Girls, Music and Computer Science

Carlos N. Silla Jr.*, André L. Przybysz†, Andriano Rivolli†, Thayna Gimenez†, Carolina Barroso†, Jessika Machado†
*Computer Music Technology Laboratory – Graduate Program in Computer Science (PPGIa)
Pontifical Catholic University of Paraná (PUCPR) – Curitiba, PR, Brazil 80215–901
†Federal University of Technology of Paraná (UTFPR) – Cornélio Procópio, PR, Brazil 86300-000
Email: {carlos.sillajr, andrepos, rivoll, gimenezthayna, carol.rezendebarroso, jessikamachado17}@gmail.com

***Abstract*—In this Innovative Practice paper we describe our experience on using an updated methodology based on the paper "Music Education Meets Computer Science and Engineering" with a focus on pre-university female students. The main differences from this work are: (1) We taught the girls how to program and how to play the music instruments in parallel, having two classes per week, one for each subject instead of weekly meetings; (2) We started the project by using some of the games and puzzles from lightbot.com and code.org and then move to the Greenfoot Initial Learning Environment; (3) We asked the students to survey some music games related to their music instrument and design three potential games that they would like to develop using the music instruments; (4) They had to present and pitch the projects they designed to the undergraduate and graduate students of our computer music technology laboratory. Given the time constrains of the project, we had to help them to select the most feasible idea; (5) We applied a questionnaire to capture the perception of the students at the end of the project. It should be noted that all students successfully developed their music-based games using the digital music instruments and the Greenfoot Initial Learning Environment. In total four games were developed: (1) A game that allows drummers to perform ear training where they list to a particular drumming sequence and must replicate the sequence; (2) A game that allows guitar players to practice the execution of musical scales; (3) A game that allows keyboard players to practice their sight reading based on the simultaneous of two or more notes at the same time; (4) A game that allows bass players to practice their sight reading. It should be noted that by participating in the project one of the students acquired the skills and confidence to join the school and church bands.**

I. Introduction

There is a growing concern across the globe about how to attract more girls and women into computer science and it's related careers. Some of the existing approaches are designed to raise Information Technology (IT) awareness by developing girls only IT summer camps, such as in the Cybergirlz and Cyberhigh initiative [1].

These camps normally focus on teaching some sort of basic programming skills and other technology related assignments such as, for example, web design. Although, these camps are useful and interesting to most of the attendees, they still focus on a particular set of tools (programming, web design, etc.). Furthermore, Scott et al. [2] has shown that female students, depending on the their background, will show a significant lower engagement and interest in computing. Therefore, we believe it is important to use as many different approaches as possible in order to successfully engage students with different backgrounds.

In the more general context of showcasing and potentially attracting students (either male or female) to computer science and engineering there are some very interesting approaches. In the work of [3] the authors present the IT-Adventures program which is an extracurricular after-school program. The IT-Adventures program focus on three areas: Game Design (using the ALICE initial learning enviorment software [4]), Cyberdefense (computer network setup and different service protocols) and robotics with Lego Mindstorms. In their project they noticed the high number of young men and the lack of young women in the program.

In [5] the authors present an outreach study using electrical circuits to K-12 students. Their main goal was to investigate the effects of two different types of electrical circuits presentations based on the self perception of the elementary and high school students. One of the interesting aspects of this work is that they gauged the impact of students gender. For elementary school students, they did not find any statistical significant differences between male and female students on perceived enjoyment, understanding, cognitive load. However, when comparing the results for the high school students, they noticed that the male students reported significantly higher enjoyment, and understanding, , than the female students. The male students also reported significantly lower perceived cognitive load than the female students. The authors of [5] believe that the results of the high school female students may have been influenced by the negative stereotypes of females toward engineering, since the female elementary school students indicated the same enjoyment as the male elementary students.

In the context of this project, we believe that one area that might help attract the interest of more students (including but not limited to female students) to computer science and engineering is to develop approaches that are based on Performatics and/or STEAM (STEM approaches integrated with Art subjects). Performatics was defined by Ruthmann et al. [6] as courses developed to showcase computer science to students of all levels by tapping the students interest in music, painting, performance, etc.

