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Music software with a Machine Learning-based feedback system as an alternative for initial piano study in children

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Abstract As evidenced in the literature, music has accompanied the human being for millennia, in different situations, emotions and activities. In addition, not only does it allow expressions of internal personal states and feelings, but it can also produce many positive effects in those who practice it. Various authors have explored these benefits that musical activity brings, mainly in children. They highlight positive aspects of learning music in different areas of knowledge, in school performance and even improvements in the IQ of infants. However, despite the large number of studies regarding the benefits of music in children and the different nascent teaching alternatives, in Colombia the situation continues to be dramatic in terms of the incorporation of musical activity in the school curriculum. The foregoing added to political factors, teaching spaces and teacher training. In this way, the present work offers a new musical learning alternative, aimed at children from 7 to 11 years old, through a musical software focused on the initial teaching of the instrumental keyboard. It is important to mention that the software has a feedback system based on decision trees, which allows reinforcing the topics covered in the application. Finally, a comparative analysis is presented between teaching using the software and traditional teaching with the book, through an Investigation-Action carried out over six days with two students from a public school in the city of Bogotá, Colombia. This Investigation-Action allowed to observe positive results based on the comments and performance of the participants, which opens a great possibility for the subsequent scaling of this application.

Resumen Según se evidencia en la literatura, la música ha acompañado al ser humano durante milenios, en diferentes situaciones, emociones y actividades. Además, no solo permite expresiones de los estados y sentimientos personales internos, sino que también puede llegar a producir muchos efectos positivos en quienes la practican. Diversos autores han explorado estos beneficios que trae consigo la actividad musical, principalmente en los niños/niñas. Ellos resaltan aspectos positivos del aprendizaje de la música en diferentes áreas del conocimiento, en el rendimiento escolar e incluso, mejoras en el coeficiente intelectual de los infantes. Sin embargo, a pesar de la gran cantidad de estudios frente a los beneficios de la música en los niños/niñas y las distintas alternativas de enseñanza nacientes, en Colombia la situación sigue siendo dramática en cuanto a la incorporación de la actividad musical en el currículo escolar. Lo anterior agregado a factores políticos, espacios de enseñanza y formación docente. De esta manera, el presente trabajo ofrece una nueva alternativa de aprendizaje musical, dirigido a niños/niñas de 7 a 11 años, por medio de un software musical enfocado en la enseñanza inicial del teclado instrumental. Es importante mencionar que el software cuenta con un sistema de retroalimentación basado en árboles de decisión, el cual permite reforzar los temas cubiertos en la aplicación. Finalmente, se presenta un análisis comparativo entre la enseñanza a través del software y la enseñanza tradicional con el libro, por medio de una Investigación-Acción realizada durante seis días a dos estudiantes de un colegio público de la ciudad de Bogotá, Colombia. Esta Investigación-Acción permitió observar resultados positivos basados en los comentarios y desempeños de los participantes, lo que abre una gran posibilidad para el escalamiento posterior de esta aplicación.

Keywords: Decision Trees, Machine Learning, Mobile App, Music Software, Musical Keyboard, Piano, Music Learning.

Palabras Clave: Árboles de decisión, Aprendizaje de Máquina, Aplicación Móvil, Software Musical, Teclado Musical, Piano, Aprendizaje musical.

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1 Introduction

Music has accompanied the human being in different situations, emotions and activities that we carry out and has been a characteristic of the human condition for millennia [1]. In addition, music is not only present in people's daily lives but in all cultures around the world [2]. Listening to music, singing, playing an instrument, creating, exploring, composing, improvising around music, either individually or in a group, are common activities for the vast majority of people [1]. It has also been mentioned that this activity, although it is an enjoyable representation in itself, its influence goes beyond simple fun.

Musical activity not only allows expressions of internal personal states and feelings, but it can also produce many positive effects in those who practice it [1]. There are increasing empirical and experimental studies on the benefits of musical activity, and research in the sciences associated with music suggests that there are many dimensions to human life, including physical, social, educational, psychological (cognitive and emotional), which may be positively affected by successful participation in music [3].

The above are just a few of the many studies highlighting the importance of music in society. However, a closer look at the purpose of this work is necessary, which is why this section focuses on the significance of each aspect supporting this development. Thus, some studies demonstrate the benefits of piano learning, especially in children. Other studies emphasize the advantages discovered through music education supported by technology, using various AI techniques in Colombia and the rest of the world. However, in Colombia, several obstacles and issues have been identified that hinder a more favorable development. For this reason, this project aims to provide an alternative method of music learning, comparing it to traditional book-based learning. The following are the key points that establish the objectives and scope of this work:

1.1 The importance of the musical keyboard

It is important to keep in mind that music education covers a wide catalog of elements immersed in learning such as: rhythm, tuning, harmony, vocal technique, instrumental interpretation, etc. For this reason, this work offers a perspective towards the learning of music, from the knowledge of instrumental interpretation, mainly on the piano.

The piano is the musical instrument that occupies the first places of preference for most musicians, due to its great richness and melodic and harmonic potential in almost all musical genres, and that hardly another musical instrument can achieve a harmonic level like that of the piano [6]. In the same way, this melodic-harmonic instrument has great phonic qualities and can be used in Primary Education by the teacher, to have the possibility of improving the teaching-learning of music and thus, develop creative qualities in students [7]. In addition, as indicated in [7], the piano has been considered the king of instruments because it is warm, intense, full and strongly influences people. Likewise, some music teachers consider the piano is an important part of elementary music and should be used mainly as an accompaniment [8] and, furthermore, they defend the importance of a melodic-harmonic instrument like the piano in the cultural baggage of a teacher within primary education activities [7]. For this reason, "the piano has become, pedagogically speaking, one of the most practical instruments for training potential musicians throughout their career, from the very moment they start learning" [6].

1.2 Technology and music in the world

Music, like many other disciplines, has been strongly related to technology. Various musical software uses technological techniques and tools. This means that the rise of technology offers opportunities for the music teaching process, which allows efficiency to be improved and the difficulty of learning music to be reduced [9].

Some important features have also been mentioned highlighting the role of computer music technology in improving the quality of music teaching in preschool:

- Promotes quality education with rich teaching aids.
- Improves the efficiency of teachers' use of technology and improves the training of musical talents.
- The use of information technology is more conducive to aesthetic ability.
- Significantly improves the efficiency and quality of music teaching.

In the same way, within the different musical technological developments, Artificial Intelligence (AI) together with Machine Learning (ML) and Big Data, have also played an important role both in the educational sector and in other aspects. An example of this is the realization of a musical chord recognition system that uses a fully convolutional deep auditory model [10]. While the extraction of chord features is often done manually, advances in ML have allowed researchers to explore data-driven methods for such tasks, as mentioned in [10]. Likewise, within the educational sector, musical AI allows teacher interaction to be more striking and interesting and can provide answers, qualifications and learning suggestions when required, which is efficient and at a low cost [11]. In addition, as

indicated in [11], AI allows human musical intelligence to be analyzed through Big Data, simulating the information process of sight, hearing, touch, feeling, thought and human reasoning, and from this it is possible to build an own neural network and generate algorithms.

Within ML, techniques such as Decision Trees have been explored to develop pre-assessment models to help determine the impact of music education on children with special needs [12]. The above, through an extraction of data from applying data mining in the successful exploration of education and child development problems.

