Teaching Introductory Game Audio to Undergraduate Students Using a Novel Digital Game Template

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Abstract: In this paper we describe the PUCPR SOUND GAME (PSG): a digital game template that was developed in order to provide support for the game audio introductory teaching to undergraduate students of Digital Games. To use the game, the student does not need to have prior knowledge of art, design or even digital game programming. It was developed to abstract them from these matters, allowing them to create, test, and refine sound effects and music by easily changing files in the game template folder. From the teacher's point of view, the game speeds up the monitoring and feedback process since the productions are centralised in a single place. The evaluation process is facilitated: the teacher is responsible for running the game containing the complete sound package of each student, identifying whether or not it meets the established criteria. We also present a thorough evaluation of eight different offerings of the module, being 4 without using PSG and 4 using PSG. The 8 offerings had the same learning objectives and were taught by the same teacher. The analysis of the results shows that there was a significant improvement in student learning and a reduction in the number of failing students when using PSG.

1 INTRODUCTION

The digital games industry is expected to generate over US$ 200 billion by the end of 2023 (Wijman, 2021). In the context of digital games development game audio plays an important role (together with game design, game programming and game art & animation) as it constitutes an element that is equally important to the complete player experience, along with the visuals, plus game design, programming, feel, and movement (Rabin, 2005). By Game Audio we are referring to the set of techniques for the production of sounds for digital games. Although there are different classifications for the audio elements in games, we consider as game audio: music, ambient sounds and sound effects (Horowitz and Looney, 2014).

The main advantage for future game developers to understand the basics of game audio is related to being able to independently produce their own sounds and music in their projects. Even in the contexts where the game developers will not produce the game audio themselves, they will still benefit from learning game audio, as that will enable them to have a better interaction with the person/team responsible for the sound production. Furthermore, it is expected that with some practice their games will start to provide better immersion. As they move forward and learn more about the potential of sound design, sound can be used more powerfully as a vehicle to provide information that can support player decisions (Ng and Nesbitt, 2013).

Despite the importance of game audio to game development, to the best of the authors knowledge, there are very few papers that discuss, investigate and address the issues of teaching game audio to undergraduate students. This might happen for mainly three reasons: First, from the perspective of music students , in order to create digital sound effects and soundtracks for games, it would also be necessary to understand more about the game development process and possi-

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bly team up with game development students. However, not all universities that offer music-related degrees also offer game development degrees. Second, from the perspective of game development students, they might need to develop their own games as well as the game audio for their games. Third, as stated by Sinclair (Sinclair, 2020) it is difficult to teach sound design in a systematic manner, since context and intention are important to the craft.

From a teacher's perspective, depending on the desired learning outcomes, it seems counter-intuitive to make the students work on developing their games in parallel to working on the game audio aspects. However, this seems to be one of the common practices in the field in the few papers that address this issue. Wang and Olivieri (Wang and Olivieri, 2018) reported their experience creating an interdisciplinary course with a diverse group of students from different areas (computer science and arts). One of their goals was to stimulate the cooperation of a disparate group of students as a learning opportunity by creating a game prototype (as a final project) and producing its sound, both collaboratively. The authors were motivated in minimizing the gap between computer science and arts and was inspired by different approaches that uses art and music as a means (Brunvand and McCurdy, 2017) or as means to an end (McCauley et al., 2017; Heines et al., 2012; Heines et al., 2011) of the learning process itself. Differently from the existing approaches, our premise is to abstract our students from the topics of game art, game design and game programming, focusing specifically on the game audio.

It should be noted that this seems to be a common problem in teaching different technology-related classes. For example, in the context of teaching artificial intelligence, the idea of using game templates[1] has been successfully applied using classical video games such as Pacman (Rohlfshagen et al., 2018) and Super Mario (Karakovskiy and Togelius, 2012).

Inspired by the works of previous researchers and educators in using game templates, the main contributions of this paper are two-fold:

- To present a novel game template for teaching introductory game audio, named PUCPR SOUND GAME (PSG), which is freely available to be used by other educators and students.
- To evaluate the effectiveness of using PSG as a tool to support the teaching of introductory game audio subjects to undergraduate students.

[1]A Game template is a previously implemented game solution that was developed to allow the students to focus on specific learning outcomes, i.e. by implementing only the content related to the classes being taught

The remainder of this paper is organized as follows. In section 2 we present the PSG, its installation and the sound effects and music that must be produced by the students. In section 3 we present our pedagogical strategies that are applied equally to classes without or with PSG. In section 4 we present our research method and strategies for evaluating the effectiveness of using PSG. In section 5 we present the results obtained from the use of PSG to support the teaching and learning process. The fact that this research was partially developed during the COVID-19 pandemic and other threats to the validity of this study are discussed in Section 6. Finally in Section 7 we present our final remarks and future research directions.

