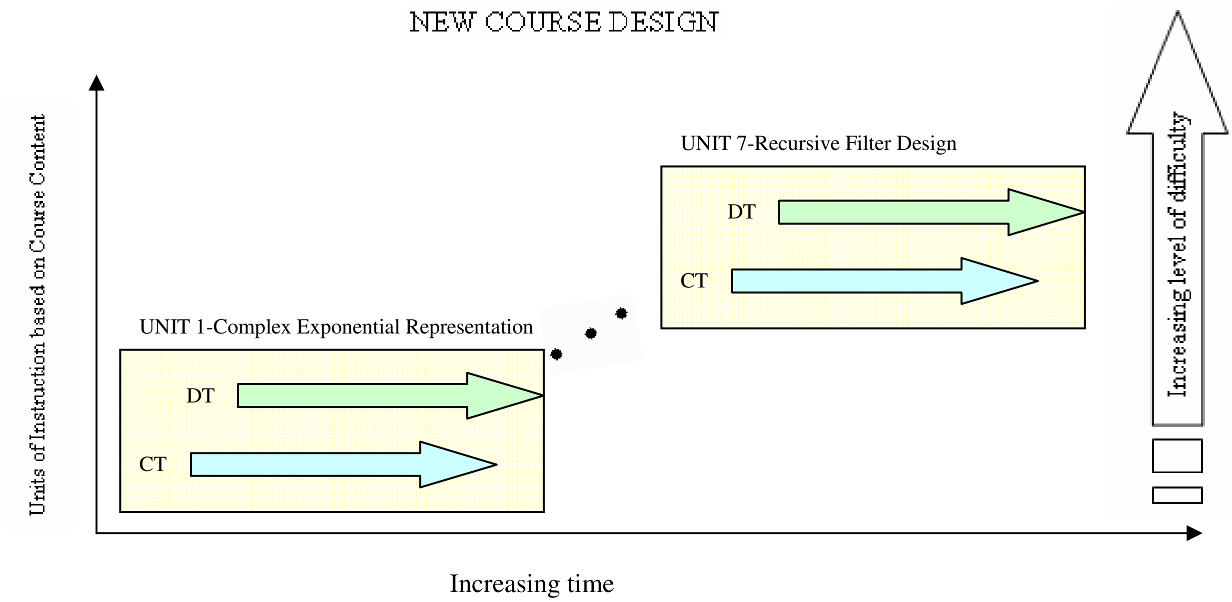

Figure 3-New Signal-Processing Course Design

Step 2: Teaching and Learning Strategies

The second step in the paradigm for assessment is to *develop appropriate teaching and learning strategies* that aid in the facilitation of learning and engage the student. Similar to step 1, this step is equally important in the assessment process. A course design is only successful if the teaching strategies used are effective. A backwards design approach[2] was used to accomplish this step. Figure 4 illustrates the steps of backwards instructional design.

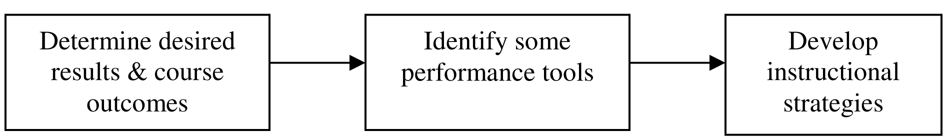

Figure 4-Steps in the Backwards Instructional Design approach

The underlined premise of this step is identifying teaching strategies that will present the material in a way that produces the desired results. Several strategies can be used and may be effective for different student learners. However, the traditional lecture style of presenting course material directly from the textbook on a black- or white-board was found to be ineffective for high student performance in this introductory signal-processing course. Note-taking was time-consuming and inefficient and students quickly became disinterested. It was observed through practice and continuous course evaluations, that a combination of different teaching styles was more effective than a single teaching strategy. In this course, information was presented using lecture slides, topical outlines and supplemental textbook materials. The Electronic Digital Visual Presenter (ELMO) was used extensively in this course, to which students adapted well. Lecture notes were made available to students through the online course webpage which allowed students to direct their attention to the actual course content and not extensive note-taking, during class time. Students appreciated the accessibility to the lecture materials.

