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An Interdisciplinary Learning Experience: The Creation of a Robot Dance

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Abstract

Students are engaging technology as a means to convey their creativity, artistic design, and appreciation of the Arts. In this paper, we share our experiences regarding an interdisciplinary project between students in an Information Sciences and Technology course and students in a General Education Arts course. Students were tasked with creating the digital musical scores and writing Java applications for the robot movements. The design and implementation of the choreography would be the bridge between discipline areas. The final product was a robot dance where the movements of robot couples were synchronized to the rhythm of the music. Active-learning exercises were utilized to expose students to a variety of music theory, animation and programming components that together provided the foundation for this project. Students used the respective software applications to realize a design in music or choreography and implement a solution. Iterative development coupled with various forms of visual and audio feedback enhanced the student learning experience.

Keywords: Interdisciplinary Project, Java, Animation, Music, Lego Mindstorms, Sibelius

1. MOTIVATION AND RELATED WORKS

Computing technology can be utilized to enhance our creativity and the learning process. When focusing on creativity in a project, one needs to be able to communicate and exchange ideas in a constructive and defined manner. To be productive, members of an interdisciplinary team must share a common vocabulary, have a common understanding of the project vision, establish goals, and constructively evaluate the efforts of each team member while working together to develop the final product (Mamykina, Candy, & Edmonds, 2002).

Within academia, faculty are seeking to include interdisciplinary projects with a significant computational component into the curriculum to enhance collaboration between computer science and other disciplines such as engineering, physics, chemistry, arts, and the social sciences. Building bridges between academic areas encourages students to explore, build hypotheses, experiment, development critical thinking for problem solving (Barr, Liew, & Salter, 2010). Replacing the traditional introductory computer science course in the curriculum with an interdisciplinary and "connected" pair of courses in creative arts, humanities, history, math and computer science, natural sciences, and social sciences has resulted in an increase in female enrollments, retention in computing, and new energy for interdisciplinary research opportunities. Connecting with Art courses in the curriculum includes design (creativity) and development (computational thinking) (LeBlanc, Armstrong, & Gousie, 2010).

Students should have opportunities to engage in interdisciplinary undergraduate research projects where they can build confidence and enhance their learning. Barker completed an interview study of both faculty research mentors and undergraduates that analyzed the organizational, social and intellectual conditions under which undergraduate research was being conducted (Barker, 2009). Barker observed that undergraduate research projects in science, technology, engineering, and mathematics (STEM) have benefits such as "improved retention in both the major and discipline-related careers; ability to work independently and to communicate well with a team; increased confidence in academic knowledge and technical skill; broader awareness of the discipline; and awareness of career opportunities and support for making career choices" (Barker, 2009 p.1-2).

Interdisciplinary teaching and interpretation of technology for various applications provides a means to maintain a computer workforce for the nation's economic, cultural, and democratic vitality. The use of robotics allows one to achieve this goal by integrating technology and software development with art, physics, mathematics, and cognitive science (Weiss & Overcast, 2008). Weinberg (2005) presents a summary of an undergraduate course in robotics that focused on developing group dynamics and teamwork skills in multidisciplinary teams. leJOS NXJ (leJOS Team, 2007) and LEGO® MINDSTORMS® (The Lego Group, 2012) were utilized in an advanced software engineering project to provide experiences with remote device interfaces, multi-threading and network communications (Lew, Horton, & Sherriff, 2010). When students develop software applications and music compositions, they follow a similar development process that includes requirements definition, design, implementation and test/debug phases (Smarkusky & Toman, 2009).

In the remaining sections of this paper, we specify technologies that were selected for the completion of the music and animation components of our interdisciplinary project. We then describe the discipline and team-based tasks that were required for the completion of the robot dance, followed by a discussion of the class presentation and project assessment. We conclude with a summary of student feedback, comments and lessons learned.

2. MUSIC AND ANIMATION TECHNOLOGIES

Sibelius

Sibelius (http://www.sibelius.com) is music notation software that provides users with the ability to insert and playback a digital musical score, refer to Figure 1. Users have the ability to create a musical score from scratch via the selection of the staff, key signature, time signature, instruments, etc.

Figure 1. Digital Score in Sibelius

Using a point-and-click interface, users can insert notes, musical nuances, symbols, lyrics, and text. Musical sequences for a variety of standard and non-standard instruments can be added to the score. This tool is equipped with digital playback where a playback indicator displays the bar number and the timeframe as the music is playing, providing audio and visual feedback to the user.