2 THE PUCPR SOUND GAME (PSG)

The PUCPR SOUND GAME (PSG) is a novel digital game template, which was developed in the Digital Games Technology Course at our University. PSG was developed with the aim of being a support tool for teaching introductory game audio for digital games.

PSG was designed to allow the students to focus only on the development of game audio aspects of the game. Therefore, it was not constructed for the purpose of entertainment where the student spends his time in gameplay. PSG serves for the students to understand the sound elements, and for the students to easily insert their own SFX and songs into the game. The current version of PSG was developed in Unity. The student can interact with PSG in two ways:

a) Playing Online with previously produced sounds.
b) Downloading the game to manipulate files and folders and make their own sound.

The first way is commonly used when the student needs to understand the sound items present in the game as a way of learning, by listening to a version with previously produced sounds. In a second moment, after understanding the sound items (both sounds and music), the students are able to explore the second way, which allows the replacement of the current sounds present in the game for their own SFX and music. From this second step, it is possible for the students to improve their understanding of the fundamentals of game audio without the need for prior knowledge about digital game programming.

2.1 General Flow and Game Interfaces

The game is composed of 3 (three) screens that make a complete game loop, being them the Main menu (presented in Figure 1), the Gameplay (presented in Figure 2) and the Game over screen (presented in Figure 3). The gameplay is focused on a single level where the students will be able to interact with the environment and hear several sound elements in addition to the background music (gameplay music). It's important to point out that the only way out of this screen is to follow the game over flow by falling off the cliff. It should be noted that the main menu, as well as the game over screen also have specific background music.

Figure 1: Main Menu.

Figure 2: Gameplay.

Figure 3: Game over.

2.2 Installing PSG

The student is encouraged to start the learning process by playing the game based on a pre-sounded version available on the internet[2]. When playing, the focus is to identify and create a list of the sound effects and music they perceive in the game.

Once the student has identified the sound items present in the game, the next learning goal is to input his own sounds. They can access its sources from the following link[3].

Based on this link it is possible to download the game. After obtaining the file PSG.ZIP, it is only necessary to unzip the file in question and a folder structure will be created.

2.3 How to Insert Sound into the Game

After proceeding with the installation, which consists of a mere unzipping, a folder structure will be created. When accessing the unzipped folder, they can find the following folder structure:

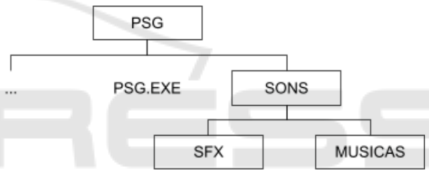


Figure 4: Folder structure created.

Figure 4 shows the folder structure created for the game. On the top in the main folder (PSG) they can find the PSG.EXE file. This file, when executed, runs the game following the flow of interfaces previously described. Below the main folder there are several files and folders, which consist of the source files (programming and images) of the PSG game.

The SONS (sounds) folder contains the subfolders of interest to students - the SFX and MUSICAS (music) folders. These folders will contain the sound effects and music files needed to run the game. All sound and music files available in the unzipped version contain silence only. The sounding of PSG will be done by replacing the existing files with new files in each folder, but keeping in mind an important detail: the files must have exactly the same names.

[2]https://pucprsoundgame.netlify.app/
[3]README from the Github Repository

2.4 Files Available in SFX and MUSICAS Folders

Table 1 presents the SFX files available in the game. Each sound must be replaced by a file with exactly the same name. The same rule is applied to the songs.

Table 1: Files in SFX folder.

File	Description
sfx_rain_int.ogg	Rain indoor
sfx_wind.ogg	Wind outdoor
sfx_wind_int.ogg	Wind indoor
sfx_grass1.ogg	One step on grass (Variation 1)
sfx_grass2.ogg	One step on grass (Variation 2)
sfx_grass3.ogg	One step on the grass (Variation 3)
sfx_grass4.ogg	One step on the grass (Variation 4)
sfx_wood1.ogg	One step on wood (Variation 1)
sfx_wood2.ogg	One step on wood (Variation 2)
sfx_wood3.ogg	One step on wood (Variation 3)
sfx_wood4.ogg	One step on wood (Variation 4)
sfx_shoot.ogg	Shoot
sfx_bonfire.ogg	Bonfire
sfx_jump.ogg	Leap
sfx_colect.ogg	Sound of a collectable item
sfx_wall.ogg	Sound of wall breaking

The music folder contains 3 files, as described in Table 2. The replacement for new songs follows the same rule as SFX (the file must have the same name).

