The Learning and Teaching Experiences in a Graduate Level Stem Course for Teacher Educators

Faculty Paper

K-12 Education (Curriculum Integration)

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Abstract: It is essential that teachers understand the content of the subjects they teach. A particular challenge in a graduate program for secondary mathematics and science teachers is how to provide teacher candidates with subject matter content, on a graduate level, that does not replicate undergraduate courses.

The School of Education and School of Engineering at University of Bridgeport designed the EDMM 600D- STEM (Science, Technology, Engineering, and Mathematics**)** for Teacher Educators course for students of the School of Education. Designed course uses audio and image processing techniques and technologies to teach fundamental STEM concepts to secondary pre- and in- service mathematics and science teachers. *Designed to enrich the teaching and learning experience*, the course activities include: (a) Lectures and Discussions, (b) Lab activities: Hands-on computer experience, and (c) Team Project.

In this paper, we will present the developed course outline, the response of our students who are pre- and in-service teachers, and the lessons learned by the instructors.

Introduction

In everyday life, people use devices such as cell phones, iPods and digital cameras, which use audio and image processing technology. Although Ngoh and Saleh (2010) in an article titled *"Is technology a curse or a blessing to our students of today"*, it was clear that these technologies can be used in classroom applications to motivate students and make science relevant to their learning. Despite some minute issues revealed as the dark side of technology for students, it was still evident that these technologies offer entry to every student regardless of his/her ability, and they offer the student a means to achieve success at his/her level of education.

In 1999, Infinity Project innovators prepared engineering curricula for middle school, high school, and beginning college students by using audio and image processing techniques and technologies. The curricula and pedagogy developed through this project continue to help educators deliver maximum engineering exposure through hands-on engineering learning in today's classrooms. Our developed course expands this project to the post-secondary level of both teacher preparation and in-service teacher training.

The principles of digital audio and image processing have applications in an amazing diversity of areas, from science and engineering (biomedical engineering, astronomy, video and wireless communications) to entertainment (music and video games). Digital audio and image processing education needs to be able to cater to a wide spectrum of people from different educational backgrounds. These fields draw from a great variety of academic disciplines, including mathematics, biology, acoustics, computer graphics, computer vision, optics, and computer science. It is essential to present these inter-disciplinary topics to middle school and high school teachers. These proposed multi-media experiences will teach pre- and in-service teachers the content and pedagogical tools with which to guide students to an understanding of these digital topics.

A particular challenge in a graduate program of secondary mathematics and science teacher education is to provide subject matter content on a graduate level that does not replicate undergraduate content. Teachers need exposure to subject matter that allows both review of key concepts in their fields and expansion of their knowledge into new fields, in constructivist settings.

Course Design and Content

This 3 credit, one semester course, *EDMM-600D STEM for Teacher Educators*, was started in Spring 2011. It needs to be revised based on students' feedback. The course offers base-level information on the theory and use of digital imaging and audio to improve the understanding of mathematical and science concepts such as arrays, matrices, sound production, how we hear the sound and how we see objects. The course is designed for the pre-service teachers in the School of Education, University of Bridgeport. Participants will be engaged in up-to-date technical information, formulas, and simple programming algorithms, all designed to improve their level of understanding. This course helps its participants relate to math concepts through a “hands-on” multimedia approach using Mathwork’s MATLAB software through audio and visual applications.

The goals of this course are:

- to teach basic knowledge on digital signal processing and technology with a creative interaction between music, speech, image and technology for STEM related courses such as mathematics, biology, and physics;
- to prepare instructional course materials for teachers to use in their classrooms.

