# AC 2011-1424: SIGNALS, SYSTEMS AND MUSIC: GENERAL EDUCATION FOR AN INTEGRATED CURRICULUM

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# Signals, Systems and Music: General Education for an Integrated Curriculum

## Introduction and Background

There have for many years been efforts to bridge the gap between educational experiences in engineering and the liberal arts and sciences. Such efforts typically take the form of courses designed to promote technological literacy for liberal arts majors, or courses designed to encourage engineering or science majors to consider the social and political implications of their professions.

Technological literacy for non-technology majors has been addressed in a variety of ways. One very popular version is to provide a course for students, early in their collegiate career, to learn an engineering application that has direct relevance to their lives. This approach has been used at Yale University in the course EE101—*The Digital Information Age*, where students are challenged to explore some of the signal-processing underpinnings of the World Wide Web[1]. At UMass Lowell, Professor Wunsch developed (and still teaches[2]) *The History of Radio*, where liberal-arts students are introduced to electrical engineering through a survey of wireless communications[3]. As with EE 101 at Yale, *The History of Radio* is intended to meet a Mathematics and Science general-education requirement for non-science majors; consequently, engineering students do not take these courses, because they either "don't count" toward their requirements or they are restricted to non-science or non-engineering majors. An additional common theme in technical-literacy courses is the effort to allay the discomfort of non-technical people with technology[4,5]. The pervasiveness of technology has made this somewhat irrelevant since today's population (particularly young people) are already so familiar with using technology that they take it for granted rather than fear it!

A number of efforts have also been made to combine engineering with the communication arts: writing and public speaking. This has been done in the senior-design course at San Diego University[6]. Some programs have merged technical design labs with courses in written and oral communication skills. These are excellent venues for providing a broadening of the engineering-education experience, but they are taught only to engineers, and the focus is traditional engineering design[7].

A new trend has begun during the past decade, where attempts are being made to bring together students from the liberal arts, sciences and engineering to learn together rather than attempt to teach them *about* one another's disciplines. At Union College, Dartmouth and the University of Alabama[8,9,10] creative solutions are being developed to Professor Snow's[11] challenge to bridge the "Two Cultures."

These learning experiences, however, are primarily clustered in the first and second year of the student's college experience and, by avoiding mathematics and complex reading assignments, provide a "taste" of the transdisciplinary experience. Fortunately, today even this trend is changing and there are a few faculty and administrators who are beginning to insist that deep knowledge can't be split along any cultural dividing line[12]. In particular, Union College in

Schenectady, NY, has developed a new curriculum, Converging Technologies, "…for integrating the arts, humanities and science with modern technology and engineering in a way that will enhance student's technological literacy for the 21st century"[13]. Their comprehensive view of the problem of eliminating the artificial separation of knowledge by culture, and their comprehensive view of the solutions, provide inspiration to programs that hope to make substantive changes to engineering, science and liberal-arts education[14].

The course Signals, Systems & Music began as a collaboration that developed among engineering faculty and technicians who have a love of and interest in music as well as a strong interest in engineering education. During a semester long, one-credit course at Rowan University that introduced students to consulting and entrepreneurship, the faculty developed a module that used music to encourage student participation and teamwork. The popularity of this technique led faculty to explore the interest level and backgrounds of the first year students in music. For the incoming 2009 class the results are shown in Table 1.

Table 1: Survey of Engineering Freshmen, Fall 2009

| First Year Engineering Students Who: | | | |
|---|---|---|---|
| Play an Instrument | Compose Music | Had a Music Class | Listen to Music |
| 37 (35%) | 26 (25%) | 48 (46%) | 104 (99%) |

There were enough students from all engineering disciplines who had a more than passing interest in music to make music as a learning tool appear to be a good opportunity for creating interest among current students, perhaps improving retention and enhancing recruitment.

The first full class effort to incorporate music into our engineering program was a section of Freshman Engineering Clinic. Freshman Clinic is a non-disciplinary course that is the first installment of the eight-semester clinic sequence at Rowan University.

Table 2: Engineering Clinic

| ENGINEERING CLINIC TOPICS | |
|---|---|
| Semester 1 | Measurement and units |
| Semester 2 | Reverse engineering |
| Semester 3 | Design and written communication |
| Semester 4 | Design and spoken communication |
| Semesters 5 through 8 | Research and development in small teams led by individual faculty |

In semester one students meet for one three-hour lab each week where the focus of the experiment is on using engineering equipment and principles to learn the techniques of measurement. A typical experiment is described as Figure 1.

I'm Picking Up Good Vibrations

Understand basic principles of operation of the piezo device – as both a sensor and output device. We will use this sensor to pickup vibrations required to trigger a MIDI signal which will drive a drum synthesizer. You will learn how different materials vibrate and how damping affects this vibration. You will also learn how to use an oscilloscope and catch single-shot signals automatically.