In the context of Performatics/STEAM some very interesting and insightful approaches have been proposed in different formats. In [7] the authors propose a four-part origami based

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curriculum to teach about renewable energy, architecture design, 3D CAD design and printing, as well as math, science and engineering principles for K-12 students. In [8] the authors report the results of an exploratory 5-day musical instruments MAKERs camp for K-12 students. In [9] the authors proposed an integrated approach to teach music, music instrument playing and computer programming (using the Greenfoot Initial learning environment [10]) with the goal of developing a game that integrated hardware (music instrument) and software (game developed by the students).

In this paper we present our experience and reflection on using a modified methodology based on the work of [9]. The main differences between our proposed approach and the original approach are presented in Section 2. In Section 3 we present the software developed by the girls who worked on the Girls, Music and Computer Science project. In Section 4 we present the analysis and reflections based on the perception of the students who participated in project. In section 5 we present the concluding remarks and highlight future research ideas we plan to explore.

II. The Girls, Music and Computer Science Project

In our project, we have recruit four female students from public schools with 16-17 years old. The reason for recruiting only four students was due to limitation involving the physical space of the laboratory as well as having the necessary digital music instruments and equipment.

A. Learning Outcomes

Our project had the following learning outcomes in mind, i.e. at the end of the project the students would be able to:

- Read music scores.
- Understand how to play simple music scores with their respective music instruments.
- Program using if-then-else conditionals and for each loops.
- Understand how to instantiate objects and call their methods from the Java class Library as well as third party libraries (such as own pre-defined library to read the input (notes) from the digital music instruments).
- Edit and Process Digital Images.

B. Materials

The project was developed using four digital music instruments, a Roland digital drum kit, a bass, a guitar and a Yamaha digital keyboard. All these instruments have MIDI [11] connections. The MIDI protocol was used for the communication between the computer and the digital instruments.

C. Methodology

The girls would have classes twice a week at the university. In one of the days they would have music theory and music instrument lessons and in the other day they would learn about logic, programming and image editing. This is one of the differences in our approach from the original approach proposed in [9], where the students would have classes only once a week.

Another important difference is that instead of starting to work directly with Greenfoot, we decided it was important to teach the girls about logic in a ludic way. For these reason in the first weeks of the project, we have used some tutorials, puzzles and challenges from lightbot.com and code.org websites, where the girls would have challenges to complete each week. Then after covering the material in the Greenfoot book, the girls would have one class about how to use the in house developed library to communicate with the midi instruments and would then move to the video editing classes.

Parallel to the technical classes the girls would have one music lesson every week. In the music lessons they would at first have lessons about basic music theory, music sheet, music sight reading followed by individual classes about how to play the instruments they would work with in the project.

After the technical content was covered in the classes the girls were asked to research about existing musical games and mobile app with the objective of thinking about three possible software's they could develop using their music instruments. Each girl then had to pitch their software ideas to the staff of the project as well as the school director. After the presentation we helped the students to select the most feasible idea that would be reasonable to develop with the remaining time. This step was particularly important, as in the work of [9] the authors reported that the students needed guidance when told that they could develop any game. We believe that it helps for the students to research existing approaches, to take ideas and get inspired by some of the existing software. Then they think about how to improve something they did not like, or try to learn how to do something they really like. After we defined with the students which idea they would develop, they would start implementing their projects.

III. Software Developed by the Girls

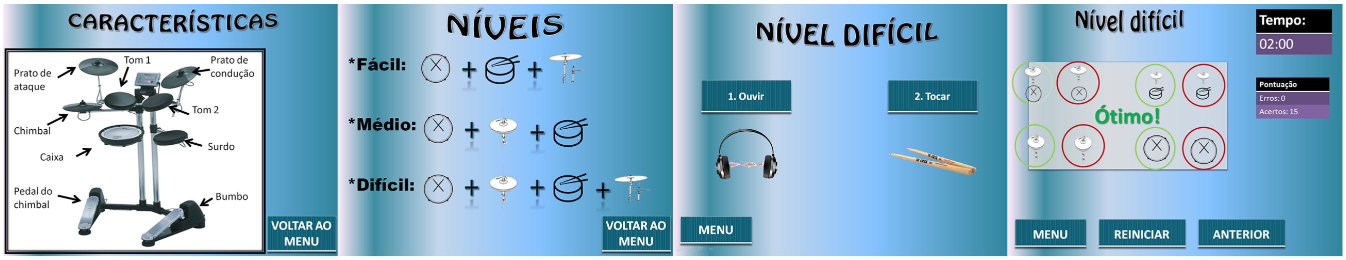
In this section we briefly present the software's developed by each of the girls that took part in the project.