1.3 Technology and music in Colombia

In Colombia there are several academies, projects and initiatives for musical learning, mainly for children and youth; supported by Mayors, Ministry of Culture and the National Government, such as: Fundación Batuta[1], Ideartes[2], LASO project[3], Viajeros del Pentagrama[4], among others.

In the same way, within the developments and studies carried out in the country, research of a non-educational nature can be highlighted, but that strengthens the relationship between music and technology. One of these studies is [21], which proposes a software based on ML for the automatic identification of Colombian music genres. The study method evaluated a data set of 180 musical pieces belonging to six Colombian folkloric genres: Bambuco, Carranga, Cumbia, Joropo, Pasillo, and Vallenato. The results showed that it is possible to automatically identify the musical genre despite the complexity of Colombian rhythms, reaching an average accuracy of 69%. This study allows us to take a new look at national folklore and rescue the value and cultural contribution offered by these artistic expressions.

Although there are various projects, programs and studies, why in Colombia the situation continues to be dramatic in terms of the incorporation of music into school curricula?, as mentioned in [22]. The previous question can cover different factors that go beyond music schools or academies, as might initially be thought.

A first glance is from the perspective of politics, where in [23] educational legislation is spoken of as another version of the contradictory nature, since from the orientation of the Ministry of Education they look high and noble purposes, making us believe that the intention is reality, because it is what is wanted. On the other hand, a second pertinent factor in the dramatic situation of music education in Colombia is the learning and teaching spaces, since it is thought that music in education is like an appendage, which represents a challenge for the educational model, since the arts are proposed as part of the training and not as a primary component [22]. A third factor of the problems that music education encompasses in the school curriculum in Colombia refers to teacher training, since it is not about teaching music in any way, nor that the child is a virtuoso on some instrument or that he plays repertoires of very good level. It is about children having significant learning processes with music [22].

1.4 Comparative Studies of Musical Methodologies

Within the literature, various research studies can be found spanning over time, aimed at comparing methods of musical education, and in some cases, through keyboard instruction. This is the case of the study conducted in [24], which sought to establish which method was more efficient in piano learning among three teaching categories: Whole (students performed the scores from start to finish without stopping), Part (scores were divided into units that were practiced an equal number of times), and Combination (it was performed from start to finish, but errors were repeated an equal number of times). For the study's results, three difficulty levels were used, demonstrating that the Whole method turned out to be the most efficient, and the Part method the least efficient. Although the study was conducted many years ago, it marked the beginning of a series of research endeavors aimed at extracting elements of musical education for later studies.

More recent studies also conduct comparisons between methods of musical education, highlighting the importance of teacher preparation and competence. The work carried out in [25] aimed to determine which methodology was most suitable for the understanding of contemporary music in Secondary Education. This research led to a quasi-experimental study in which traditional lecture-style classes were compared with classes based on different types of listening approaches. The most significant results were found at a qualitative level, where it was observed that the experimental methodology yielded better outcomes.

[1] Fundación Batuta. Available at: www.fundacionbatuta.org.
[2] District Institute of Arts. Available at: https://idartes.gov.co/es.
[3] LASO. Available at: https://mincultura.gov.co/.
[4] Viajeros del Pentagrama. Available at: www.viajerosdelpentagrama.gov.co.

In a similar manner, recent studies have demonstrated that, through experimentation, interpretation, manipulation, and direct observation by the child, music can be learned in a playful and enjoyable manner [26].

Another study, conducted in [27], employed an exploratory qualitative design through an Investigation-Action (IA) approach in a municipal music school in Barcelona (Spain). The objective was to identify technical issues in the initiation of violin playing by comparing two teaching approaches: 1) the use of the right hand introducing the gradual management of the left-hand fingers, and 2) the simultaneous study of both hands. In this study, the teacher acted as a participant researcher, continuously observing to gather reliable and corroborated qualitative data through repetition. Additionally, the AR design was carried out in a single cycle (Planning, Action, Observation, Reflection) over the course of a school year with children aged 4-5, comprising 30 individual sessions of 30 minutes each. Once again, the results underscore the application of experimental methods, giving significant weight to qualitative elements.

In relation to the previous subsections and considering the previously mentioned works, the ideal situation for this project is based on achieving the provision of tools to children in Colombia. These tools aim to facilitate the development of the various benefits that come with musical learning, while also attaining implementation and advancement in different educational centers, such as schools, music academies, and even for independent studies. Moreover, integrating music software with AI techniques allows the creation of tools with a broader scope for addressing more specific problems. Furthermore, as described in one of the referenced works, supporting music learning with technology and technological tools can reduce the difficulty and enhance the efficiency of such learning, if it is managed appropriately and controlled [9]. However, from a more realistic perspective, the challenges in Colombia are diverse. Starting with the incorporation of these technologies into the educational model, finding appropriate budgets and spaces for the development of these musical activities, having qualified professionals who can provide guidance in handling these musical tools, and securing substantial support from governmental entities that promote developments with AI.

This work provides a fresh musical learning option, targeted at children aged 7 to 11, through a music software centered on the initial teaching of the instrumental keyboard. It's noteworthy that the software features a feedback system based on decision trees, which facilitates the reinforcement of the covered topics within the application. Finally, due to the positive outcomes of various qualitative practical studies, an Investigation-Action (IA) was conducted in a public school in the city of Bogotá, comparing traditional learning through textbook with learning via the software developed in this project. The work was carried out through 4 stages, which will be detailed in the following sections.

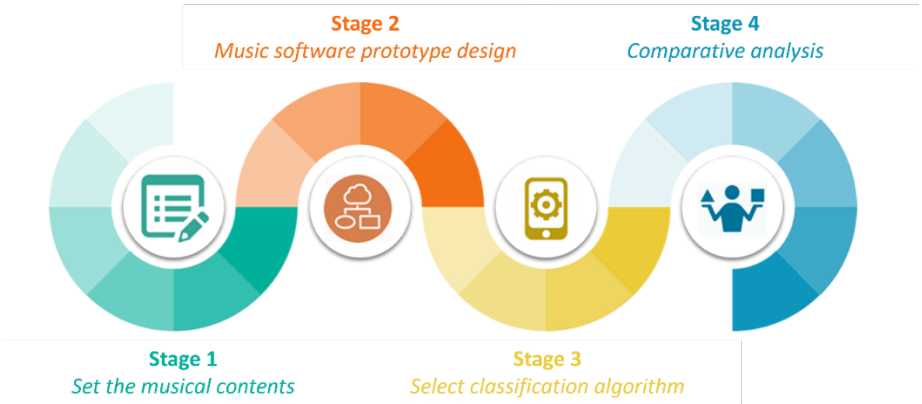

Figure 1. Stages of the research design.

2 Contributions

This project originated in the year 2019 as a proposal for the University Apps Tournament (TuApp), which encourages Ibero-American university students to develop technological ventures that solve real problems. Thus, focused on the educational sector, the application began to be developed as an initiative for initial music learning through the keyboard. This project managed to secure the second place in this international tournament, competing against over 160 teams from various countries. Since then, the decision was made to further develop this idea using the technologies presented in this document. Additionally, this project managed to reopen a musical space at Carlo Federici Public School in the city of Bogotá, where for several years this realm of knowledge had been set aside and replaced by other activities. In this manner, with the school principal and some teachers of the institution, future

discussions were established to carry on with the teaching process, holding the hope of achieving a comprehensive musical educational process.