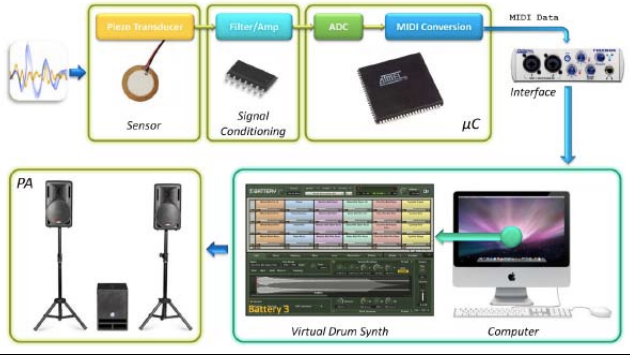


Figure 1: Brief description of music-focus experiment used in Freshman Engineering Clinic

The Freshman Clinic curriculum is narrowly focused on engineering issues associated with the production and analysis of music as a system of signals and is open only to engineering students. The opportunity to move beyond this limited focus is the driving force behind the effort to develop and offer the new course, Signals, Systems & Music.

The Course

Integration of liberal studies and engineering is the overall goal of our pedagogical efforts. Prior to development of this new course, the College of Engineering offered no courses that were available to non-engineering majors without special permission, that is, there were no general education courses available in engineering topics.

Signals, Systems & Music addresses the merged topics of music composition and electronic signal analysis and generation. The existing course is a collaboration between the Electrical and Computer Engineering Department and the Music Department. The initial target audience is first-year electrical and computer engineering majors and undergraduate music majors, although the course will have neither math nor music prerequisites and can be taken by any student on the Rowan University campus. The course will treat the title-topics from a holistic perspective as both a systems-engineering project and a music-composition project. A syllabus for the current offering of the course is shown in Table 3.

Table 3: Course Syllabus

| SIGNALS, SYSTEMS & MUSIC SYLLABUS | | |
|---|---|---|
| SESSION | TOPICS | LABORATORY |
| 1 | History of Electronic Music & Music Theory<br>Units 1-4 | Demonstration |
| 2 | Sound and Hearing<br>Music Theory Units 5 – 8 | Garage Band Training<br>Simple Arrangement |

| | | |
|---|---|---|
| 3 | Elements of a Pop Song, Song Structure and Lyrics<br>Music Theory Units 9 – 12 | Instrumentation and Connectivity |
| 4 | Diatonic Chords, the Blues Form, Core Signals, Amplitude Frequency Period | The Core Signals (sine, triangle, saw, square & noise)<br>Create a Song |
| 5 | Writing a Melody, the Frequency Domain, Harmonics and Timbre | Melody<br>Harmonics: Part 1, Core Signals |
| 6 | Writing a Baseline<br>Analysis of Timbre and Harmonics – Instruments | Baselines<br>Harmonics: Part 2, "Real" Signals |
| 7 | Instrument selection by Timbre | Additive Synthesis, Make your first Synthesizer (Matlab) |
| 8 | Putting it Together – Chords, Baseline & Melody | Filters & Resonance<br>Wine Glass Explosion (demo) |
| 9 | Exam: Music Theory & Lab | Subtractive Synthesis<br>Doepfer A-100 Synth |
| 10 | Drum Programming<br>Music, Harmonics & Psychoacoustics | Adding Analog Synth to the DAW |
| 11 | Elements of Composition | Drum Programming |
| 12 | Workshop & Help Session | Workshop & Help Session |
| 13 | Workshop & Help Session | Workshop & Help Session |
| 14 | Workshop & Help Session | Workshop & Help Session |
| 15 | Recital Day | Recital Day |

The initial course offering in Spring 2010 was co-taught by professors from Electrical and Computer Engineering and Music and the labs were supervised by technical staff from the College of Engineering who coincidentally were also musicians. A full complement of equipment has been assembled to support the course and student projects. Each laboratory station includes:

- iMAC 11,2 3GHz, dual boot computer
- Agilent DSO1012A Oscilloscope
- Agilent 33210A Function Generator
- Agilent 34405A Multimeter
- Agilent U8001A Power Supply
- Cakewalk UA-25EX Audio Interface
- ARTcessories HeadAmp4 Headphone Amplifier
- Axiom 49 Midi Controller and Keyboard

Assessment

Informal assessment was completed for the initial offering. The students were asked to respond to a survey that measured perceptions of the scope of the course. The results of the 27 responses are shown in Table 4 with number of responses indicated in parenthesizes.

