THE INVESTIGATOR®: A STUDIO-BASED DSP LEARNING PARADIGM[1]

Ryan Frankel, Nicholas Nezis, and Fred Taylor

The University of Florida

ABSTRACT

Driven by $32 billion in semiconductor 2003 sales alone, the DSP industry continues to be in need of trained entry-level engineers. Preparing neophytes for DSP careers has historically been the role of higher education. Typically, undergraduate DSP studies have evolved from research-centric graduate programs and are delivered in a conventional lecture format. Unfortunately, this approach to often emphasizes theory and analysis to the exclusion of technology and design. The University of Florida (UF), with the support of the National Science Foundation (NSF), Texas Instruments (TI), and Mathworks, are developing the InvestiGATOR, an inquiry-based learning paradigm that provides undergraduates with an understanding of core DSP-concepts using authentic hands-on technology-centric studies delivered in a studio-based format.

1. INTRODUCTION

DSP is a relatively young academic study being well established at the graduate level and with a growing undergraduate presence. In fulfilling its mission to prepare young scholars for DSP leadership roles, one must be mindful of a caveat raised by the National Academy of Engineering (NEA). The NEA charged academia to change its emphasis from "knowing about" to "knowing how" [1]. Most DSP academic programs are strongly influenced by existing graduate courses and faculty research interests. The result of extrapolating this model into undergraduate programs often led to pedagogical chaos. In addition, studies at the Universities of Colorado and Washington have found that engineering majors increasingly lack an *a-priori* understanding of what the engineer does or how they do what they do [2]. While today's students are eminently familiar with technology as end-users, they are less familiar with its inner workings than where earlier generations. While today's student may have technology at their fingertips, their predecessors have technology under their fingernails. This presents a challenge to the DSP educators and content builders.

The UF's undergraduate DSP-track consists of a sophomore/junior discrete-time signals and systems (EEL3135) and a senior-level DSP (EEL 4750) course. An assessment of these courses would lead one to conclude that they are both academically strong by *engineering science* standards. They are also in danger of failing to provide the technology-relevant learning experiences requested by students and employers alike. This condition persisted in spite of the fact that courses were based on popular textbooks and supported with a laboratory based on a modern DSP development system kit (DSK). These concerns motivated the NSF InvestiGATOR, a new DSP learning environment.

During the InvestiGATOR planning phase, candidate content delivery schemes were accessed for possible InvestiGATOR assimilation. Of those evaluated, a *studio-based* strategy (see Section 2) was deemed to be the most promising, having been demonstrated effective at Rensselaer Polytechnic Institute (RPI), MIT, and in informal use at UF [3,4,5].

Professional training models, developed in the private sector, were also studied. Many have been shown to be useful in training practicing engineers with a very short time-line. The workbook based methods used by Texas Instruments in their DSP short courses was selected if for no other reasons that it had a track record in the DSP arena. Adapting private sector training methods, however, raised some academic concerns. It was therefore anticipated that special care would be needed to repackage these experiences into activities that properly met academic goals and objectives.

Previous experience suggested that the hands-on (laboratory) element of the InvestiGATOR must go well beyond simply populating a laboratory with necessary hardware and software. Prior attempts to introduce DSP technology into the undergraduate curriculum, using the Texas Instruments (TI) C6711 DSKs and Code Composer Studio 1.x (CCS), created a host of problems. Most

[1] The InvestiGATOR is a registered trademark of the University of Florida for educational products and technology.

tribulations were due to the DSK's predilection to operate in an unpredictable manner. This problem obviously needed to be mitigated.

Lower divisional engineering and signals and systems textbooks generally avoided technology and thereby created downstream problems. As a result, seniors electing to study DSP, often arrived lacking proficiency in some basic skills. It had been assumed that prior Matlab simulations to promote inquiry and develop experimental skills. While students had been exposed to such tools at the lower divisional level, it was usually in an applied mathematics context. Computer simulation tools where rarely used to perform system level studies. Promoting this style of analysis was considered important. Determining how best to achieve this goal was consider to be part of the InvestiGATOR's mission statement.