3 Target population

The purpose of this project has focused on the initial learning of the musical keyboard in children. In this way, it is important to consider the stages of cognitive development of Jean Piaget[5], this in order to select the stage most suitable for the work. The importance of these stages makes it necessary to know how and what children can learn according to their ages, in order to offer information that can be better understood depending on their cognition and processing capacities.

Piaget's stages are divided into four as it is presented in Table 1, from which the third being the target group of this research.

Table 1: Piaget's stages of cognitive development.

N°	Name	Ages
1	Sensorimotor	From birth to 2 years.
2	Preoperational	From 2 years to 7 years.
3	Concrete operational	From 7 years to 11 years.
4	Formal operational	From 11 years old and up.

Unlike the two previous stages (Sensorimotor and Preoperational), where children constantly experiment and learn through trial and error, and intelligence is egocentric and intuitive, not logical; in the **Concrete Operational** stage thinking begins to be more flexible and intellectual development is demonstrated through the use of logical and systematic manipulation of symbols, which are related to concrete objects [4]. However, they also manage to resolve situations without the need to have objects present [5].

4 Stage 1: Selection of content for the software

This first stage of this project is aimed at the selection of the teaching topics that the musical software prototype contains. For this, it was important to carry out a review of the contents of the *Piano for Dummies* book. With these topics, the most suitable ones were selected to include in the software. It should be clarified that each theme of the book was adjusted and modified with words, images and other appropriate elements for boys and girls of the Concrete Operational stage (see Table 1). However, these modifications and adjustments to the contents are intended not to affect the purpose of each theme.

4.1 About the *Piano for Dummies* book

"For Dummies" is a series of books, generally freely accessible, aimed at learning different topics through simple guides for readers. Although "For Dummies" may sound offensive, the editor emphasizes that it is not literally like that, but that it is aimed at inexperienced or beginners in a subject. This collection is not only aimed at music, but at different areas of knowledge. In addition, just as "Piano for Dummies" is available, we can also find "Guitar for Dummies", "Percussion for Dummies", "Opera for Dummies", "Music Theory for Dummies", among many others.

Specifically, *Piano for Dummies* is aimed at people who are interested in learning to play the keyboard or read music. According to the method, a constant dedication will allow to learn to read piano music, know the names of the notes, scales and chords, understand different musical styles much better and, in general, acquire solid skills to put fundamental techniques into practice of the piano. In addition, the Piano for Dummies book is organized into six (6) sections, each divided into chapters, with the aim of gradually covering different musical concepts focused on learning the musical keyboard.

- **First part: First approach to the keyboard.** Here is an introduction to know the keyboard family. Information on electric or digital pianos and keyboards is offered. Also, it talks about finding a suitable

[5] Swiss epistemologist and biologist, considered the father of genetic epistemology, recognized for his contributions to the study of childhood.

keyboard. Finally, it clarifies why the instrument should not be allowed to be dirty or not very operational? and also gives tips on how to sit at the piano, what all the keys consist of, how to use your hands and how to use the pedals.

- **Second part: Learn to get sounds from a paper.** It gives a guide to understand the multiple symbols, lines and points that constitute written music and how these are translated into real music. Special importance is given to the rhythm, how it is written, how it is counted and how well-known songs are played.
- **Part Three: One hand at a time.** An introduction is made on how to play well-known melodies, for now with the right hand. Likewise, the importance of scales is highlighted and how they can help master the piano. Finally, the use of the left hand begins.
- **Part Four: Life in Perfect Harmony.** The main focus is harmony, what it is, how it is built and how it can be used to fill songs. In addition, the operation of the tonalities and chords is explained.
- **Fifth part: The technique, a valuable ally.** In this part some tricks, techniques and stylistic embellishments will be offered to give more body to the melodies.
- **Sixth part: The three decalogues.** There are a number of lists and tips including: ideas for getting the most out of rehearsal hours and tips for sharing talent in various situations. Likewise, some possible directions are proposed that can be used to expand the knowledge of the piano beyond the limits of this book.

4.2 Adaptation of the contents within the software

It is important to mention that, although there are various guidebooks and learning methods, it was decided to choose one that had easy-to-understand texts, supported by images, examples and other appropriate content for boys and girls of the Concrete Operational stage (7 to 11 years). In addition, it was hoped that the book would not need to be directed by a musical tutor present but would aim at a self-study or in the company of a person in charge not necessarily knowledgeable about music, that is, it was necessary a text that was easy to understand for anyone. Thus, within the teaching methods explored, it was decided to choose "For Dummies" focused on the piano or musical keyboard.

Although the book handles a simple writing, with appropriate images, examples associated with the themes and some humorous touches that make reading more enjoyable, it was necessary to adapt the texts that were desired to have in the mobile application, this because with the prototype of musical software it is intended to have significant learning advances on purely musical topics and some texts exposed in the book are not relevant at this time of the work: types of piano, advice for acquiring the right piano, comparison of brands and prices, among others. In addition, another reason for adapting the contents of the book within the music software was that some sayings, words, and jargon did not correspond to the environment of the target population (Bogotá, Colombia), since their translation is in Castilian Spanish. In this way, six classes composed of three lessons each were built, for an estimated time of thirty minutes per class.

5 Stage 2: Software design and development

This second stage is aimed at building the musical software prototype through a mobile application. The application is focused on music education, emphasizing learning the keyboard (piano).

The first step is to carry out an initial design of the application with Mockups, using the Balsamiq Wireframes[6] tool, which allows building the user interface as an approximation to the final product. It is important to note that within the design and due to the target population, it is necessary to manage appropriate styles, images, words and colors.

[6] Software tool to create prototypes or sketches of a web or mobile page. Available in: https://balsamiq.com/wireframes/

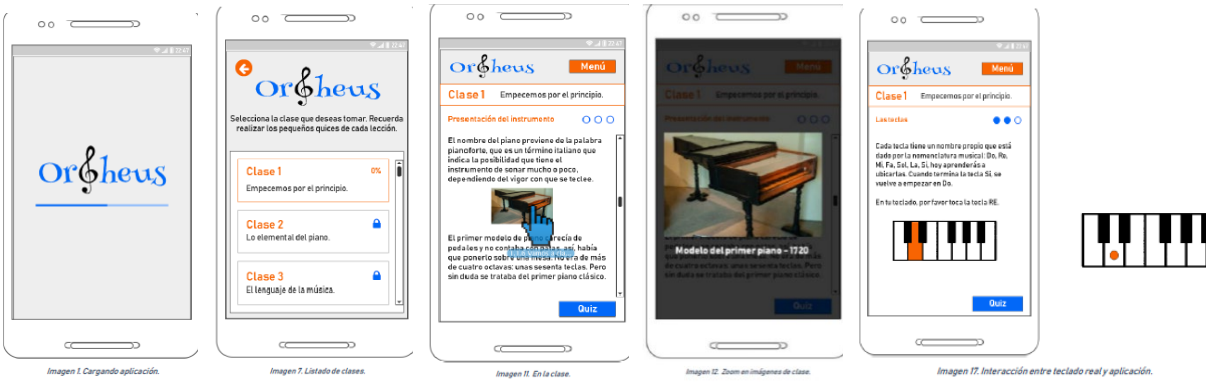

Figure 2. Mockups of the design stage as an approximation of the final application for learning the musical keyboard.

