Abstract - We describe the development and evaluation of the educational musical computer game for preschool children that offers a first experience with music education. The game is used as a case study to demonstrate, evaluate and discuss the principles of game design for digital game based learning. We describe the game’s scenario along with the explanation of the logics and mechanics of this game, and present its evaluation from the educational point of view. The game fills the niche of the Lithuanian educational musical games, while the study results show that preschool children show great interest in exploration and creation of musical sounds thus ensuring the enrichment of educational game-based process with elements of creativity and emotional learning.

Keywords - digital game based learning, emotional learning, musical learning, children, games, STEAM.

I. INTRODUCTION

Today preschool children are already digitally engaged and are acquainted with handheld computers (smartphones, tablets) at a very young age [1]. Especially, computer games attract children with immersive game worlds, capturing game stories, and rich multimedia experience. The games can also contribute towards children’s discovery of the world and provide motivation for learning new knowledge. The pedagogical use of digital games has been recently a subject of an increased attention from researchers [2]. There is a need to associate and explore gaming activities that could be useful when applying for educational purposes [3]. An example of such game is the game designed for adult seafarers as well as undergraduate maritime students of maritime academies/institutions presented in [4], where the knowledge in navigational safety training was delivered using a multimodal game framework that included images, words, sounds, music, and movement.

Contemporary neuro-didactics [5] emphasizes the importance of passive (e.g., music listening) and active (e.g., singing, playing, dancing) child’s musical involvement of music into children education [6]. Music is important for children's holistic development, especially in the socio-affective domain. The study [7] showed that children in the early and preschool age are very interested in music-related activities such as sound exploration, which encourages children’s creativity and enhances their emotional intellect. Digital music games are increasingly being developed for educational purposes, like learning to sing, play the piano or read musical notes. Gradually, these games are being recognized as active learning environments, which can reinforce learning-oriented motivation of players and allow to sustain interest in learning while playing [8]. Moreover, music is effective in developing working areas such as auditory memory [9].

The use of Information and Communication Technologies (ICT) in combination with arts (including music) is relevant in the context of Science, Technology, Engineering, Arts and Mathematics (STEAM) education. Introducing young people to hybrid works of art and technology and by offering digital games as an educational art tool opens new opportunities to mix technology/engineering with artistic/creative process and design thinking, and keep young people attracted to the fields of Science, Technology, Engineering and Mathematics (STEM). For example, robotic music has been employed to help children enhance their educational motivation and effects [10].

The structure of the remaining parts of the paper is as follows. Section II describes the theoretical framework. Section III describes the development of the game. Section IV evaluates the game, and Section V presents the conclusions.

II. THEORETICAL FRAMEWORK

The pedagogical backgrounds of our research are Digital Game Based Learning (DGBL), self-determination theory (SDT), immersive learning and Technological Pedagogical Content Knowledge (TPACK).

Digital games can instill learning experiences in different learning fields, as these can respond to the intrinsic motivation of learners, when the tasks are interesting and fit the learners’ abilities [11]. DGBL is related to the constructivist principles of active learning, in which understanding and knowledge of the world is constructed through personal experience and reflection on those experiences. This is also relevant to music education, as pupils need to not only recognize, but also
experience essential music elements; i.e., duration, pitch, tone color, dynamics and structure of music.

We also use the TPACK framework [12]. TPACK integrates technological (TK), pedagogical (PK), content (CK), pedagogical content (PCK), technological pedagogical (TPK), and technological content knowledge (TCK). Here CK is knowledge about the subject matter to be learned or taught. PK is knowledge about the methods, processes and practices of teaching. PCK is knowledge to develop and deliver effective content-specific instruction. TK is knowledge of basic ICT. TCK is knowledge of how the content can be represented by and researched with technology. TPK is knowledge of using technology to implement teaching methods, and the ICT tools fitting for achieving learning aims and implementing [13].

Immersive learning [14] focuses on learning design through achieving immersive experiences rather than conventionally transferring formal sets of knowledge between a teacher and a learner. Games provide a tool for achieving immersive learning in virtual spaces to provide the gamers with complex skills and information they need to become successful [15]. In line with SDT [16], games can be intrinsically motivating, when they make players feel competent, autonomous and provide psychological relatedness.