This required course for the program will expose future teachers to new content materials. In addition, this “cross fertilization” will provide opportunities for participants to view subject matter in new perspectives. It will open avenues for new lesson development. *EDMM-600D* provides comprehensive professional development for teachers in two major engineering technologies which use many concepts from mathematics and science: digital audio and image processing. *The principles of digital audio and image processing have applications in an amazing diversity of areas*, from science and engineering (biomedical engineering, astronomy, video and wireless communications) to entertainment (music and video games). These fields draw from a great variety of academic disciplines, including mathematics, biology, acoustics, computer graphics, computer vision, optics, and computer science. It is essential to present these inter-disciplinary topics to middle school and high school teachers.

The objectives ***or*** *outcomes of the course:*

- Develop knowledge and understanding about the practical and real world applications of audio (voice, speech, music) and image processing.
- Become familiar with audio and image processing hardware and software.
- Value and appreciate new technologies that enhance STEM learning.
- Be able to conduct hands-on activities and to teach the topics in the classroom.
- Be able to prepare instructional course materials for the classroom.
- Develop a range of skills relating to the presentation of course materials in a formal setting.

Course Activities:

- Lectures and Discussions
- Lab activities: Hands-on computer experience

Grading:

Midterm exam: 30%
Homework: 20%
Final Project/Exam: 50%

Organization of the Course: Lectures and Labs

Students are organized into groups of 2 or 3. Laboratory sessions are usually 2-3 hours. Sets of readings for each lab have to be read before class. Some readings are in text. Others will be handed out. Lecture will cover background material pertinent to lab, in these areas:

- The physiology of speech production
- The respiratory system
- The acoustics and acoustic analysis of speech
- Periodic and Aperiodic Signals
- The Ear and How we hear
- Logic, Truth Tables, and Sets
- Algorithms, Recursion Formulas, and Induction
- Linear Algebra
- The Eye and How we see
- Digital imaging

Course Content and Schedule:

Week 1: Lecturer: Dr. N • The Respiratory System • Voice Production	Week 8: Lecturer: Dr. B • Applications
Week 2: Lecturer: Dr. C • Periodic and Aperiodic Signals	Week 9: Lecturer: Dr. C • Linear Algebra: Matrix operations
Week 3: Lecturer: Dr. N • The Ear and How we hear	Week 10: Lecturer: Dr. B • Applications
Week 4: Lecturer: Dr. B • Applications	Week 11: Lecturer: Dr. N • The Eye and How we see
Week 5: Lecturer: Dr. C • Logic, Truth Tables, and Sets	Week 12: Lecturer: Dr. B Applications
Week 6: Lecturer: Dr. B • Applications	Week 13: Team Project Week 14: Team Project
Week 7: Lecturer: Dr. C • Algorithms, Recursion Formulas, and Induction	Week 15: Student Project Presentations (30-minutes Power point presentations)

Team Project:

Students choose one of the following possible projects.

1. Choose a topic (Logic, Truth Tables, and Sets, Algorithms, Recursion Formulas, and Induction, Periodic and Aperiodic Signals, Linear Algebra, The Ear and How we hear, The physiology of speech production, The respiratory system, The acoustics and acoustic analysis of speech, The Eye and How we see, Digital imaging) and develop a two-week unit designed to promote problem solving success in the area of your topic at a particular grade level.
2. Choose a topic (Logic, Truth Tables, and Sets, Algorithms, Recursion Formulas, and Induction, Periodic and Aperiodic Signals, Linear Algebra, The Ear and How we hear, The physiology of speech production, The respiratory system, The acoustics and acoustic analysis of speech, The Eye and How we see, Digital imaging) and develop a unit illustrating the use of problem solving in this area over several grade levels.

Evaluation and Assessment

To assess and evaluate the students' impressions of the new course, discussions were held with the students and a questionnaire was developed for distribution and collection at the end of the nine weeks. The questionnaire is given in Appendix with the combined responses shown in Table I.