Table 2: Files in MUSICAS folder.

File	Description
bgm_menu.ogg	Main menu music
bgm_gameplay.ogg	Gameplay music
bgm_gameover.ogg	Game over music

3 PEDAGOGICAL STRATEGIES

The module of introduction to Digital Game Audio is offered every semester for students in their first year of their undergraduate Digital Game Technology degree. At the end of the course, the student develops sound effects and songs that comprise the whole sound package for a computer game. The remainder of this section describes the learning outcomes, the study topics, course project structure and student's assessment.

3.1 Learning Outcomes

At the end of the module the students will have developed:

- A project SFX library containing 16 produced, edited and processed (SFX) items.
- A report detailing the editing and processing performed for each SFX.
- A project's Musical library containing 3 songs (menu, game play and game over).

3.2 Study Topics

The module takes place once a semester and is offered to freshmen (first period of the course). There are no prerequisites of any kind, which implies that students in general have no prior knowledge of sound production (as well as art and programming). The course has a workload of 1h and 30 min per week for 18 weeks. Table 3 details a summary of information about the course.

3.3 Course Project Structure

The module project is divided into two phases. The first phase is intended for the production of sound effects that are inserted and tested in a game. While studying the fundamentals of sound, digital audio and sound production, the student learns to apply these fundamentals from a practical point of view, developing a library of sound effects, duly edited, processed, mixed and mastered. In phase 1 there is no evaluation by grade - students receive feedback from the teacher on the improvements that should be made for the next phase.

3.4 Student's Assessment

For the student grading, we introduce four different stages presented in Table 4. Students are graded as being: *Autonomous (AU)*, for example, and it can be achieved if, during the course, the teacher perceives the presence of all the required sound effects, edited and processed according to the established criteria, with refined mixing quality. Similar reasoning can be applied for the grades *Capable (CP)*; *Apprentice (AP)* or Under *Development (UD)*.

The second phase is dedicated to Music Production (and review of sound effects based on the feedback from teacher and peers). At this point, the student goes deeper into topics about music theory and production and, at the same time as producing the

[2]Available at: https://www.audacityteam.org/
[3]Available at: https://www.presonus.com/
[4]Available at: https://www.reaper.fm/
[5]Available at: https://www.bandlab.com/
[6]Available at: https://www.image-line.com/

Table 3: Study topics.

Study Topic	Main Goals
Sound Design Fundamentals.	Introduce the student to fundamental concepts of sound, principles of acoustics and fundamentals relating to sound design for games.
Introduction to Sound Production.	Provide the student a first contact with Digital Audio Workstations (DAWs), such as Audacity [2], Studio One[3], Reaper[4] so that they can start their sound productions. Students learn the basics of audio editing, processing and sound synthesis.
Introduction to Music Production.	Provide the student an initial knowledge for producing their first musical soundtracks. An introduction to music theory is covered and additionally students use other types of DAWs such as BandLab[5], FL Studio[6] among others.
Introduction to the Sound Designer's Workflow.	Introduce the student to the sound designer's workflow for games and their responsibilities in their day-to-day work.

Table 4: Student´s evolution.

Grade	Description
Autonomous (AU)	Fulfils 90% to 100% of activities
Capable (CP)	Fulfils 70% to 89% of activities
Apprentice (AP)	Fulfils 40% to 69% of activities
Under development (UD)	Fulfils 0% to 39% of activities

songs, they make the necessary corrections in the sound effects (if any). For this phase, we established three criteria, concerning all aspects of a complete digital game sound design:

1. *Sound Effects Production (editing and processing) - 40% of the grade. In this first criterion we evaluate the SFX library produced by the students, by considering the feedback from the first phase. Also, in this criterion it is important to carefully evaluate the quality of each SFX produced by the students at this point.*
2. *Music Production - 40% of the grade. In this second criterion we evaluate the three new songs produced, mixed and mastered by the students. It is important to evaluate the quality of each one of the produced songs.*
3. *Overall Sound Production - 20% of the grade. In this third criterion we evaluate the soundscape, i.e. the SFX and Songs together with the game context. It is important that the sound production as a whole has quality.*

The phase 2 evaluation rubric, which includes the review of sound effects and music production, is detailed as follows. Table 5 presents the evaluation *Criterion (C)* on the first column, and the necessary requirements for the student to be evaluated as *Autonomous*, *Capable*, *Apprentice* or *Under Development* (other columns, from the second to the fifth).