Step 3: Identifying and Incorporating Assessments

The pinnacle step in the paradigm is the *identification and incorporation of course assessments* that can be used to measure student learning and effective instruction of this introductory course. It is clear from step two that the process of continuously evaluating the course and modifying real-time course instruction based on those results is imperative to effective teaching, and consequently, effective learning. Data was collected from three sections of this course and assessments were developed based on the analysis of this data.

Traditional assessments such as quizzes, examinations, homework assignments, and laboratory experiments, were still used to assess student performance in the course. However, additional assessments that emphasized self-evaluation of student learning were also incorporated. Unit pre-tests were administered at the start of each unit to gauge foundational knowledge of important concepts that would be studied within the unit. In this course, students have little knowledge about the practical aspects of signal-processing, which is expected since it is an introductory course. Unit post-tests provide a comparison mechanism for measuring how well students learned the concepts in the unit. The same questions were used in the post-test since it measured a student's understanding of fundamental concepts defined in the unit. An example of a typical unit pre/post test is shown in Figure 5.

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Unit 3 (Sampling and Reconstruction) – Pre-Assessment Survey

1. (5) Describe how discrete-time signals are created.

2. (5) What is Shannon's Sampling Theory?

3. (5) How is a sampled signal reconstructed?

4. (5) What is aliasing?

Figure 5-Example of Pre-Assessment Survey

After analyzing the results of the initial pre and post tests, one-minute course evaluations and self-evaluations were incorporated into the course to aid in the student learning process. Students were given approximately one minute to answer questions related to the course and their performance. These questions included discussion about their current understanding of course material, their method of preparation for exams, whether course expectations were being met, and identifying strategies for improvement. As a result of analyzing these assessments, course modifications were made such as more practice problems to help student learning, more example problems during lectures, study groups were formed, etc. In general, students valued the feedback from the assessments and were very active in improving their performance in the course. The next section describes some observations.

Results

This section describes the results that were achieved after implementing the paradigm in the third section of the introductory signal processing course. Figure 6 illustrates the results of the pre and post tests for each unit.