Table 1. Results of EDMM-600D STEM for Teacher Educators Evaluation

Question Number	**% Agree (SA and A)**	**% Neutral**	**% Disagree (D and SD)**
1	33	67	0
2	83	0	17
3	34	33	33
4	50	33	17
5	50	17	33
6	83	0	17
7	67	17	17
8	33	50	17
9	50	50	0
10	83	17	0
11	100	0	0
12	50	33	17

	% Very good /good	% Neutral	% Poor/very poor
13	83	17	0
14	83	17	0
15	100	0	0
16	67	17	17
17	67	33	0
18	100	0	0
19	100	0	0
20	83	17	0

*Sample size is 6 students Response rate is 100%

In composing the questionnaire, questions 4, 6, 7, and 12 are of special interest in assessing how the students value the new course. More than half of the students selected “Strongly Agree” or “Agree” when answering these questions as compared to less than one sixth who “Disagree” or “Strongly Disagree.” Of particular note were the responses to these questions, where 83% of the students agreed or were neutral. The authors believe that these results demonstrate that the newly offered course does enhance the students’ understanding of the STEM concepts in this course. 100% of the students agreed that this course is very good or good as a learning experience.
One major concern of the faculty that was also expressed by the students was the prerequisite knowledge and skills required from for this course. 33% of the students think that they have the prerequisite knowledge and skills for this course. They felt that if there was a physics instructor to have elaborated on the concepts and the calculations of the frequency, wavelength, with reference to waves and sound as well as on the concepts and calculations of the focal lengths, angles of reflection and refraction of light, they might have had the computations of the digital sound processing and digital imaging easier than what they experienced in the engineering laboratory.
STEM is a common topic of conversation in many academic circles today and the integration of teaching methods is highly recommended. Always teaching subjects in isolation does not enable students to see clearly how one course is related to the other and how a course could be readily applied in real life situations.

When this course, EDMM 600D, was designed, thought was given to topics that could easily demonstrate this concept of integration, relatedness and application of science, technology, engineering and mathematics in the society. It was for this reason that we chose sound or speech production, transfer of the sound waves to be heard and the acoustics involved and also how light and its characteristics made it possible for objects to be seen.

For biology then, the instructor involved had to start with the respiratory system with emphasis on the larynx and the vocal cords. A clear description was made of how the the vocal cords, the tongue and the lips all functioned in the production of sound.This was followed by a lesson on how the structure of the ear was adapted to be able to transfer the vibrations through the ear to the brain for the noise, music to be heard. The waves gathered by the pinnae into the auditory canal hit the tympanic membrane whose vibrations were transmitted by the ear ossicles to the oval window into the inner ear where sensory cells in the cochlear started off an electric stimulus through the auditory nerve to the brain which interpreted the particular sound. Frequency, amplitude, pitch and wavelength were explained in such a way that students could easily understand when the technology/engineering instructor would be calculating the wavelengths, frequencies and analyzing the acoustics of the speech. Similarly, the structure of the eye was discussed for the student s to understand how the reflection of light rays on an object made it possible for the refraction of light by the cornea, lens and the aqueous and vitreous humors helped formed the inverted image on the retina. The sensitive photoreceptors pick up the stimulus and send out the electrical impulses through the optic nerve to the brain which decodes the information for one to see the object in its up-right perspective. This principle is demonstrated by comparing the function of the camera with the human eye. When the students grasp this process of accommodation, they are well prepared to put this into practice with the math and engineering instructors calculating the object distance, focal length, the refractive index of the lens and the practical digital imaging concept.

The science part of the course was accepted without hesitation by this cohort of students because a good number of them had a solid base in human physiology. The real challenge and excitement came as the students saw these seemingly obvious topics approached from a practical angle as the engineering instructor simply transformed those concepts of wave production into sound production and hearing. Similarly, the reflection, refraction and transmission of light rays brought about digital imaging and seeing. Students realized practically how the convex and concave lenses were used to correct myopia, hypermetropia as well as astigmatism and diplopia.