The last legacy problem that needed to be overcome was teaching assistant (TA) training. In general, TA's had an operational understanding of DSP material but often had limited experience in working with DSP technology. Nevertheless, due to their historically defined role as service providers, they too often remained disconnected from the academic decision making process. It was felt that TA's must become a more visible part of the learning processes, planning and setting learning objectives.

2. STUDIO FORMAT

At the core on the InvestiGATOR innovation is a studio-based delivery system. The studio format consists of a topical review, followed by in-class problem solving activities applying the reviewed material, concluding with a presentation of new material. This format has been shown to be effective in reinforcing technical studies, moving the emphasis from learning abstract concepts to one of applying knowledge in a collaborative setting. Due to repeated in-class exposures, studios are claimed to be particularly effective in a skill development role. Early attempts to integrate a studio model into UF curriculum began in the 1990's under the Synergy banner [6]. This experience was used to guide the development of InvestiGATOR. This prior experience had demonstrated that compared to a traditional lecture-based course, developing a studio course was more time consuming and required careful scheduling. Another lesson learned was that all material should have a common touch and feel. Standard templates and content holders needed to be designed that can also be developed for Web viewing.

At the core of a studio experience are so-called challenge problems that translate DSP abstractions to reality. Students, through guided inquiry, can explore deeper issues relating to design choices and analysis techniques as they apply to a variety of DSP circumstances and applications. Since studio activities are planned in advance, they also turn out to be an ideal forum in which to deliver pre-arranged demonstrations of complex system-level concepts. Such experiences are designed to provide the students with a high level understanding of DSP concepts, technology, and profession practice.

3. LABORATORY ACTIVITES

A demanding task is creating authentic laboratory (experimental) activities that present the student with a very shallow learning curve without trivializing the outcome. While many learning theories abound on how to achieve this condition, the InvestiGATOR study adopted a workbook approach that is based on TI training material. This was justified at a number of pragmatic and pedagogical levels. Students were first given skill development training using a TI 320C6713 DSKs (which were far more reliable than the earlier 6711 systems). After specific skills are developed, student's are assigned projects that apply elements of their DSK training, Projects are constructed to be pursued using the following flow:

- Use Matlab and Simulink to develop parameterized simulations and soft prototypes.
- Prototype a candidate solution using Code Composer Studio (CCS V2.x), verify using CCS simulation.
- Demonstrate solutions on TMS320C6713 DSKs.

There was, however, an unexpected obstacle encountered. There was a documented assumption that Mathworks products supported TI DSKs through Simulink and appropriate toolboxes. As it turns out, the TMS320C6713 DSK is not supported (at this time).

4. RESULTS

The InvestiGATOR project officially began in August 2003. The project, however, was unofficially launched in July in order to prepare material for use in the fall semester. Fortunately, the initial efforts and activities had been pre-planned in the original NSF enabling proposal. Two courses were specified in the proposal for studio delivery, Signals and System and Introduction to DSP (both scheduled for fall 2003). Unfortunately, the textbooks had been pre-assigned [7,8] and would probably been changed if it had been known that the course was to be delivered in a studio format. Requisitioned resources including TI DSKs plus CCS compliers (provided by TI), and cost-shared Mathworks licenses. Although several months were needed to complete the initial acquisition phase, the delays were not a serious impairment. The greatest challenge was preparing class content virtually in real-time. As of mid-October, the studio lessons listed in Table 1 were prepared and delivered. Others are being prepared for delivery in fall 2003. The developed lessons follow the prescribed studio-format previously described. Signals and Systems lessons emphasized computer-based instruction (Matlab) with the expectation that the content would be re-used downstream (e.g., DSP). The lessons developed for the DSP course, stressed technology, system-level solutions, and meaningful applications.