LEGO MINDSTORMS NXT

The LEGO MINDSTORMS NXT, shown in Figure 2, has strong community support and provides an extensible platform (The Lego Group, 2012). There is an abundance of documentation available for the LEGO MINDSTORMS and they tend to be less expensive that other robot kits. The kits provide flexibility in that they can be assembled into a variety of configurations based on the project being completed. The NXT brick includes four sensor ports ('1', '2', '3', and '4') and three input ports ('A', 'B', and 'C'). LEGO

Figure 2. LEGO® MINDSTORMS® NXT

offers a wide variety of sensors to include Sound Sensor, Light Sensor, NXT Color Sensor and Ultrasonic Sensor. Communication between the computer and the brick was accomplished via a USB cable connection.

leJOS NXJ

leJOS NXJ is a Java programming environment for the NXT that was originally created from the TinyVM project, which was an implementation of a Java Virtual Machine for LEGO MINDSTORMS RCX system (leJOS Team, 2007). This firmware is used to replace the NXT MINDSTORMS factory-loaded software, which includes a drag-n-drop environment for programming. This leJOS NXJ environment includes a Java Virtual Machine, a library of classes that implement the NXJ Application Programming Interface (API) for execution on the brick, a library of Java classes for computer programs that communicate with the brick via USB or Bluetooth, PC tools for debugging and flashing the firmware, and the capability to compile, link and upload programs and other files to the NXT brick. The original firmware can be reloaded at any time using the supplied LEGO software.

The benefits of using leJOS NXJ include the use of a high-level Java programming language, support for object-oriented programming, an opportunity to use open source software, and development via NetBeans (www.netbeans.org) or Eclipse (www.eclipse.org) Integrated Development Environment (IDE) with associated plugins for each environment. For the more advanced Java Developer, it supports multi-threading, listeners and events, support for the playing of 8-bit WAV files, and it provides opportunities for challenging, multimedia-based and problem-solving projects.

3. ROBOT DANCE REQUIREMENTS

In this section, we discuss the requirements of our robot dance project that was completed by eighteen students in a Fundamentals of Music Theory course and eight students in a Distributed Computing course. The project duration was four weeks with Music students involved for the entire project and Information Sciences and Technology (IST) students participating for the final three weeks. A snapshot of a robot dance is shown in Figure 3.

Figure 3. Robot Dance Snapshot

Discipline Specific

Music students utilized Sibelius for the creation of the digital musical score. The Music Theory course introduced students to the fundamental concepts of music and music terminology (pitch, melody, rhythm, time signatures, major and minor scales, key signatures, intervals, chords, and proper setup of a musical score) which prepared them for this interdisciplinary robot dance project. Using these concepts, students were given selected piano sheet music in which they entered the notes from the sheet music with exactness into Sibelius using the point-and-click interface. The sheet music score was enhanced further by adding additional instruments such as trumpet, flute, clarinet, guitar, bass guitar, and drums using plug-ins that are integrated within Sibelius. Students have full control of their musical score by being able to control dynamics, tempo, and other musical nuances of their playback. Once the digital musical score was complete, it was exported to a WAV format. The Sibelius and WAV files were uploaded to the on-line team space for use by the IST student to utilize in the timing of the music and the synchronization of the dance steps that were created.

In preparation for the robot dance project and while the Music students were creating the Sibelius and WAV files, the IST students were becoming familiar with the leJOS Application Programming Interface (API). IST students would need to implement the choreography using Java for deployment on the leJOS NXJ firmware for the LEGO MINDSTORMS NXT platform. We assigned a Robot Maze project where IST students had an opportunity to learn how to interact with the leJOS interface using Java as well as compile, link, upload and execute programs on the NXT. Students experienced Java Threads, interaction with various sensors, but most importantly how to pilot the robot which included moving forward and backward, turning a specified number of degrees, moving in an arc motion, etc. This opportunity prepared the IST students with the knowledge they needed to communicate with the Music students when discussing the capabilities of creating the choreography for the robot dance. Once the maze project was complete, IST students focused their attention on the robot dance.

Interdisciplinary Team

We selected students from each course and assigned interdisciplinary teams based on student performance from previous course assignments. Each team consisted of one IST student and two or three Music Theory students. Team spaces were setup in an on-line course management system for students to post their Sibelius files, WAV files, choreography design, and the Java source code files. Each team was assigned a different song for this project.

The next step of this interdisciplinary project was having an IST student listen to a sound clip sample of the assigned song before their initial meeting with the music students. Since the music students were creating digital musical scores in Sibelius of these songs, the final product would sound slightly different due to additional instruments (bass, drums, etc.) and may have a variation of tempo (how fast/slow the music is played). The choreography would need to match the length of the team’s cover version and would also need to be synchronized with the timing of the music created by each team.