Our original plan was to explain rather general mathematical principles of logic, algorithms and recursion formulas used in computer engineering, and then illustrate these principles in light of specific content materials in the course. Our first meeting concentrated on truth tables, basic principles in Boolean algebra and elementary circuit design, with specific problems involving simple series and parallel circuits. For some of the students the material was a review, others found it a bit challenging.

While all had backgrounds in various sciences their knowledge of mathematics was very uneven. For example, those students who had degrees in physics, computer science, electrical engineering were comfortable with the mathematics we introduced , while those with degrees in biology, earth science, and to some extent chemistry, frequently had not studied much mathematics at the undergraduate level. They did not find the material particularly easy to grasp. Nevertheless, student feedback from the session was good. They had learned new ideas and were positive about the experience. .

A much clearer picture of students' understanding came during the next lab period. We realized that we had vastly overestimated their understanding of some basic mathematics. During this session problems arose with calculations involving logarithms. Many of the students were completely confused. They did not understand the most fundamental properties of logarithms; in fact, a number of them could not even give a specific example of a logarithm.

This situation required us to face two problems. The first dealt with our long range goals: How to give students the basic mathematical background needed to ensure success in the course? The second was more immediate: What mathematics must we cover with students to ensure they would be prepared to complete the present course?

We decided that before we offer this course again, we would have to consult with each other, before the start of the course, about the exact mathematics that students needed to understand the engineering and computer science they would cover. We had to be careful to over-reach our goals. For example, if students needed to know information about linear functions we would not start talking about matrices, operations with matrices, inverse operations and matrix solutions of systems of equation. Rather, we would be sure that a student understood carefully the slope-intercept form of the equation of a line, and how to solve two equations with two unknowns by various methods.

With this new insight into students' backgrounds we decided that the next "mathematics" class would concentrate on basic trigonometric functions. To the surprise of many in the class, we introduced trigonometric functions as circular and the corresponding reciprocal functions. Understanding that the basic three trigonometric functions, were values that could be read off the unit circle, allowed for a simple, yet rigorous development of trigonometry. The graphs of the trigonometric functions followed immediately. It was these graphs that formed the basis of the computer analysis of sound and light.

This experience underscored the constructivist nature of our work as teachers. We needed to exchange ideas with students about how they were constructing or not constructing knowledge. This dialogue, this exchange of ideas, then allowed us to construct course materials which students found meaningful.

Instructor B is responsible of connecting mathematics and biology learnings, which are taught by Instructor N and C, to appropriate real-world concepts such as audio and image processing technologies. The authors think that the present and future K-12 Math and Science teachers need to teach their curricula by an interdisciplinary approach. George and Thomaskutty stated that *"...most of the Mathematics classrooms are boring, especially, in the school level. Students either hate Mathematics, or fear it. The blame for this plight is partly to the teachers and the rest to the curriculum. Students get no interest in studying this subject, because neither the teacher, nor the syllabus points out the practical use of the prescribed portions. Here comes the need of coining Mathematics with other disciplines. There should be an interdisciplinary approach in teaching Mathematics...*"

Mathematics is a common language of many disciplines and teachers should know mathematical concepts used in those disciplines so that they can teach their students how to connect their mathematical learning to appropriate real-world contexts. Although there is a belief that Biology is free from mathematics, Biology needs mathematics in a great amount. Instructor B presents computer/programming-based activities by combining the biology concepts --respiratory system, voice production, the ear and how we hear— with audio processing technologies and --the eye and how we see, vision-- with image processing technologies.

Instructor B has faced several challenges during her lectures. One of them is the weak mathematical background of the students. Secondly, some of the students believe that applying this interdisciplinary approach in their classroom will be very difficult. This misbelieve or misconception blocks their creativity.