The student gradually advances in learning, completing steps that will naturally enable them to take part in the second phase assessment. The novelty of this evaluation moment are the 3 songs the student developed during the second phase classes (menu, gameplay, game over). The student is considered *Autonomous* if, at the end of the second phase, they fully produce the sound effects and music, according to the established criteria, safeguarding the quality of mixing and mastering and the soundscape. Similarly, Table 5 presents criteria for determining whether the student is *Capable*, *Apprentice* or *Under Development*. At this point, the teacher has all the sounds and music separately in order to thoroughly evaluate the productions of each student.

4 METHODOLOGY

The main objective of this research is to analyze the effectiveness of using PSG as a tool to support the teaching of introductory game audio subjects to undergraduate students of a digital games development course. In order to answer this question, it is important to evaluate the data from the students from classes without and with the use of PSG.

It should be noted that for the purpose of this analysis, we retrieved the evaluation data of 4 (four) classes prior to using the PSG. At the same time, we tabulated data from another 4 (four) classes that used the PSG as a basis for learning during the years 2020 and 2021. Also, we want to emphasize that the 8 (eight) offerings of the module had the same learning

Table 5: Assessment rubric.

Criterion (C)	AUTONOMOUS (AU)	CAPABLE (CP)	APPRENTICE (AP)	UNDER DEVELOPMENT (UD)
1	The sound effects, in their completeness, have been edited and processed properly in accordance with the exposed requirements. Previous feedbacks were taken on consideration or justified.	The sound effects, in their completeness, were edited and processed properly according to the exposed requirements. Previous feedbacks were neither taken on consideration nor justified.	The sound effects, (at least 50%), have been edited and processed properly in accordance with the requirements. Previous feedbacks were neither taken on consideration nor justified.	The sound effects, (less than 50%), were edited and processed properly in accordance with the exposed requirements. The checkpoint has not been made, is not complete or does not fully reflect what was requested.
2	The songs, in their entirety, were created properly in accordance with the requirements. Care was taken in relation to the peculiar characteristics of each one (menu, game play, game fully construction.	The songs, partially, were created properly according to the exposed requirements. Despite all of them having been developed, there was integral care regarding their characteristics.	The songs, partially, were created properly according to the exposed requirements. Of all the planned ones, one was not developed.	The songs, partially, were created properly according to the exposed requirements. Of all the predicted two or three were not developed.
3	The complete sound (including all sounds and music), when demonstrated in the game presents accurate mixing quality, allowing all sounds and music to be audible and to match each other.	Full sound (including all sounds and music) when demonstrated in-game features partial mix quality. A maximum of 2 sound effects and/or 1 song have the problem of sounding different from what the sound actually is, or at a very different volume from the rest.	Full sound (including all sounds and music) when demonstrated in-game features partial mix quality. From 2 to 5 sound effects and/or 1 song have the problem of sounding different from what the sound actually is, or at a very different volume from the rest.	Full sound (including all sounds and music) when demonstrated in-game features partial mix quality. More than 5 sound effects and more than 1 song have the problem of sounding different from what the sound actually is, or at a very different volume from the rest.

objectives and were taught by the same teacher. The main pedagogical difference between them was the use of the PSG. For this purpose, the game template was incorporated as a tool in some classes in order to carry out this analysis. As an immediate benefit, students were able to perform tasks using this support tool. Table 6 details student tasks using PSG during the whole process.

In each week or sequence of weeks the student uses the PSG (or their own game) for some specific purpose, related to the current study topic. The exceptions are weeks 9 or 18, when the student receives feedback and is evaluated by the teacher. As presented in the previous section, the project is divided into two phases. Phase 1 coincides with the first 9 weeks, differing only by the use of PSG. It is important to emphasize the cyclical characteristic of this process: the student gradually creates sounds and tests them on the PSG. From there, it goes through frequent feedback that makes it go back to creating, editing and processing the sounds again until the first version of the library is produced (culminating with the end of phase 1).The teacher of the module will then evaluate all the submitted sound packages. The idea is for the teacher to perceive the presence of all the required sound effects, and whether or not they were edited and processed according to the established criteria, with a refined mixing quality.

Phase 2 coincides with music production. Here again, the cyclical and facilitating aspect of the game is important: as the students produce new music and correct sound effects, they test immediately in the game and can immediately see the results, allowing them to make new revisions until producing the final result. Besides, the teacher will be able to test all the sounds and music, together, directly in the game. For the teacher in this area, this feature is essential and facilitates their work, allowing them to listen to the student's soundscape while covering the entire route provided for in the game.