A. Drums Listen and Execute Game

The Drums Listen and Execute Game was developed by Student #1 (S1). It is a game developed to improve the player musical perception of the different parts of the digital drum kit (Illustrated in Figure 1a). The game has three levels of difficult: Easy, medium and hard (as shown in Figure 1b). After choosing the difficulty setting, the user needs to listen to a given sequence, and then play that particular sequence (Figure 1c). The game will then analyze what the user played in the digital drum kit and will give him visual feedback by showing what was played correctly in green and erroneously in red. An example is shown in Figure 1d).

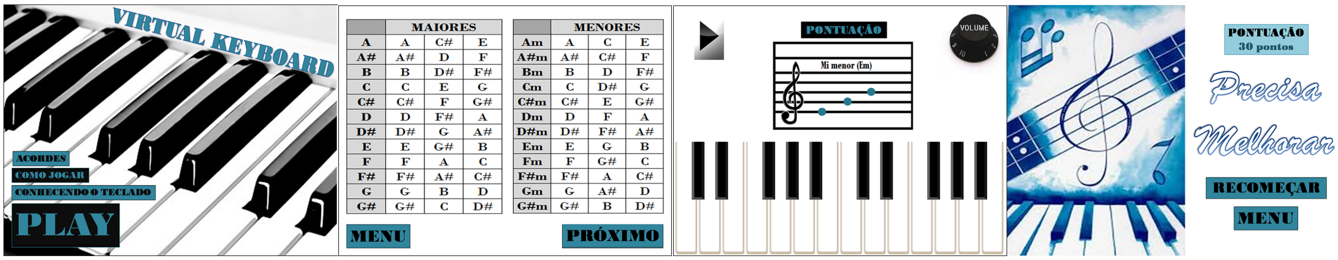
B. Keyboard Chord Trainer

The Keyboard Trainer was developed by Student #2 (S2). The goal of the game is to improve the user's music score reading at first glance, focusing on major, minor and seventh chords.



(a) Different Parts of the Drum Kit (b) Level Selection Screen (c) Action Selection Screen (d) Game Feedback

Fig. 1: The main screens of the Drums Listen and Execute Game.

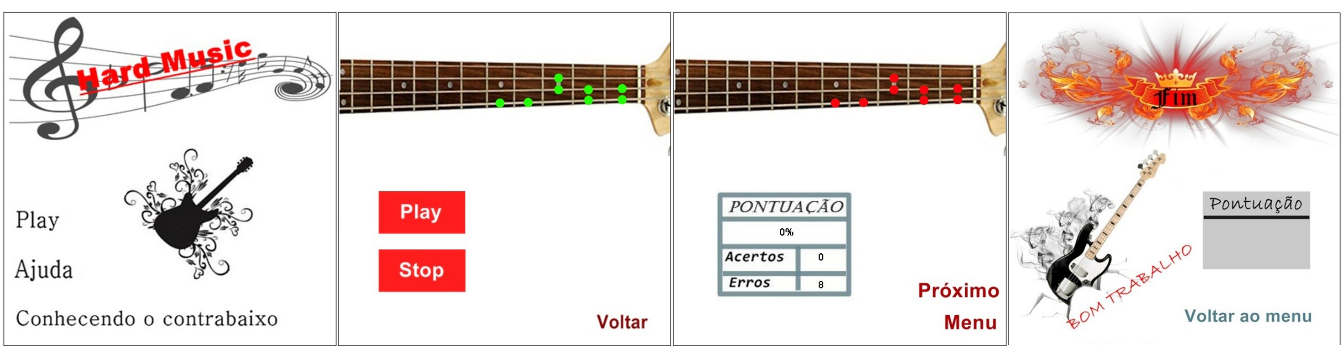


(a) Main Screen (b) Chord Formation (c) Game Screen (d) Score Screen

Fig. 2: The main screens of the Keyboard Chord Trainer.

(a) Main Screen (b) Chord Formation (c) Game Screen (d) Score Screen

Fig. 3: The main screens of the Keyboard Chord Trainer.



(a) Main Screen (b) Listening to the notes (c) Game Feedback (d) Score Screen

Fig. 4: The main screens of the Bass Game.