Each team worked on the design phase of the choreography for the robot dance. Students were informed that each robot couple (two robots) should remain on the dance floor (6’ X 12’) at all times, the robots were not to come in contact with each other and that the wheels of the robot were to be in contact with the dance floor or other solid surface at all times. Both Music and IST students defined the dance routine to include right and left turns, arcs, spins, forward and backward movements and the starting and ending points in the song for each movement and the duration of each movement. During class meetings and between meetings, the IST student would work to implement these motions in Java so that the identified robot movements would be synchronized to the timing of the music. Timing of the movements was critical to the quality of the dance. Students utilized the playback indicator in Sibelius for the proper timing of the music to be synchronized with the robot’s moves. Together the IST and Music students observed the robot movements, listened to the music, and precisely documented the start/stop times for each movement as they followed the design of the choreography. Once the movements for the first robot were complete, the IST student then needed to write a program to mirror the choreography for the second robot, altering the movements, rotations and directions, and yet keeping the timing the same.

Similar to patterns in musical scores, the IST student recognized patterns in the choreography and the timing of the movements. This provided a unique learning opportunity for the IST students as they realized the importance of threads and the writing object-oriented methods for each routine with parameters for time, duration, direction, or rotation for various movements.

As the teams worked side-by-side on the completion of this project, we began to see the communication between interdisciplinary members come together using a common language to describe the dance steps and how this was to be accomplished. Similar to the comparison presented in Do & Gross (2007), the music student is not expected to be a programmer, and the programmer is not expected to be a music student. Each member of the interdisciplinary team utilized their strengths for the success of the project. Teams were very excited about the outcome of the robot dance project and would often stay after class to work on their projects so that their dance would be better than other teams. During this process, the IST student appreciated the time and effort that the Music student had put into the digital musical score and the Music student appreciated the attention to detail that was needed for the creation of the choreography.

Presentation and Assessment

The completed project was presented to students from both classes and invited guests from the campus community. To provide the proper ambiance for the Robot Dance Party, we reserved a conference room; setup the dance floor area surrounded with tables and chairs; and provided a sound system and data projector for the playing and display of the digital musical score while the dance was being performed.

Grading criteria for assessment of the digital music scores included correct staves, key signature, time signature, notes, rhythmic durations, slurs, expressive and tempo markings, dynamics, musical symbols, correct number of measures repeat signs, etc. The addition of other instruments to the basic piano score included flute, clarinet, trumpet, saxophone, guitar, bass, and drum set. The final assessment component was the conversion of the score from a Sibelius (.sib) file to a WAV file. The IST student efforts were assessed on the creativity and complexity of the choreography for two robots; synchronization of movements between two robots; synchronization (timing) of movements to the music file for both robots; overall appearance and quality of the choreographed dance for the two robots; and submission of project deliverables and student feedback.

This project included an element of creativity that allowed students in both disciplines an opportunity to work together towards a common goal. By providing students with an opportunity for participatory learning and defining an assessment that included a set of learning objectives linked to grading criteria, we could level the playing field for different types of students (Carter, Bouvier, Cardell-Oliver, Hamilton, Kurkovsky, Markham, McClung, McDermott, Riedesel, Shi & White, 2011). Assessment criteria for the music and animation components were provided to the students to help identify the roles of each team member, provide a guideline for project success, and promote a positive learning experience for students in an interdisciplinary team.

4. FEEDBACK AND LESSONS LEARNED

After the project was completed, we asked students to complete a survey to evaluate the creative nature of the robot dance project. Our survey used a 5-point Likert Scale (where 1 = Strongly Disagree, 2 = Disagree, 3 = Undecided, 4 = Agree, and 5 = Strongly Agree). All 26 students (18 Music and 8 IST) completed the surveys. The survey results for the Music and IST students are shown in Table 1 and Table 2, respectively, of the Appendix. The percent of positive responses noted in the table include all responses with Agree or Strongly Agree.

Students in both disciplines, Music (100%) and IST (100%) had positive responses regarding working with students in other disciplines and that both disciplines worked together as a team. Although 61% of the Music students thought of themselves as creative in ART, only 39% had positive responses about being creative when using Technology and/or Software. Similarly, 100% of the IST students thought of themselves as being creative when using Technology and/or Software, but only 38% had positive responses about being creative in ART. As predicted students felt more strongly about the concepts and focus of the course in which they were enrolled.