For the classes with students without PSG, it should be noted that the process is the same, but the students also had to develop their own games. Therefore, if they had any issues with their own game development, this would reflect on the time they had to work on their game audio library. Method section,

Table 6: Student´s tasks using PSG.

Class(es)	Student´s Tasks using PSG	Study Topics
01	Students play the game to identify all the sounds that exist in PSG. They elaborate a list of all the sounds in the game and the events that trigger them.	Introduction to Sound Production.
02-08	Students develop their own SFXs. They use PSG to receive immediate tests of the SFX soundscape. Students receive feedback about their SFXs. (Week 9 is for teacher's feedback).	Introduction to Sound Production.
10-15	Students make adjustments in their SFXs and test them in PSG. They also develop their own music. Students test each soundtrack in different moments of the game (without the SFXs they created before).	Introduction to Sound Production. Introduction to Music Production.
16-17	Students test the SFX+music soundscape. (Week 18 is for teacher´s feedback and evaluation).	Introduction to Sound Production. Introduction to Music Production.

concerning Participants, Materials, Design and Procedure inspired by (Christensen et al., 2015) is detailed as follows.

4.1 Participants

Participants in this study included 248 undergraduate students from the Digital Games from our University. Participants included 40 females and 208 males. This study is based on their evaluation during the offering of a module of introduction to Digital Game Audio. The module occurs once a year for two classes. In total 8 classes were evaluated. Students' privacy is ensured as the study is based on the analysis of their grades in different criteria.

4.2 Materials

During the 8 module offerings, student grades were catalogued. For each student there is a grade for each criterion (totaling 3 grades) and a final average for the subject. The first 4 classes did not use PSG. The last 4 used. A complete compilation of these data was carried out by separating them into two groups.

4.3 Design and Procedure

The variables of this study are 3 grades of different evaluation criteria and the weighted average of each student. Students are divided into two groups (those who did not use PSG and those who used PSG). In order to know if there was a significant variation in the students' averages without and with the use of the software, we applied a method of analysis of variance One way – ANOVA and chi-square test on the variables involved(Miller, 1997)(Şahin and Aybek, 2020).

5 RESULTS

In this section we are interested in answering the following research question: What is the effectiveness of using PSG as a tool to support the teaching of introductory game audio subjects to undergraduate students?

We will break our analysis into three parts. In the first analysis we will look at the overall results by considering the amount of passing and failing students. In the second part we will provide a detailed evaluation by analyzing the different learning evaluation criteria presented in Section 3.4. In the third part we will present a detailed statistical data analysis.

5.1 Overall Evaluation of PSG

In our first analysis, we will refer to the data presented in Table 7 which contains information about the class offering (including the year), whether or not PSG was used with that class, the number of student enrolled in the class, the number of approved students, the number of not approved students and the average final mark for each class based on the individual evaluation of each student in a scale from 0 to 10, being 0 the worst possible grade and 10 the best possible grade.

In total 150 students were evaluated without PSG and 98 students were evaluated using PSG. The analysis of Table 7 shows some interesting results. First, is that we can see an improvement of the mean overall scores of the classes without and with PSG. If we take into account the average values from the grouping of the classes without and with PSG, we can see an improvement from 8.30 without PSG to 9.01 with PSG. Second, we can also observe a reduction in the

Table 7: Comparision between classes.

Classes	Used PSG	Number of Students	Approved Students	Not Approved Students	Overall score
1) 2018 - Day	NO	32	28	4	7.97
2) 2018 - Night	NO	24	21	3	8.13
3) 2019 - Day	NO	55	52	3	9.06
4) 2019 - Night	NO	39	32	7	7.60
5) 2020 - Day	YES	38	35	3	8.84
6) 2020 - Night	YES	18	18	0	9.00
7) 2021 - Day	YES	35	34	1	9.06
8) 2021 - Night	YES	7	7	0	9.66

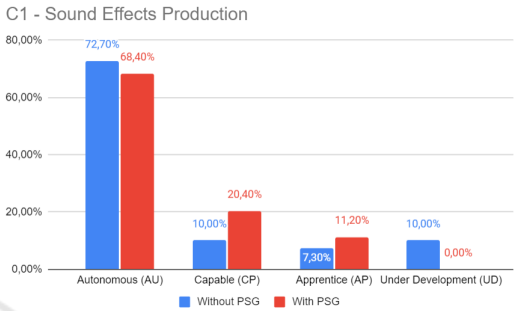
number of failing students in the classes which used PSG. In total the number of students who failed the module that did not use PSG was 17, while the number of students who failed the module using PSG was 4.