Figure 2a shows the opening screen of the game. From the main screen it is possible to select to learn more about how the chords as formed (Illustrated in Figure 2b) and to play the game. The game basically shows the user a succession of chord formations that the user needs to execute on the instrument. One example using the Em (E minor) is shown in Figure 2c. After a given number of chords, the game ends showing the score screen (Figure 2d).

C. Guitar Scale Mastery

The Guitar Scale Mastery was developed by Student #3 (S3). The goal of the game is to help people to improve their guitar playing skills by mastering the scales. The game works using three scales that intrinsically have different difficulty levels. In the main screen 3a the user can choose to play, learn about the game, or learn about the guitar. In the main game screen the user can choose to listen to the scale he needs to play (which will also show the notes being played and where they are played as illustrated in Figure 3b. The user then has to play the scale by him/herself (Figure 3c). After playing the scale, the game will show a score screen (Figure 3d.

D. Bass Sight Reading Game

The Bass Sight Reading Game was developed by Student #4 (S4). The goal of the game is to help people to improve their bass playing skills. In the main screen (Figure 4a the user can choose to play, to learn more about the game, or to learn more about the instrument. The game itself works by playing and showing a series of notes that they user needs to play (Figure 4b). After the user plays the notes the game will show which notes were played incorrectly (Figure 4c). If the user fails to play at least 4 correct notes each round, the score screen (Figure 4d) is shown.

IV. Project Evaluation

A. Participants Perceptions

At the end of the project we interviewed the students to listen about their opinions and feedback's about the project. In this section we present a summary of the answers that the students provided in a questionnaire about the Project. The questionnaire had a qualitative part and a quantitative part (shown in Table I). We will now present a summary of the qualitative part of the questionnaire.

1) What influence did the project have in your usual day-to-day activities inside and outside School?
   - S1 "In my day to day activities inside the school the project did not have any type of influence because we do not use computers at school, only a pen and paper. However, outside school, it highly influenced me because a have the opportunity to play the drums and understand a digital drum kit works".
   - S2 "At school it did not have any influence, but in my day-to-day I can say it had. I can now imagine how some of the programs normally use could be implemented, for example, which and what commands I would use, etc.".
   - S3 "It did not help me at school. However it helped me outside of the school with things related to computing.
   - S4 "The greatest influence that the project had in school was the interest of my classmates in learning more about the project and how it was developed. Outside of the school it was totally cool, for me everything changed in the way I see programming, that until then, was something very abstract in my day by day and I learned that it is not like that.
2) Did you comment about the project with your classmates at school? What was their reaction? Did they show interest in participating?
   - S1: "Yes, I commented many times with friends from school and also from outside the school. Everyone wanted to know how the project worked, what we learned, how were we evaluated. One fact that I thought it was interesting is that the boys got frustrated because only girls were able to participate and they wanted to learn more about music and technology.".
   - S2: "Yes. When I told them about the project to develop a game of our own, everyone showed a great interest in participating."
   - S3: "I commented about it in school. Some people showed interested but there were others who did not.
   - S4: "Yeah I commented. They were totally interested, specially the ones who are interested in music. They were always asking how the integration between music and programming happened. They demonstrated a huge interest in programming and were frustrated that the project was only for girls and that boys could not participate.
3) What do you think that could be improved in the project or made in a different way?
   - S1: "The project is really good and fruitful, in my opinion that is nothing to be improved. It would be nice if we could continue to have music classes when we enter the final phrase of the project.".
   - S2: "Maybe have ,ore music lessons in order for us to feel confident that we can really play the instrument".
   - S3: "I think it is fine as it is."
   - S4: "I liked the way it was developed, I do not think any changes are necessary."
4) What did you find most interesting in the project?
   - S1: "I thought the programming aspect was interest, albeit a bit hard when we started seeing vectors. But the part where we make a game about our instrument was really interesting, because I had never tried to do a game before.".
   - S2: "Learning about how the programs are made. There are so many codes."
   - S3: "Learning how to program a game and figuring out how they are before they get to our hands."
   - S4: "To learn how to program."
5) What was your greatest difficulty in the project?

TABLE I: Questionnaire applied using the likert scale where 1 means strongly disagree and 5 means strongly agree.