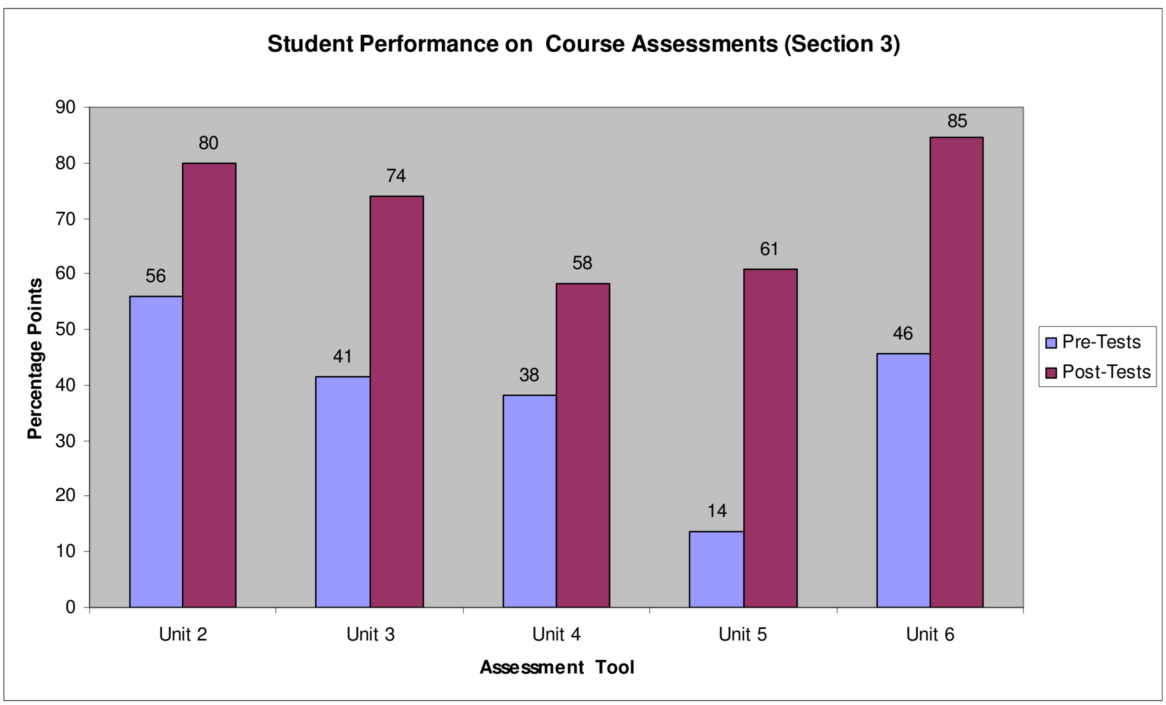

Figure 6 - Results of Unit Pre- and Post-Tests

There is a decreasing pattern observed for the pretest scores until unit 6 is reached. This is expected behavior since as the course progresses new concepts are being presented to students. Also, it is observed that a priori knowledge of the fundamental concepts in Unit 5 (Spectrum Analysis) was very low. This instructional unit focused on using Fourier Analysis techniques. In theory students should have been exposed to Fourier Theory in the prerequisite math course, Calculus II. Using this expectation in the original DSP course design, unit 5 material was presented earlier in the semester. However, students found it difficult to grasp many of the main concepts and as a result, their performance was poor. In the new course design we decided to introduce these concepts later in the course which helped students build sufficient background knowledge to understand the main concepts and perform well in unit assessments. Example questions from the Unit 5 pre/post test is given in Table 1 with their corresponding composite scores. The averages are based on a rating scale of 0 (worst performance) to 5 (best performance).

Table 1 – Unit 5 (Spectrum Analysis) Assessment Survey Results

Unit 5 - Survey Question	Pre-test Composite Score	Post-test Composite Score
What is the importance of studying Fourier Theory?	**0** out of possible 5	**2** out of possible 5
In general terms, what is the difference between the Fourier Series and the Fourier Transform?	**0** out of possible 5	**3** out of possible 5
Why is ***Gibbs Phenomenon*** significant?	**1** out of possible 5	**2.83** out of possible 5
What information about a signal can be obtained by using Fourier Analysis?	**0** out of possible 5	**4.17** out of possible 5
Why is the Discrete-time Fourier Transform (DTFT) an important analysis tool in signal processing?	**0** out of possible 5	**1.83** out of possible 5
What is frequency aliasing?	**2** out of possible 5	**4.33** out of possible 5

From these results it is clear the student learning is achieved. By the end of the unit, students have a better understanding of basic spectrum analysis concepts. However, it is also clear that more learning must be achieved to gain a solid understanding of major concepts. Of particular interest is the result of the first question. If one considers *average* performance to be 2.5 out of a possible 5 rating, then students still need better understanding and clarification of the *importance of studying Fourier Theory*. The significance of using pre- and post-test assessments to accurately measure what students are learning is clearly illustrated in this example. From Figure 6, it appears as though a large amount of learning is being achieved during the Unit 5 presentation. However, in reality, using the results in Table 1, only *some* learning is being achieved. Students still need improvement in their basic knowledge of major concepts. As a result of these data, more emphasis was placed on the significance of Fourier Analysis as the semester progressed.

In Figure 6 it is also noticed that there is a significant increase in the amount of prior knowledge for unit 6. One possible reason for this pattern could be due to the effective instruction of a preliminary introduction of unit 6 concepts presented at the end of unit 5. This strategy was used at the end of each unit, but due to the increase in knowledge gained from unit 5, it is possible that a deeper understanding of related concepts was achieved by the student. Based on these results, more in-depth observations about effective pedagogical strategies for each unit will be explored in future work to increase student performance.

Future Course Enhancements

The results of the course modifications have been successful in terms of providing effective assessments that measure student learning based on student self evaluations. Through informal interviews and student comments, positive ratings were given to the methods of analyzing student performances. In addition to the future strategies already mentioned, more online assessments can be incorporated into this course to enhance student understanding of complex signal-processing concepts. In addition, students can be more proactive in their own learning process through periodic opportunities within the course to provide technical feedback in the form of creating their own course assessments. This will force them to gain a deeper understanding of the material, and ultimately increase their overall performance in the course.

Conclusion

The assessments that have been introduced in this course have provided a basis for enhanced instruction and improved student performance. The paradigm was successful in providing a framework for measuring and analyzing student learning. Moreover using this paradigm, areas of instructional improvement have been identified and used to enhance the course. Student performance evaluations were also used to modify and adapt the course to meet the learning needs of the students as the semester progressed. It may be necessary in future work to research and support diverse learning styles of engineering students in order to produce deeper cognitive skills in students, it, as suggested by recent literature[3]. Students will gain more practical abilities and be more productive as engineering professionals.

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