Once the software design was completed, the mobile application was developed based on the Mockups (Fig. 2). For the content of the classes and as mentioned above, the topics of the *Piano for Dummies* book were taken and adjusted with words, images and expressions that were considered more appropriate for children of the Concrete Operational stage. It is also worth mentioning that the application was developed using Unity software, a tool that allows the creation of video games (mainly) for different platforms, however, Unity also offers different useful components for the creation of all kinds of apps.

Figure 3. Mobile application for learning the musical keyboard with contents of the book *Piano for Dummies*.

The app has two sections: **With the piano** and **Without the piano**. The difference between these two sections is that in the first the user has the possibility to connect the mobile application via Bluetooth to a physical piano built with circuits, LEDs and speakers programmed in Arduino and designed exclusively for this application. In addition, this built musical keyboard has recyclable elements such as popsicle sticks, wooden sticks, carton, paper, among others (see Fig. 4).

Due to the complexity of constructing the instrument, a single octave was created featuring the main musical notes, which are sufficient to cover the six classes built in Section 4.2. Additionally, the programming logic that activates and deactivates LEDs, produces sound for each note through the speaker, and interprets each pressed key was developed using Arduino. Arduino enables programming a board or microcontroller, in this case, the Arduino Mega 2560, which comprises integrated circuits that recognize instructions provided in the code to establish connections and interact with various sensors and actuators.

The intention of having made the construction of this mini musical keyboard (a single octave), is that the child has a more interactive teaching. As the contents are viewed on the mobile device, the application connects with the mini piano (via Bluetooth), by sending characters that are recognized by the software programmed in Arduino and the software programmed in Unity.

Figure 4. Musical keyboard (mini piano) of a single octave built for interaction with the software described in this paper.

On the other hand, the second section: **Without the piano**, offers the same knowledge as the previous section, but only the interaction is done with the screen of the mobile device. This possibility occurs in case the child does not have present the musical keyboard built (Fig. 4).

In Section 4 (Stage 1 of the research design), a list of six classes was adapted, scaling according to the level of content. Each of these classes covers three topics or lessons. At the end of each lesson, the children will have a short multiple-choice question that will test the knowledge acquired from the content. By answering each question, the child will be able to proceed to the following lessons. The answers provided by each user will be considered within the feedback system detailed below.

6 Stage 3: Feedback system

Being a software focused on teaching/learning, the application has a feedback system that reinforces the content seen in each class according to the performance obtained in the lessons. This performance is measured through the questions asked in each lesson, considering the score for each question and the time taken to answer them. Fig. 5 illustrates the general behavior of the application with the feedback system.

The scheme can be summarized as follows:

- The music software prototype contains a list of six classes (with or without piano).
- Each class contains three lessons. We will call this section the Test Module, because there, the student will see the musical contents and at the end of each of these lessons they will be able to have a question with an associated score according to the answer given. Likewise, a record of the time it takes the participant to answer the questions will be kept.
- The three scores of each lesson (Q1, Q2, Q3) in addition to the Total Time, will be sent to the Feedback Module where the selected classification algorithm will evaluate the results and will classify the type of feedback the student needs.
- Finally, the type of feedback will be reflected in the music software through new content that will reinforce what was seen in each class.

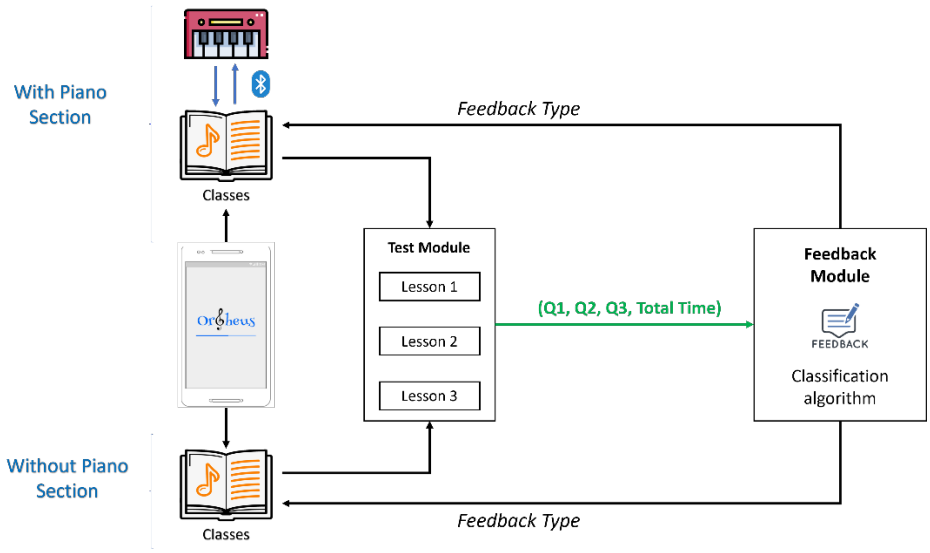

Figure 5. General scheme of the mobile application with feedback system.

6.1 Feedback types

Once the student finished all the lessons of a class, the feedback system, through the music software, will offer one of the four types of feedback that the classification model will recognize:

- **High feedback:** When answering the questions of the lessons of a class, the student did not have a good score of these, and it is necessary to give the child a greater reinforcement of the contents.
- **Medium feedback:** When answering the questions of the lessons of a class, the student had a lower score than the minimum expected, and it is necessary to give the child a medium reinforcement of the contents.
- **Low feedback:** When answering the questions of the lessons of a class, the student had a good score and it is necessary to give the child a low reinforcement of the contents, simply summarizing what was seen in the lessons.
- **Time feedback:** Although the student performed well in the class, the child took longer than expected to answer the questions and needs a little advice to improve this factor.

6.2 ML classifiers for the feedback system

For the implementation of the feedback system, it was necessary to find the most appropriate Machine Learning classifier for the objective of this stage. For this, a comparison was made between the following classifiers:

Decision Tree classifier. A decision tree is like a flowchart, where each internal node (non-leaf) represents a test of an attribute, each branch represents a result of the test, and each leaf node contains a class tag [13]. In addition, the decision tree has the advantage that it does not require domain information or parameter configuration, which facilitates the extraction of information.

Random Forest classifier. Random Forest is a classification algorithm that uses a set of classification trees. Each tree is built using an initial sample of the data, and at each split, the set of candidate variables is a random subset of the variables [14]. It is important to mention that they are binary trees, driving the response path through true or false statements. The use of binary trees allows this algorithm to be fast Log(n).

Multi-layer Perceptron classifier. MLP is one of the most common neural networks. It consists of two main computational stages: a *feed-forward* network and a *backpropagation* network. In the forward pass, the input vectors are applied to the input nodes of the network and at each node (neuron) the weighted sum of the input is performed. In the final stage of the forward pass, the output set is produced as the actual output of the network. Now, during backpropagation, the actual output of the network is subtracted from a desired output to produce an error signal, and the weights of the network are adjusted to move to the desired response according to the errors that propagate back [15].