Question	S1	S2	S3	S4
Q1. Would you recommend your friends to attend a new class of this project?	5	4	4	5
Q2. Before taking part in the project, did you consider computer science to be something from a different world?	2	5	2	5
Q3. After participating in the project, do you consider computer science to be something from a different world?	2	2	2	2
Q4. Was your interest in the project increased because of the music part of it ?	4	5	4	5

S1: “My greatest difficulty was programming the variables. Sometimes I got lost with that”.
S2: “To integrate the music instrument with the my software.”.
S3: “To learn to program.”.
S4: “To understand how to use programming to achieve what is in my imagination in lines of code.”

6) What was your greatest learning experience in the project?

S1: “I learn how do make images and create buttons using photoshop and how to program them in Greenfoot to do what I wanted them to do.”.
S2: “Learn that programming is not something from a different world.”.
S3: “Notes and music scales”.
S4: “To see that nothing is a seven headed dragon if you dedicate yourself”.

B. Discussion and Related Work

Considering the students answers to the qualitative part of the questionnaire it seems that the project changed their perception about computing. It also showed that they have a better understating about how the software’s they use on their daily lives can potentially work. It also shows that by using music it is possible to intrigue (and potentially engage) a large number of students. However, how to adapt this project to a larger number of students, due to the number of musical instruments, remains a challenge and shall be addressed in future research.

The analysis of the answers from Table I show that all students would recommend their friends to attend a new class of the project. Considering the students perceptions about computer science being something from a different world, it seems that the project changed the perception of two students who before taking part of the project strongly agreed with that statement. It also shows that their interest in the project was increased because they knew they would work with music. This corroborates with our vision that it is necessary to develop different approaches that will tap into different interests of the students.

When evaluating the technical aspects of the software’s developed by the students, it is clear that all students were able to properly use some object oriented concepts (induced by the Greenfoot ILE) such as: inheritance, fields, internal method calling (with and without parameters), object construction, external method calling using external libraries (mainly ArrayList and our class that handles reading the midi notes from the digital music instruments). They have also effectively used if-else-then and for-each statements in their developed software. Furthermore, due to the nature of the projects that were developed, the girls also learned about how to use String, SubString and how to make String comparisons is order to give some sort of score or feedback to the user.

Another side aspect that is important to mention is that all three undergraduate students (two computing engineering students and one information system student) have all graduated. Furthermore although no formal assessment was done with them, it was clearly from all the activities of the project that that it helped them with different skills. Furthermore, by taking part of the project, the undergraduate students were able to work in *Active Expert Roles*, which is one of the seven ”key practices’ presented in the work of [12] for K-12 educators to create gender-inclusive STEM classrooms.

In comparison with the first version of this project, it is clear to us, that by teaching both music and programming in parallel was better than teaching one then the other. The reason being that the students were highly motivated throughout the whole course, instead of having (perceived) motivational changes during the project. Another fact that is worth mentioning, is that the laboratory where the students did their projects had an even number of male and female students.

In relation to related work, this is still to the best of our knowledge the only approach that deals with teaching how to play a real musical instrument and object-oriented programming in an interdisciplinary approach. However, there are other very interesting projects that deal with teaching some aspects of music and computer science to difference degrees and with different aims.

In 2018 there were two panel sessions at the ACM Special Interest Group of Computer Science Education (SIGCSE) conference that dealt with issue. These panels were the ”Team-Teaching with colleagues in the Arts and Humanities” [13] and the ”Perfect Harmony: Team Teaching Computing Music” [14]. While the first panel had a more broad scope of arts and humanities the second one focused specifically on music. In both panels best practices and their experiences were discussed as well as challenges in team teaching with colleagues from different departments. These discussions are important to grow the number of approaches that tap into the different interests of students at different contexts.

V. Concluding Remarks

In this work we have presented a modified methodology based on the work of [9] and applied with four female students at pre-university level from a public school. The main differences introduced in our updated methodology were to start programming using tutorials, challenges and puzzles from the lightbot.com and code.org websites. We also had classes twice per week, one for technical subjects (logic, programming, video editing, MIDI) and one for music theory and music instrument playing. Another important difference, was that after the technical classes were over, the students had to think about three different software's they would want to develop and present their ideas to the project staff.

The qualitative analysis of the feedback provided by the students showed that a high number of students were interested in participating in the project. The methodology current limitation is to have one instrument per students. Therefore, in future research we will look at alternatives, such teaching the students how to build their own digital music instruments using educational hardware such as Arduino and/or Raspery Pi.

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