It is interesting to note that Music students had a 100% positive response about this project being a creative learning experience, but only 71% of the IST students felt this project was a creative learning experience. This reinforces the statement that computing technology can be utilized to enhance creativity and the learning process in interdisciplinary areas. Although students in both disciplines thought of themselves as being more creative in their discipline, students in both Music (53%) and IST (50%) had positive responses about this project allowing them to improve their creative skills. Both Music and IST students agree that this project should be offered again, with 83% and 88% providing positive responses.

Utilizing software tools for both the music and animation components allowed students to correlate real world activities with those contained in the final robot dance. The extent to which students were pleased with their final product had a direct correlation with the students ability to communicate with each other in the team and translate what they had completed with the music composition to that which was to be developed for the robot choreography(Yardi, Krolikowski, Marshall, & Bruckman, 2008). This collaborative and interdisciplinary project was a positive learning experience for students in both departments. Statements of lessons learned from the IST students follow:

- *"The choreography project specifically has provided interaction with students who did not have a programming background and therefore provided a more realistic experience for a project. Working out a solution that satisfies the expectations of someone who may not understand the complexity and hurdles [of programming] that could prevent the completion of the project provides a real world aspect that can be lacking in other projects.* "

- *"One of the things I did learn while doing this project was the similarities between Java code and music as a whole. I play guitar and have learned repeated riffs in songs before, but I never really viewed them as functions in a program until working on this project. I always viewed myself as uncreative because I can't write music if my life depended on it, but seeing this correlation between music and code really sheds a new light on things. This project helped to show me that I am creative. I'm just creative through my own outlet, not through the standard views of creativity."*

- *"This project has given me so much confidence and knowledge on how to work with a new API. Doing this interdisciplinary project, I have gained the knowledge of not only the new API but also something that I wouldn't have learned as an IST student, and that would be music. At first when we got this project, I thought it would be really easy and it wouldn't take that long. But, after implementing the choreography and starting to synchronize the robots with the music, it became harder and harder."*

In summary, this interdisciplinary project provided students in both Music and IST courses with an opportunity to become familiar with terminology and concepts from both disciplines. Students quickly learned that the creation of digital musical scores and the Java programs that controlled the choreography both required attention to specific detail and the following of a very similar development process. In identifying tools for application of concepts, both departments preferred software that would provide instant feedback to students during project development. Understanding the importance of being patient in learning the step-by-step process for the creation of successful projects in these disciplines is essential. By using Sibelius, we have found that students are trained to look for specific details that are required for the creation of a correct and complete musical score, which enforces that which is taught to students when they are programming in Java for the leJOS NXJ firmware on the LEGO MINDSTORMS platform for the robot choreography. The success of this project and support from student feedback warrants offering it again in the future. By broadening the scope of this project we can add more technical requirements to include Bluetooth communication between robots, or utilizing the LEGO MINDSTORMS software with the drag-and-drop interface to expose students who are not familiar with programming in Java to robots and music. The robot dance can be extended to other courses, taught in summer camps, or demonstrated during recruiting events to enhance student interest in IST-related degree programs.

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APPENDIX

Table 1. Music Perspective Survey Results (1=Strongly Disagree; 5 = Strongly Agree)

Project Evaluation by MUSIC Students	**Mean**	**Std Dev**	**% of Positive Responses**
This project was a creative learning experience	4.33	0.49	100
I enjoyed working with students in other disciplines	4.39	0.50	100
Both MUSIC and IST students worked together as a team to create a successful and complete project	4.50	0.51	100
I think of myself as a creative person in ART	3.56	1.20	61
I think of myself as a creative person when using TECHNOLOGY and/or SOFTWARE	3.33	1.03	39
This project has allowed me to improve my creative skills	3.47	1.01	53
I would recommend offering this project again	4.11	0.96	83

Table 2. IST Perspective Survey Results (1=Strongly Disagree; 5 = Strongly Agree)

Project Evaluation by IST Students	**Mean**	**Std Dev**	**% of Positive Responses**
This project was a creative learning experience	4.00	0.82	71
I enjoyed working with students in other disciplines	4.38	0.52	100
Both MUSIC and IST students worked together as a team to create a successful and complete project	4.25	0.46	100
I think of myself as a creative person in ART	3.13	1.25	38
I think of myself as a creative person when using TECHNOLOGY and/or SOFTWARE	4.38	0.52	100
This project has allowed me to improve my creative skills	3.50	0.93	50
I would recommend offering this project again	4.13	0.64	88