Support Vector Machine (SVM) classifier. SVM is basically a binary classification method that builds a hyperplane in a high-order space that separates samples of two classes. Its design uses kernels that are typically based on linear, polynomial, radial basis function (RBF), or sigmoid [16]. In other words, given the labelled training data, the model creates a hyperplane that categorizes each class and divides them with the most suitable hyperplane (in a two-dimensional space it is a line; in three dimensions, a plane, and so on).

K-Nearest Neighbors classifier. It is very famous for its simplicity of execution. The k-NN has a non-linear design and can detect information propagation directly or indirectly [17].

6.3 Selection of the classification algorithm

Once the candidate classification methods were established, the data set that will be used in the training of each method was selected for its subsequent comparison. It is necessary to remember that each time the student finishes a class (composed of three lessons), the chosen classification model will obtain the results of each lesson and the time the student lasted to answer the questions of these lessons for the corresponding classification within the feedback system (Fig. 5).

6.3.1 Dataset

The feedback module shown in Figure 5 works from a classification model that predicts the type of reinforcement that the student needs. This prediction is made based on the score and time achieved by the participant, that is, to train the candidate classification models, the application's own data must be used. For this reason and because this application has not been previously implemented in a data collection environment, a dummy Dataset had to be used with the necessary characteristics for training.

In the literature there are different works that use fictitious data for different purposes, even in non-musical environments. In 2018, Data Mining and Machine Learning (ML) techniques were used to study the patterns and characteristics of suspicious and non-suspicious credit card transactions to predict behavior based on fictitious data [18]. In 2021, a study was carried out to predict the academic performance of students using an efficient machine learning algorithm. Although an existing data set was used for network training, a fictitious data set with information from students from past semesters [19] was used to verify the most efficient algorithm. On the other hand, data mining has also been used for the discovery of business strategies with the intention of achieving lasting goals for companies, this through the generation of fictitious data from different organizations [20].

6.3.2 Dataset construction

For the score of each question in the lessons, it was decided to establish a weight from 0 to 1 for each answer option according to how close or far it is from the correct answer. For instance, if the answer is correct, the score will be 1; if the answer is very close to the correct one, 0.8 could be assigned; if the answer is far from the correct one, 0.2 could be assigned. It is important to clarify that the weights of each answer option were assigned according to own criteria of how correct or incorrect the selected option is. Figure 6 represents what was previously described.

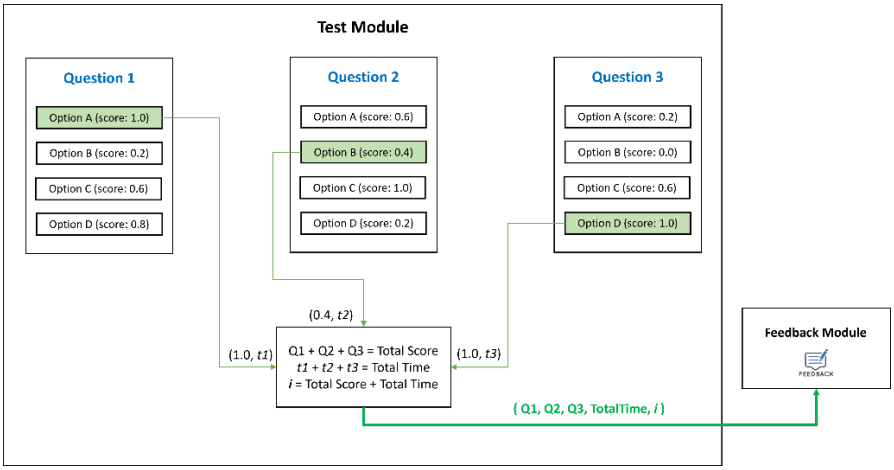

Figure 6. Question scoring scheme within the feedback system.

Now, with the captured scores, the time the student spent on the three questions must also be considered. To do this, the music software will count the time (in seconds) from when the question is shown to the student until when it is answered. These three times are added to obtain the Total Time as seen in Figure 6. Finally, an index was also established that allows comparison with a defined optimal threshold to evaluate if a score is high, medium, or low.

With the above, 2000 data were created with the characteristics described. For Question 1 (Q1), Question 2 (Q2) and Question 3 (Q3) numbers between 0 and 1 of one decimal were randomly generated, for the Total Score these three values were added (see Equation 1), for Total Time a random number between 1 and 120 seconds (2 minutes) was generated and in addition, a new column called Relative Rate was created, which is calculated as the reciprocal of Total Time (see Equation 2). Although Relative Rate is generally used in various contexts (mainly chemical) to measure the reaction speed of some change in an experiment, as the Dataset was generated, a small difference was observed between the accuracy of the labeling calculated with Relative Rate and the labeling calculated with the Time, being the most accurate label results with the Relative Rate. For this reason, the index, which will be compared with the threshold, is calculated as the sum of the Total Score and the Relative Rate (see Equation 3). Likewise, the optimal threshold was established at 3.03 since the expected Total Score for the questions is 3 and the expected Relative Rate is 0.03 (see Equation 4).

$$TotalScore = Q1 + Q2 + Q3 \tag{1}$$

$$RelativeRate = \frac{1}{TotalTime} \tag{2}$$

$$Index = TotalScore + RelativeRate \tag{3}$$

$$OptimalIndex = OptimalTotalScore\ (3) + OptimalRelativeRate\ (\frac{1}{30}) \tag{4}$$

On the other hand, by requiring a classification model, it was necessary to label each data element created so that the model could be trained, therefore, each record was labeled considering the following metrics and the optimal threshold defined for the index.

- The best score that can be obtained is 3.0 (1 point for each question).
- The worst score that can be obtained is 0.0 (0 points for each question).
- As the questions are so short, it was established that the optimal time to answer each question is less than or equal to 10 seconds.
- The best Total Time that can be obtained in the class is less than or equal to 30 seconds (10 seconds for each question).

With the metrics and threshold defined, each record took one of the types of feedback described in sub section 6.1 of this paper.

6.3.3 Training and testing for classifier selection

The training and testing process was carried out using a program built in Google Colab through a Python interpreter. Before processing, the data generated and described above was stored in a .csv file. Following this, the input columns (Q1, Q2, Q3, RelativeRate and Index) and the output column (type of feedback) were selected. Following this, 1200 data for training and 800 data for testing were selected.

Thanks to the **sklearn** Machine Learning library, each of the candidate classification methods (see section 6.2) was defined and implemented in code. Once the methods were trained and the test performed, the precision results for each classification method were as follows:

Table 2: Accuracy of candidate classification methods.

Method	Accuracy (%)
Decision Tree	99.50
Random Forest	99.50
Multi-layer Perceptron	92.25
Support Vector Machine (Linear Kernel)	92.50
Support Vector Machine (Polynomial Kernel)	95.00
Support Vector Machine (Radial Basis Kernel)	92.25
Support Vector Machine (Sigmoid Kernel)	50.50
K-Nearest Neighbors	98.50

As can be seen in the Table 2, most of the candidate classifiers have good precision, however, Decision Trees and Random Forests have better results. Therefore, it was decided to choose Decision Trees as the classification algorithm in the feedback system within the application.