Table 1: Development Studio Content

Signals and Systems	Introduction to DSP
Sinusoids	Sampling theorem
Periodicity	ADC/DAC
Fourier Series	Aliasing
Pulse trains	Aliasing applications
Sampling	Signal generation
Aliasing	Linear time invariance
FIR filters	z-transform
FIR convolution	Inverse z-transform
FIR frequency response	Introduction to the DFT
FIR design	DFT principles
z-transforms	Cooley-Tukey ordering
Convolution theorem	Good-Thomas ordering
z-transforms and systems	Other FFT forms
IIR filters	
IIR frequency response	
Inverse z-transform	

The experimental, or laboratory phase of the DSP experience, relies heavily on contributions and content developed by the TA graduate assistants. Furthermore, several laboratory activities where defined to be training activities. Two two-hour workshops, based upon TI training material, were TA authored and delivered. The workshop topics related to inputting data to the DSK, the second study related to outputting data. Students, in small groups of 3 to 4, completed a set of procedural activities using CCS and the 6713 DSKs. Students, upon completing the workshop, were found to be self sufficient in the area of DSK data importing and exporting. This provided a framework into which applications code can be installed. Students were assigned projects that required teams to develop and insert original application code into this framework. For example, small student teams were required to implement audio special effects from a list that included volume swell, panning, echo, reverberation, chorus, flagging, pitch shift, and ring modulation. Students prototyped their solutions in Matlab, developed them in C code, and then demonstrated their audio special effects on the DSK. The project concluded with the generation of a written and oral report. Oral reports where delivered using a PowerPoint motif.

5. INVESTIGATOR ENVIRONMENT

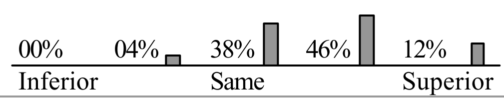
The senior-level DSP course is delivered in two different rooms, depending on content and needs. One room was a multimedia lecture hall, the other was an interactive lab (see Figure 1). DSK studies were conducted in the lab using seven (7) DSK stations similar to those shown in Figure 2 by groups of 3 to 4 students. In-class instruction, when required, was delivered using a PC, video projector, and smart board. This arrangement was very satisfactory in that it allowed a group to carry on intra- and inter-group dialog in a non-invasive manner, and actively engaged TAs (2 per class). The only serious problem encountered with this model was a lack of physical security of laboratory resources during off-hours.

6. ASSESSMENT

The brief history of the InvestiGATOR project prohibits conducting meaningful learning assessments at this time. Instead, a formative evaluation [9,10] is being used to identifying appropriate modifications, if any, need to be made to the learning model. Two sets of questions, regarding delivery and experimental studies, were composed and presented to 25 senior Introduction to DSP (Fall 2003) students. The first set of questions relate to the DSP content delivery. The second relates to laboratory experiences. The results of the Q&A is as follows:

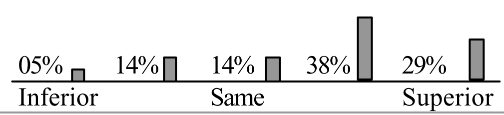
Q: Compared to other engineering courses, evaluate the effectiveness of the Studio method in delivering content.

A:



Q: Compared to other engineering courses, assess the Studio style of content delivery.

A:



Q: Would you recommend continuing with the Studio-based experiment?

A: Thirty-three (33%) said Yes, 66% with minor reservation. Nobody recommended continuing with major revisions or project termination.

Q: Access the value of the DSK workshop sessions.

A:

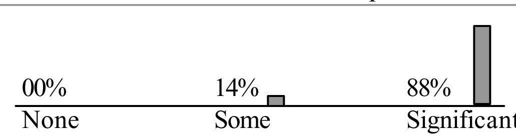
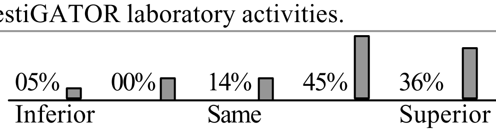


Figure 1: Laboratory Facilities.

Q: Compared to previous laboratory experiences, assess the InvestiGATOR laboratory activities.

A:



It can be seen that the initial reviews are encouraging. While it was anticipated that the InvestiGATOR would fare well against the current pedagogical frameworks, the laboratory activities were especially gratifying.

7. REFERENCES

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Figure 2: Example of a signal processing lab similar to that currently in use at UF (source: Matlab) with a DSK board shown in the insert (source: Texas Instruments).

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