Table 4: Survey Results

| ASSESSMENT SURVEY | |
|---|---|
| Music Signals and Systems is a 3 credit hour course. The amount of work required to complete the assignments was: | (6) Less than other 3 credit courses I have taken<br>(21) About the same as other 3 credit courses I have taken<br>(0) More than other 3 credit courses I have taken |
| The amount of time I spent working on the assignments for this course was: | (16) 1 to 2 hours per week<br>(11) 2 to 4 hours per week<br>(0) 4 to 6 hours per week<br>(0) more than 6 hours per week |
| Music Signals and Systems meets the requirement for an Artistic and Creative Experience course. Was the amount of engineering content: | (0) Too much<br>(20) About right<br>(7) Too little |
| Music Signals and Systems meets the requirement for a Math/Science general education course. Was the amount of Music content: | (7) Too much<br>(20) About right<br>(0) Too little |

Additionally, each student was interviewed and asked to talk about their experience, indicating the best aspects of the course and asked to make a constructive criticism. The students commented often that the change of pace and incorporation of music theory with engineering content was a very satisfying way to learn about instrumentation and signal analysis. Some students felt that they were at a disadvantage because they did not have a music background – others thought that the music theory instruction was too fundamental. Some wanted more engineering content – some thought there was too much. Formal assessment instruments are being developed for the next offering.

## Conclusions

As experience with the format and content of this course grows, the number of students who participate is expected to increase. In addition, the example of integration across the engineering liberal studies divide is expected to produce greater opportunities for students to view knowledge from a holistic vantage and increase their ability to think well and critically about their world.

## References


1. Kuc, R., "Teaching the nonscience major: EE101-The digital information age," *Education, IEEE Transactions on* , vol.44, no.2, pp.158-164, May 2001.
2. http://www.uml.edu/registrar/term_fall/schedule/LEECSENGR.html , accessed 5/22/10.

3. Wunsch, A.D., "Electrical engineering for the liberal arts: radio and its history," *Education, IEEE Transactions on* , vol.41, no.4, pp.320-324, Nov 1998.
4. Mahajan, A.; McDonald, D.; Walworth, M., "General engineering education for non-engineering students," *Frontiers in Education Conference, 1996. FIE '96. 26th Annual Conference., Proceedings of* , vol.3, no., pp.1264-1266 vol.3, 6-9 Nov 1996.
5. Pearce, J.A.; , "Technology for non-technical students: adventures on the other side of campus," *Frontiers in Education Conference, 2000. FIE 2000. 30th Annual*, vol.1, no., pp. T2F/1-T2F/3 vol.1, 2000.
6. Kramer, K.A., "A senior-level engineering course that meets general education requirements," *Frontiers in Education Conference, 1997. 27th Annual Conference. 'Teaching and Learning in an Era of Change'. Proceedings.* , vol.1, no., pp.383-386 vol.1, 5-8 Nov 1997.
9. J. Marchese, R. Ordonez, C. Sun, E. Constans, J. L. Schmalzel, R. Ramachandran, H. L. Newell, H. Benavidez and J. Haynes, "Integration of Multidisciplinary Design and Technical Communication: An Inexorable Link", *International Journal of Engineering Education*, Vol. 18, No.1, pp.32–38, 2002.
10. Bolding, K.; Bauman, E., "Integrating engineering into a freshman liberal arts curriculum," *Frontiers in Education Conference, 1999. FIE '99. 29th Annual*, vol.3, no., pp.13C2/1-13C2/5 vol.3, 1999.
11. Heywood, J., ""Think…about how others think", liberal education and engineering," *Frontiers In Education Conference - Global Engineering: Knowledge Without Borders, Opportunities Without Passports, 2007. FIE '07. 37th Annual*, vol., no., pp. T3C-20-T3C-24, 10-13 Oct. 2007.
12. Hansen, E.W., "Technological Expertise with Liberal Education: The Dartmouth College A.B. in Engineering Sciences," *Frontiers in Education Conference, 36th Annual*, vol., no., pp.17-22, 27-31 Oct. 2006.
13. Snow, C.P., *The Two Cultures*, Rede Lecture, 1959.
14. Duan, Yun, "Discussion on the Design Education Divided between Sense and Artistry," *Education Technology and Computer Science (ETCS), 2010 Second International Workshop on*, vol.3, no., pp.701-704, 6-7 March 2010.
15. Klein, J.D., Balmer, R., "Engineering, Liberal Arts, and Technological Literacy in Higher Education," *Technology and Society Magazine, IEEE* , vol.26, no.4, pp.23-28, Winter 2007.
16. Klein, J. Douglass; Traver, Cherrice; Raucci, Stacie; Jones, Sharon A., "Special session - inventive courses: Blending engineering and the liberal arts," *Frontiers in Education Conference, 2009. FIE '09. 39th IEEE*, vol., no., pp.1-2, 18-21 Oct. 2009.