With the above, it was verified that the amount of data generated from the beginning (2000 data) was adequate. For this verification, a data set of 4000 records was created by iterating them in increments of 50 records. Figure 7 shows the graph where each iteration is compared, putting on the X axis the number of records and on the Y axis the accuracy of the training. In this way, the graph allows us to appreciate that from approximately 100 to 1500 data the accuracy is constant at 100%, however, it does not leave a feeling of reliability. On the other hand, before 2000 records the accuracy percentage begins to vary slightly and once more than 2000 a strong precision distortion is observed. For this reason, it was decided to keep the amount of data in the model at 2000.

6.3.4 Final architecture of the system

Once the classifier (decision tree) was trained, the generated model was saved in a SAV file for later reading. Furthermore, using a Python script that would allow reading the saved SAV file, it was decided to create a local server that waits for a new connection via socket, where it receives the values to be evaluated. That is, once the child finishes the last lesson of any class, the music software (mobile app) sends to server: the score of Question 1 (Q1), Question 2 (Q2), Question 3 (Q3), and Index; waiting so the server responds with the type of feedback that the user needs.

When the server responds to the mobile application with some type of feedback (see section 6.1), the music software will show to the student a new content that reinforces the topics seen in those three lessons, based on said response. It is important to clarify that these new reinforcement themes were previously elaborated according to the four types of feedback. The final system architecture and the behavior of the components is shown in Figure 8.

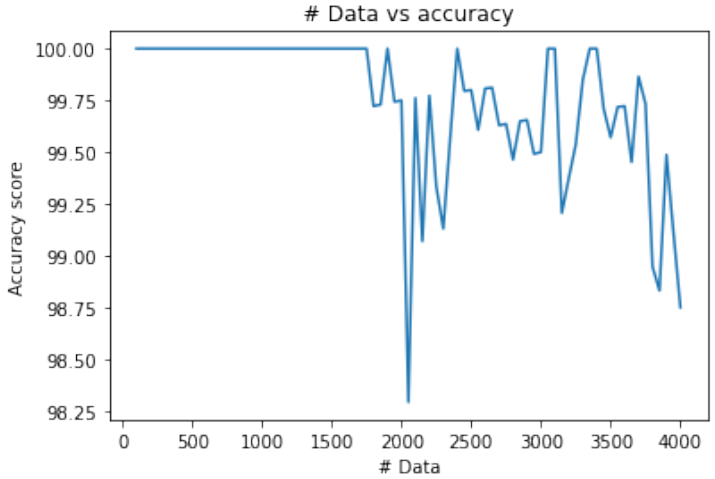

Figure 7. Quantity of data vs Accuracy (Decision Tree).

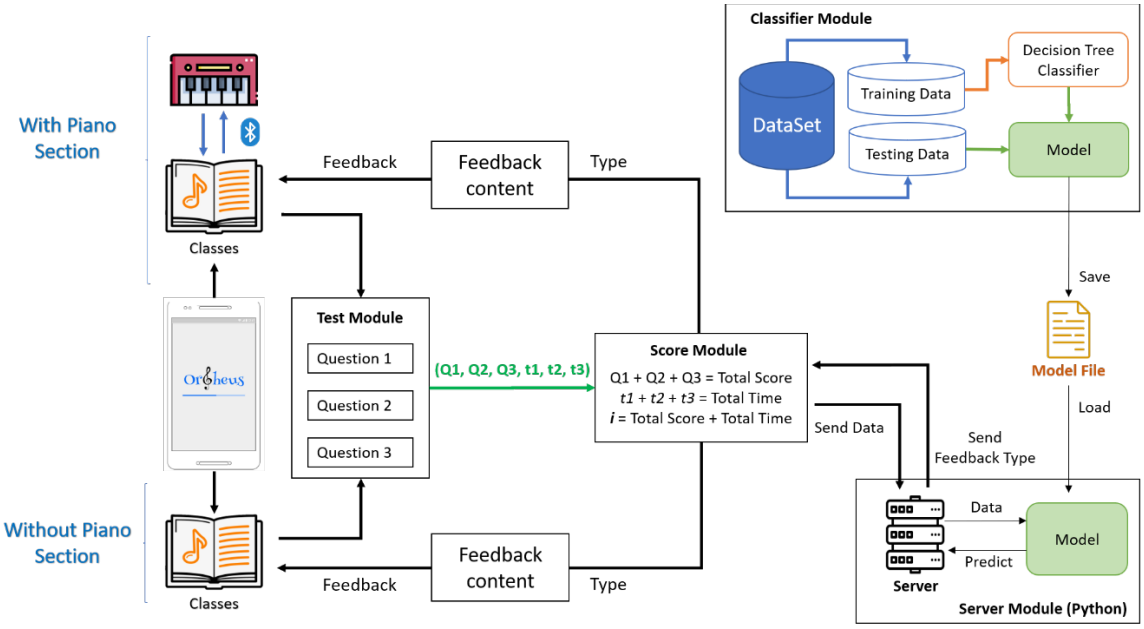

Figure 8. System architecture and component interaction.

With this feedback system, it is expected that the student will better understand the concepts that were not very clear in class.

6.3.5 Software feedback system

The classification using the selected model is not executed within the developed music software, as this is a process that would directly affect the performance of the mobile application. For this reason, the decision was made to build a testing server that connects to the music software using the IP of a local network. This server was developed using Python code, creating a Socket connection awaiting a client. When the mobile application is opened, the link between the server and the client is established through the local network to which the mobile device and the server-running device are connected. With the connection established, the server will wait for a message sent by the client (mobile application), either containing the parameters of a class to return the type of feedback (section 6.1) or indicating the termination of the connection. It is important to clarify that both server and client can send and receive messages from each other.

Now, at this point, it's important to mention that prior to socket configuration, the server loads the SAV file containing the pre-saved Decision Tree model, as specified in section 6.3.4. Once the connection is established and furthermore, the client (music software) sends the necessary parameters for classification (Q1, Q2, Q2, RelativeRate, i), the server, using the model, will predict the type of feedback required for those values and send the message back to the client. Upon receiving this message, the client will display on the mobile application the content set for that type of feedback.

7 Stage 4: Comparative analysis

The processes carried out to successfully achieve the first three phases of the methodology have been described (Figure 1): the contents of the book 'Piano for Dummies' were adapted to establish the themes of the music software (section 4). The mobile application was developed along with all its contents, and in conjunction with the manually crafted mini piano, a Bluetooth connection was established for a more realistic interaction (section 5). Finally, the most suitable Machine Learning classifier was chosen to enable the construction of the entire feedback system within the music software (section 6).

7.1 Components of the comparative analysis

Based on the previous information, this final phase focuses on the comparative analysis between learning using the developed musical software and learning through the book "Piano for Dummies." This comparative process involved the participation of two students in the Concrete Operational stage and was carried out over 6 individual sessions of 30 minutes each, totaling 1 hour per day. In addition, this stage comprises the following elements:

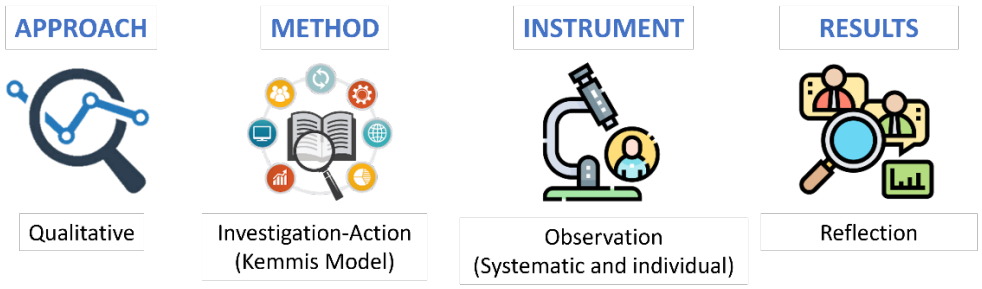

Figure 9. Components for comparison analysis.