It is important to note that, due to the natural oscillation between the number of students present in each class, the number of students evaluated decreased between the first 4 classes and the last 4 (from 150 to 98). This is not a specific issue of the discipline: there is a natural drop in newcomers to the course in question in recent years, furthermore, if we were to evaluate the dropout rates using percentage of students instead of the absolute number we would reach a similar conclusion, i.e. that using PSG reduces the number of failing students. However, one might ask, in which subjects does PSG improve student learning, and that is precisely the reasoning behind our second analysis, where we provide an in-depth evaluation and comparison of the different classes.

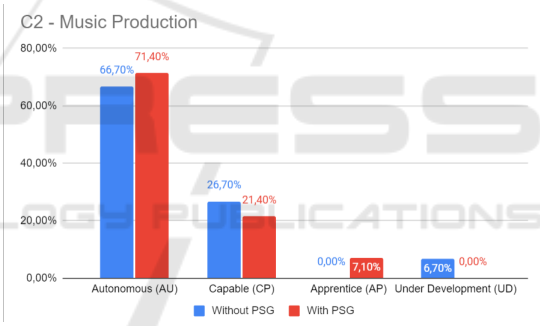
5.2 In Depth Analysis of PSG

In our second analysis, we will refer to the data presented in Table 8 which contains detailed information about the different class offerings with respect to the different evaluation criteria presented in Section 3.4. On the remainder of this section when we mention, for example, Class #1 - Criterion 1, we are referring to all the students in the 2018 – Day class and their respective achievements with regard to criterion 1 (Sound Effects Production (editing and processing)). For each criterion, we also present the number of students according to the category assigned after the evaluation of their submitted work. The categories are *Autonomous (AU)*, *Capable (CP)*, *Apprentice (AP)* and *Under Development (UD)* and the evaluation process for each criterion was previously presented in Section 3.4.

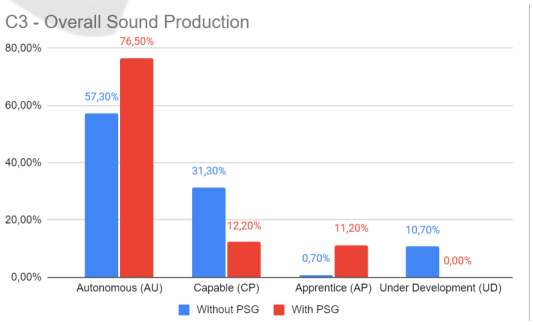
The data analysis corresponding to the 8 modules offered brought detailed information about the use of the PSG software to support the introductory teaching of Game Audio. During 2018 and 2019, 4



(a) Criterion 1 - SFX Production.



(b) Criterion 2 - Music Production.



(c) Criterion 3 - Overall Sound Production.

Figure 5: Comparative analysis between classes by criteria.

(four) classes attended the subject in question. These 4 classes did not have the experience of using the software. The next 4 classes of the years 2020 and 2021 used the software. Based on the analysis of Table 8

Table 8: Student's grouping by criteria per module offering without and with PSG.

	Without PSG											
	Class #1			Class #2			Class #3			Class #4		
Criterion	1	2	3	1	2	3	1	2	3	1	2	3
Autonomous (AU)	13	17	17	16	7	9	52	52	37	28	24	23
Capable (CP)	5	15	11	6	17	12	0	0	15	4	8	9
Apprentice (AP)	11	0	0	0	0	1	0	0	0	0	0	0
Under Development (UD)	3	0	4	2	0	2	3	3	3	7	7	7
Total students	32			24			55			39		
	With PSG											
	Class #5			Class #6			Class #7			Class #8		
Criterion	1	2	3	1	2	3	1	2	3	1	2	3
Autonomous (AU)	28	20	33	12	11	14	21	32	22	6	7	6
Capable (CP)	7	14	1	6	5	4	7	2	7	0	0	0
Apprentice (AP)	3	4	4	0	2	0	7	1	6	1	0	1
Under Development (UD)	0	0	0	0	0	0	0	0	0	0	0	0
Total students	39			38			18			7		

and Figure 5 some evidence of learning improved by using the PSG appeared and can be summarized in the following points:

1. The average of students in the category *Autonomous* generally grew. Considering the criteria separately, the following can be observed:
   (a) *Autonomous* in criterion 1 went from 72.7% to 68.4%.
   (b) *Autonomous* in criterion 2 went from 66.7% to 71.4%
   (c) *Autonomous* in criterion 3 went from 57.3% to 76.5%