Conclusion

In developing a new STEM course, several issues needed to be addressed. First, the students with varying backgrounds as biology, earth sciences, and mathematics majors must be able to understand basic mathematical concepts in order to learn advanced STEM concepts. All of the students revealed or admitted that that they did not have a strong background in math and need recalls for performing basic numeric operations such as the elementary exponential, logarithm, and trigonometric functions. This issue has become a serious drawback, especially in MATLAB applications. A second issue is how to address the time commitment of the students. The students require more time for the MATLAB applications since they do not have a prior knowledge of programming. A change in the curriculum and credit-hours can be made, but this issue remains to be resolved by the authors. The instructors have emphasized cooperation and teamwork, and the students always are reminded to work on their communications skills with their team members. We hope that continues improvement of this course will push whom they need for integrating science, technology, engineering, and mathematics in our school. This will further highlight the relationships and the applications of the knowledge of these subjects into the society today.

References

N. Ngoh and S. Jahangir, “Is technology a curse or a blessing to our students of today”, Journal for the Advancement of Educational Research, 2010.

M. George and P. G. Thomaskutty, “Interdisciplinary Programs Involving Mathematics”, math.arizona.edu/~atp-mena/.../Mary_George_Interdisciplinary.doc

Appendix:

EDMM 600D- STEM for Teacher Educators
Evaluation Questionnaire
INSTRUCTIONS
Please circle your response to the items. Rate aspects of the course on a 1 to 5 scale 1 equals "strongly disagree" and 5 equals "strongly agree." 1 represents the lowest and most negative impression on the scale, 3 represents an adequate impression, and 5 represents the highest and most positive impression. Choose N/A if the item is not appropriate or not applicable to this course. Your feedback is sincerely appreciated. Thank you.

NA=Not applicable, 1=Strongly disagree, 2=Disagree, 3=Neutral, 4=Agree, 5=Strongly agree

COURSE CONTENT (Circle your response to each item.)

1. I have the prerequisite knowledge and skills for this course.	N/A 1 2 3 4 5
2. I am informed about the objectives of this course.	N/A 1 2 3 4 5
3. This course lives up to my expectations.	N/A 1 2 3 4 5
4. The content is relevant to my job.	N/A 1 2 3 4 5

COURSE DESIGN (Circle your response to each item.)

5. The course objectives are clear to me.	N/A 1 2 3 4 5
6. The course activities stimulate my learning.	N/A 1 2 3 4 5
7. The activities in this course provide sufficient practice and feedback.	N/A 1 2 3 4 5
8. The difficulty level of this course is appropriate.	N/A 1 2 3 4 5
9. The pace of this course is appropriate.	N/A 1 2 3 4 5

COURSE INSTRUCTORS (FACILITATOR) (Circle your response to each item.)

10. The instructors are well prepared.	N/A 1 2 3 4 5
11. The instructors are helpful.	N/A 1 2 3 4 5

COURSE RESULTS (Circle your response to each item.)

12. I will be able to use what I learned in this course.	N/A 1 2 3 4 5

	Very good				Very poor
13. Presentation of the course material	A	B	C	D	E
14. Explanation of course material..	A	B	C	D	E
15. Accessibility of instructor(s)…………………………………………	A	B	C	D	E

16. Explanation of assignments……………………………………………A B C D E
17. Relevance of assignments to course content……………………… A B C D E
18. Overall, the instructor's treatment of students in class, regardless of their group or background was…………………………………..………...................................A B C D E
19. Course as a learning experience…………………………………… A B C D E
20. The physical arrangements are conducive to learning…………..… A B C D E
21. How would you improve this course? (Check all that apply.)
___Provide better information before course.
___Clarify the course objectives.
___Reduce content covered in course.
___Increase content covered in course.
___Update content covered in course.
___Improve the instructional methods.
___Make course activities more stimulating.
___Improve course organization.
___Make the course less difficult.
___Make the course more difficult.
___Slow down the pace of the course.
___Speed up the pace of the course.
___Allot more time for the course.
___Shorten the time for the course.
22. What other improvements would you recommend in this course?
23. What is least valuable about this course?
24. What is most valuable about this course?