Qualitative approach:

The research method adopted in this fourth stage is the qualitative approach. In the literature, qualitative approaches are highlighted as the primary research method in educational sectors. An example of this is the study conducted in [28], where they emphasize that qualitative research emerges in the field of education sciences as a valid methodological choice for addressing socio-educational problems. In the same work, they indicate that the qualitative aspect of the experiment successfully achieves a comprehensive understanding and interpretation of the results, thus determining the most suitable methodology for comprehending contemporary music.

Investigation-Action (IA):

Within qualitative research, there are various methods of application. However, for the purpose of this project, the Decision was made to choose Investigation-Action, based on the literature. Some authors argue that IA aims to enhance education through change and learning from the consequences of those changes. Similarly, IA aims to understand and interpret social practices (inquiry) to modify them (action) and to enhance them (purpose) [29]. Finally, as mentioned in [28], IA is presented in this case not only as a research method but also as an epistemic tool oriented towards educational change.

IA has also been the product of various studies and adaptations over time. One of the most well-known Investigation-Action models is that of Stephen Kemmis. He proposes the construction of IA in cycles, where each cycle consists of: planning, action, observation, and reflection, as shown in Figure 10. With this in mind, it is important to note that for this project, a single cycle will be conducted.

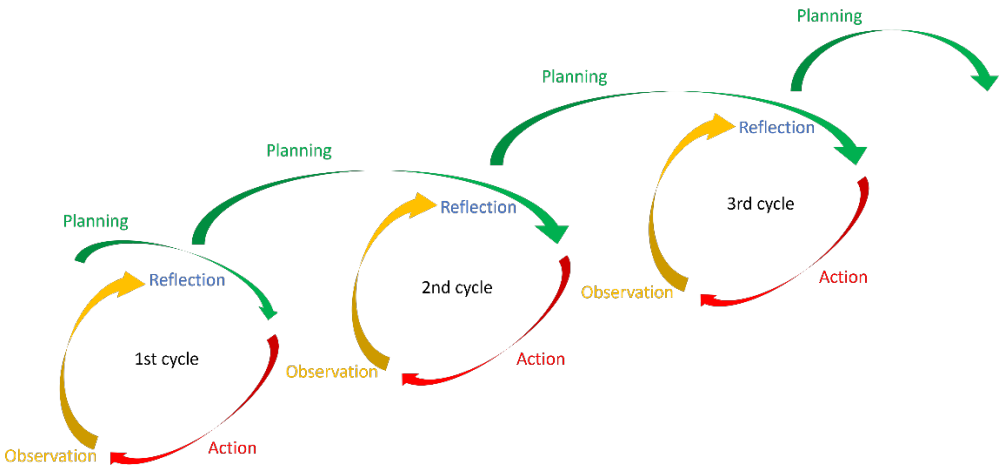

Figure 10. Investigation-Action method under the Kemmis Model. Adapted from " Características y retos de la IAP: Una experiencia personal en investigación turística " by Pilar Espeso-Molinero, 2017. ***Planning***: It is

necessary to have a clear understanding of what will be done, defining priorities in needs and elaborating options among possible alternatives; ***Action***: The plan is put into practice, taking into account everything planned beforehand, in order to carry out the observation; ***Observation:*** The action carried out is observed to gather evidence that enables an evaluation; ***Reflection***: The recorded action during observation is analyzed to provide the basis for new planning and to proceed with the next cycle.

Observation as instrument:

The Investigation-Action method described above employs observation as an instrument, which is one of the data collection alternatives in descriptive research. It is important to highlight that the observation will be systematic: with specific prior planning of what is to be observed; and individual: referring to the fact that the sole observer of the process is the researcher themselves.

Results:

As seen in Figure 10, reflection is the final step in the Kemmis model. This is where the collected data are analyzed, and conclusions are drawn to facilitate more suitable planning for the next cycle. For this work, given that it's only a single evaluation cycle, those conclusions will be taken as outcomes for the comparison process.

7.2 Implementation of the comparative analysis

Before conducting the comparative analysis, a public school in the city of Bogotá was selected, considering 5th-grade student groups (ages between 10 and 11 years). Following this, discussions were held with the school principal and the students' course director to reach an agreement and carry out the proposed 6 classes, as well as to designate the 2 participating students. Additionally, an informed consent was provided to the parents of each student to ensure the proper execution of the process. In this manner, and following the Kemmis model (see Figure 10), the 4 stages were carried out as follows:

Planning:

Here, the 6 days in which the music lessons would take place were organized. Each class had an approximate duration of 1 hour, 30 minutes for the student who would learn through the software and 30 minutes for the student who would learn through the "Piano for Dummies" book. It's important to note that the student using the software-based lessons also had access to the mini-piano created (see section 5), while the student learning through the "Piano for Dummies" book used a Yamaha keyboard with 5 octaves (61 notes) as their tool.

In addition to the above, the planning involves developing a clear action plan for what will be observed and analyzed. Therefore, it was necessary to create a format that allowed the recording of key elements noted during each session with the participants. This way, two formats were created (one for each learning method) for the defined six sessions. Prior to each lesson, the expected duration of the class was determined, along with the expected ratings for each lesson. These values were established in order to compare them with the actual time and ratings achieved by the participant. Additionally, extra aspects were taken into account such as the student's enthusiasm for the class, their concentration, their level of calmness, and their ease in using the learning tools. Finally, an observation section was included to detail any elements or situations that arose during the sessions.

Action:

Before starting the first class session, a brief project introduction was provided to both participants, along with inquiries about their musical goals and interests. Both students expressed an appreciation for music, even without prior knowledge. They were also given the choice to select which teaching method they wanted to use for the sessions (musical software or "Piano for Dummies" book), as this did not impact any aspect of the predetermined plan.

Throughout the 6 days of sessions, the teacher in charge of the students facilitated the participation of the first participant. Upon completing the session for this student (approximately 30 minutes), the second student would exit the classroom and proceed to the area where the music lessons were being conducted.

The first student underwent the 6 sessions using the "Piano for Dummies" book method. It was expected that the student would read at their own pace, without pressure, and with the freedom to ask about any topic that was not clear. This participant used both the book and the Yamaha keyboard as they saw fit and, on some occasions, summarized the topics covered in the classes to the observer. The observer then filled out the predetermined evaluation form based on their observations. On the other hand, the second participant underwent the sessions using

the musical software (mobile application). Prior to starting these sessions, the server was run via Socket, which performed classification on the type of feedback the user needed (see section 6.3.5). Additionally, the student was also free to interact with the mobile device and the created musical keyboard (see section 5). At the end of a class (comprising 2 or 3 lessons), the classification process was carried out, and the mobile application displayed new reinforcement content. Once again, there was a space for dialogue with the observer about the topics covered. This dialogue and the responses to the questions were part of the assessment in the defined format.