   Based on these values, the growth of students in this criterion, went from 65.50% (computed as the average between 72.7%, 66.7% and 57.3%) to 72.10% (computed as average between 68.4%, 71.4% and 76.5%).
2. The category *Under Development* practically disappeared. This result is highly relevant since it means that the group of students that were likely to struggle with the class topics and being in risk of failing the class had an improved learning experience and were able to perform better.
3. The overall average of students in the category *Apprentice* grew from 2.66% (average between 7.30%, 0,00% and 0,07%) to 9.88% (average between 11,20% 7,10% and 11,20%). In our analysis, this is due to the rise of students Under Development to the other categories.
4. The overall average of students in the category *Capable* decreased slightly from 22.66% (10,00%, 26,70% and 31,30%) to 18% (20,40%, 21,40% and 12,20%). In our analysis, this is due to the redistribution of students into the categories Autonomous and Apprentice.
5. In particular, the average number of students *Autonomous* in criterion 3 (Overall Sound Production) grew (from 57.3% to 76.5%). Our analysis on this item is that PSG gave students greater independence to be able to mix their sounds and music in an easier way in the game, which allowed them to produce better results in this regard in comparison with students that did not use PSG. We believe that this is greatly in part due to the PSG giving the students an authentic environment to make the final production, since it allows them to perceive and tune the audio parameters for the different moments in the game. For example, the volumes of the footsteps, the rain and the shooting with regard to each other as well as with the volume of the background song.

5.3 Statistical Data Analysis

The comparison of the averages of the scores in each criterion and in the overall grade was performed using ANOVA (Şahin and Aybek, 2020). As detailed in section III, our three assessment criteria (C1, C2 and C3) constitute a student's overall grade G that is formed on the basis of 40%, 40%, 20% weighting. Even so, for the purposes of analysis, we have scores from 0 to 10 for each criterion. Table 9 details the mean and deviation for each of these data:

Knowing that the calculation of each criterion is independent of each other, we ran different tests considering the group (with or without PSG) as an independent variable and criterion as a dependent variable. Levene's test (Glass, 1966) was applied to ver-

Table 9: Means and overall grade.

	PSG	C1 (SFX Production)	C2 (Music Production)	C3 (Overall Sound Production)	G (Student Overall Grade)
Mean	NO	8.31	8.41	8.07	8.30
	YES	8.92	9.03	9.13	9.01
Std Dev	NO	2.89	2.58	3.00	2.63
	YES	1.63	1.73	1.70	1.32

Table 10: Homogeneity of Variances Tests (Levene's).

	F	df1	df2	p
C1	11.02	1	246	0.001
C2	6.21	1	246	0.013
C3	8.24	1	246	0.004
Grade	14.63	1	246	$<.001$

ify whether or not there was homogeneity of variance. The results of the test are presented in Table 10. Additionally, and following the same reasoning, a qualitative analysis using the chi-square test was performed according to the classification in each criterion that varies according to the categories *Autonomous (AU)*, *Capable (CP)*, *Apprentice (AP)* and *Under Development (UD)* comparing students by using or not using the software. The results are presented in graphical form in Figure 6. For all cases, a value of $p = 0.05$ was used. The chi-square test results for the categories and respective values were: C1=0.00; C2=0.00; C3=0.00 and Grade=0.01. This result reinforces our hypothesis that there was a statistically significant difference for the groups (with or without PSG) and that supports the comparative presentation of the data presented in Section 5.2.

6 THREATS TO VALIDITY

The possible threats to the validity of this research are the following.

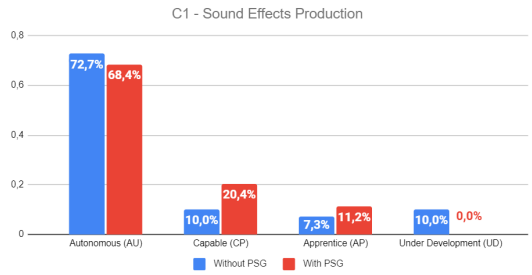
a) COVID-19 Pandemic. This research was partially developed during the COVID-19 pandemic. When the pandemic hit we had roughly one week to transition between in person classes to remote emergency teaching. We describe more details about this transition in our game development undergraduate course in a previously published paper (Moro et al., 2021). Therefore, having the PSG available was very helpful for our remote classes, even though it was originally designed to be used in the in-person classes. Even under the emergency remote teaching the students were able to perform better than in the previous classes that did not use PSG. In that sense, having a specific game context where they focus on developing only the game audio artefacts might have helped more than usual.

b) Using PSG vs. Developing their own Games. One aspect that is important to recall is that usually our traditional approach teaching introductory game audio is to make the students develop their own games (for other classes that they are taking in parallel) and then use that same game for them to create the game audio assets. In our experience, the students will have the whole course to create the game audio assets for their games, and normally most of them find it very challenging to create their game and to also produce the game audio assets. Therefore, for introductory game audio classes, we believe that PSG is very helpful as it allows the students to focus only on the game audio related tasks and assignments. Furthermore, as soon as the students finish working on their game audio, they can readily test it with context, which helps them to perceive if their game audio assets are working as intended or if they should still work on it. This might be the main reason why students in the classes where PSG was used obtained better scores on average than those in the classes without PSG.