Observation:

In the observation phase of the Kemmis model, evidence is collected to facilitate its evaluation. This collection was done using the predefined formats, as previously mentioned. Some of the metrics measured for each participant included: class duration, performance in each lesson, participant's enthusiasm, comfort level, among others.

Reflection:

The observation and fingering process did not serve as a distraction for the student. Moreover, the space was very suitable for carrying out the activities. While there were several interactions between the researcher and the participant to assess their understanding of the concepts, this did not prevent the student from taking autonomy in using the available tools (book, mobile device, and musical keyboard).

As the student progressed through a lesson, observations were recorded in the format. Likewise, during the evaluation of the lessons, the ratings were noted based on the responses provided by the participants (both in the software and with the book). This information was crucial for a better analysis and conclusion in the reflection stage.

8 Results and Discussion

A primary factor that stands out in the 6 sessions for both participants is that they consistently displayed enthusiasm, high concentration, calmness, confidence, and ease in handling the tools. However, there were moments of nervousness and shyness in the initial classes, which gradually gave way to increased confidence between the researcher and the participant as the days progressed.

Now, regarding the durations of the classes, they were designed to last for approximately 30 minutes. With the learning method through the book, the durations were around this time, and in some sessions, these durations extended to 40 minutes. One of the reasons for this behavior can be attributed to the unfamiliar language used in the book for the participant. It's important to remember that the original translated text is in Castilian (of Spain). Additionally, the amount of text in the book could be dense and slow down the pace. On the other hand, the contents of this book were didactically adapted to the musical software, and a significant difference in the session times through the mobile application was noticeable. This method improved the time by approximately 10 minutes from what was expected.

While there was an improvement in times of approximately 20 minutes per class with the musical software method, does the student's learning also improve? To answer this question, it's important to recall that the content was the same in each session; only the manner in which the information was presented varied. Through the observation process, it was evident that in learning from the book, the overall ratings for each class, in most cases, were similar to the expected performance. However, learning through the software showed an improvement in comparison to the expected ratings. A primary factor associated with this behavior is the extensive amount of text in the book and the uncommon terminologies for the student. In contrast, the musical software summarized the book's topics and highlighted the key elements to be taught, making them easier to understand due to the language used.

Other noteworthy aspects observed included the presence of complex topics that required additional explanation for initial comprehension. Furthermore, both participants displayed a clear recollection of the subjects covered in previous sessions. Additionally, they both intuitively and effortlessly utilized the provided tools and used the musical keyboard when they deemed it appropriate. In this regard, no learning method proved to be more influential than the other.

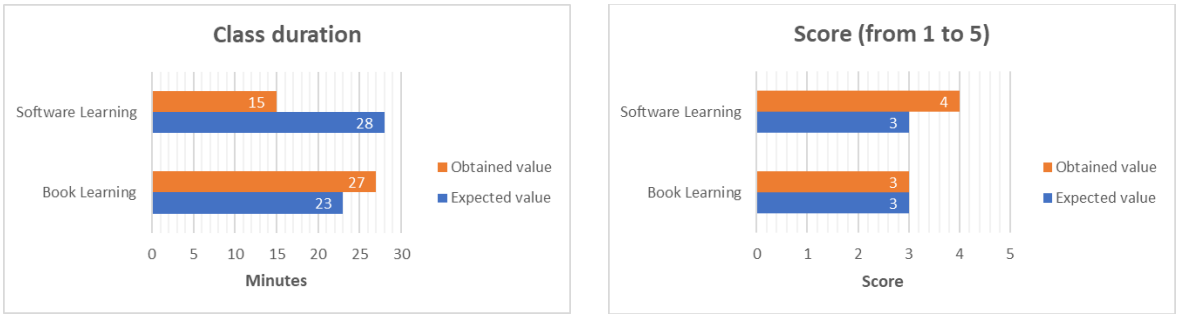

Figure 11. Average duration and average rating of the 6 classes for each teaching method. Both graphs display the comparison between the average of the expected duration versus the obtained duration, and the average of the expected score versus the obtained score, for both learning methods (software and book). In the learning with the book, a greater time than expected was obtained, while the student's performance matched the expected evaluation. On the other hand, through the musical software, the learning time was significantly reduced, as well as the scores achieved, compared to the expected values.

9 Conclusions and future works

Firstly, choosing the most appropriate content, translating it into a more common language for the target population, incorporating graphics and interactive elements, and supporting it with questions and exercises was a significant decision in the construction of the musical software. The results show that better performance in terms of time and learning was achieved with the method supported by the mobile application. However, it is important to carry out further comparative processes with 'Piano for Dummies' or other methodologies to avoid premature conclusions.

Although six classes, consisting of two or three lessons each, were constructed, many topics were still left uncovered. This allows us to contemplate the great potential that the application holds. With practical exercises, a variety of reinforcements, different types of questions, and the vast amount of content that can be included, it would be possible to create a comprehensive musical method that could be taken into educational classrooms.

With respect to the selected classification algorithm, the results that were observed in several tests carried out show that the classifier does its task correctly and coincides with the user's performance in the classes. In addition, it was possible to appreciate that it is not necessary for the student to answer the questions of a class in a short period of time or consecutively, that is, the questions can be answered at any time, since the progress is saved in local data of the mobile application.

Likewise, through the tests carried out, it was possible to appreciate that the decision trees, within the feedback system, integrate well with the mobile application since reliable results are achieved. Although the training and testing of the model were developed with a fictitious data set, these data are not far from reality, since each random data generated could become a valid real data. However, it is important to consider that carrying out new training and tests with real data collected could give a new perspective. On the other hand, because the data generated does not have a very wide range (for questions, from 0 to 1 with one decimal place, and for times, from 1 to 120 seconds), increasing the size of the data set does not change significantly the accuracy of the candidate classification models.

Furthermore, incorporating application interconnectivity with other systems adds significant value to the project. Firstly, through Bluetooth with the manually crafted musical keyboard, allowing the user to immediately apply the concepts using the keyboard, as the data transmission time is quite short. Secondly, the socket connection with the classification server enables the user to receive immediate reinforcement based on their performance, providing clearer content, ideally with examples, for better comprehension.

On the other hand, conducting practical work like the one carried out at the public school provided perspectives that contribute to the project's objectives and go beyond the theoretical aspects presented in the first three phases of this work. Hence, conducting the six sessions with the two participants was necessary to analyze whether the project's direction had a solid outlook or not.

As future work, it is desired to automate the generation of the new content that is given to the student in the feedback of each class. That is to say, it is expected that it is not a previously elaborated content but that through

Machine Learning techniques (Curriculum Learning for example), the reinforcements of the classes can be generated.

Improving the design and composition of the built musical keyboard would allow a more real experience, since the materials used make the interaction basic and elemental. Although it is an initial version of the prototype, it can be improved with more suitable elements or with a better assembly of these.

Finally, the goal is to expand the number of cycles in the Investigation-Action, as it's important to clarify that each cycle plans according to the reflection process carried out in the previous cycle, aiming to continuously enhance the teaching method. Likewise, involving more students in the comparison process would be ideal to obtain results that are closer to reality.

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