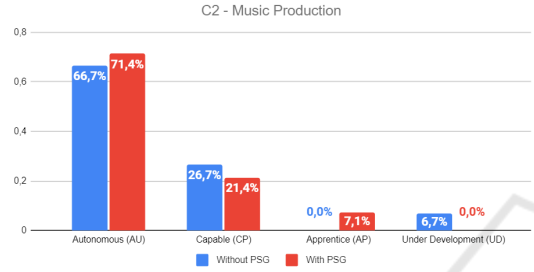
c) User-Bias. It should be noted that the main users of PSG are also their developers. Therefore there might be some usability issues when used by other educators worldwide but we will gladly assist other educators who are willing to use PSG in their introductory game audio classes.

7 CONCLUSION

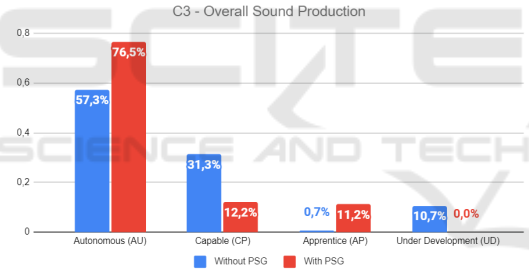
Game Audio plays an important role in the digital games industry, however there are very few papers that address initiatives about the challenges of teaching game audio or that propose and validate novel approaches for teaching game audio. In this paper we have presented and evaluated the PUCPR Sound Game, which is a freely available digital game template developed in Unity, that supports the teaching



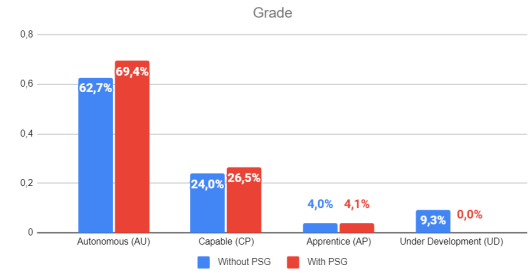
(a) Statistical Results for Criterion 1 - SFX Production.



(b) Statistical Results for Criterion 2 - Music Production.



(c) Statistical Results for Criterion 3 - Overall Sound Production.



(d) Statistical Results for Overall Grades.

Figure 6: Statistical Results.

and learning process for introductory game audio as the students are able to focus on the production of different game audio artefacts. Furthermore, the students can use any music production tools and do not need to understand unity to load their developed game audio artefacts in the game.

In order to gauge the benefits of using PSG in the classroom, we have performed an analysis of 8 different offerings of the introductory game audio module (4 without and 4 with PSG) in the Digital Games Development undergraduate course at our university. The evaluation processes across all offerings of the module is based on a specific rubric for the different game audio artefacts. In total three sets of game audio artefacts are evaluated: Sound Effects (SFX) Productions; Music Production; and Overall Sound Productions. Grades are assigned to all classes based on this rubric and depending on the student grade they are classified among one of four different groups. Based on the analysis of the results of the grades obtained by the students across the different offerings of the modules, it has become clear that students who had access to PSG were able to achieve better grades, as there were in learning, making students more autonomous and also drastically reducing the number of students who were practically unable to develop almost anything of the subject. This evidence was reinforced considering the increase in the mean overall score of the students and the decrease in the failure rates.

As future research direction we plan to continue to improve PSG in order to add new functionalities for educators and students:

- New Phases. Currently the software has a single scenario. With planning, it is possible to develop different scenarios taking into account gradual degrees of difficulty from what is expected to be explored from the point of view of sound learning.
- Report Mode. It would allow the teacher to receive a closure on the student's actions (with their permission) facilitating the evaluation process.
- Sound Exploration Mode. would let students to experiment with different sounds developed by other students. This could include good and bad sound designs to enable the students to experimentally understand these concepts.
- Additional Game Genres. the current version of PSG contains only one game loop. It will be interesting to create more game loops with different themes and eventually allow students to customize their games on other aspects such as the aesthetics of the game.

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