The main motivation for gamification is to increase player motivation to perform some kind of a task (e.g., to learn, in our case) or to increase and retain addiction to some process (such as learning) or a product (such as learning environment) using a game as a tool. Fogg Behavior Model (FBM) [17] explains gamification in terms of converging motivation and ability to perform until the desired behavior occurs. Motivation must be continuously supported and reinforced by game mechanics and player incentives so that the player is kept on the desired path in the game flow and his interest to continue playing is maintained [18]. For gamification to be effective, however, the elements (layers, actors, tools) of the game must be linked to learning outcomes [19].

III. DEVELOPMENT OF A GAME

A. Prerequisites

Hereinafter we describe the development of an educational musical play called “Happy piano sounds” (original title: “Pianinas linksmieji garsai”), which can be played on any Android smartphone or tablet, and is available to download from the GooglePlay store at play.google.com/store/apps/details?id=com.erfe.gtegw. The game was downloaded nearly 500 times from 2016 until April of 2018, and its average evaluation rate is 4.9 stars.

In designing the game, we followed the principles formulated by Chung et al. [20] as follows: (1) age-appropriate game content; (2) multi-touch applications to support interaction, and problem-solving; (3) game design with creative functions and recorded audio files to encourage meaningful repetition; (4) no prerequisite musical knowledge and skills; and (5) the potential to expand gameplay to a higher level of symbolic knowledge.

B. Design considerations

For the first time in the game, it may be difficult for the player, especially for a preschool child, to understand what the purpose of the game is, what needs to be done in a particular case. To help solve this problem, the game should provide an assistance tailored to be understandable for target user audience. Such assistance is presented in different (multimodal) ways - written, visual or audio. Considering that in the games for young children, the help provided by the text is difficult to understand, because most of the preschool age children still can not read. For this reason, the help provided by elderly (e.g., a parent, older brothers or sisters) is essential for playing. To create a game that small children can play on their own, needs to create visual or audio help. Monotony should be avoided in order to create a game that is playful, fun and interesting for children. For this reason, there is an option to choose, which sound (animal, instrument, or other object) will be propagated when the player clicks on the corresponding key/button.

The piano keyboard simulator is a necessary part of the game aimed at teaching the meaning of the piano keys and associated musical notes. Usually, 7 to 8 keys (one octave) are used from the start. The number can be explained by the Miller’s Magical Number Seven Law, which claims that the number of objects an average human can hold in his/her working memory is $7 \pm 2$ [21].

The selection of colors used is another important issue to consider. While the real-world piano keys are black and white, the black color is usually associated with negative concepts such as fear, anger, death, evil, aggression [22]. Black color has been shown to make children unhappy [23]. Vivid colors rather than black & white have been shown to increase emotional attachment, attention, and memory [24], thus facilitating the learning process. While black keys are necessary to learn the piano keyboard correctly, but on the other hand, there is some difficulty of learning with the help of black keys. Therefore, the piano keys have been painted in different colors to induce positive emotions from children and encourage playing.

When developing an educational game, its main purpose is to train. The entertainment side of the game is only to sustain the attention of the player. This functionality is especially important in order to create a game that is not only fun to play, but also can fulfil its main goal – to teach. Creating a game that is tailor-made for everyone is very complicated, because the needs of each player are different. Individual settings, which the player can adjust themselves, helps to meet his/her needs more easily. Vast majority of children music education games do not have any settings. Such a solution adopted by game developers may be due to the fact that a child does not inadvertently turn off or turn on the features he likes. To make settings, but to prevent unintentional changes to them, the proper solution would be to make the settings button tailored for the elderly.

We added the non-binding functionality to the playful musical game - songs already recorded in the game that can be selected and played back. Although the game has aimed for diversity, it is not an essential function for an educational game. A good atmosphere in the game helps
to create background music and background sounds. Background music has been noted to increase overall user satisfaction, support immersion, prevent from boredom, and provide more pleasure and higher perceived social richness in terms of personality, liveliness, and emotionality [25]. The main features of background music are playfulness, childhood and integrity. When some object appears on the screen or when some object is clicked, its name or relevant information is displayed. In this way, the player learns more about music and piano.

Each level of the game features a specific animal (sheep, dog, cat or cow), which provides a narrative and helps the child to learn. Pets provide children with positive experiences and feelings thus facilitating communication, fostering imagination, and supporting learning [26]. Companion animals, even if only virtual ones, are powerful motivators for learning, due to children learning and retaining more about subjects with whom they develop emotional attachment [27].

Creativity is one of the characteristics, which is important to promote from an early age. The most creative way to promote the child’s creativity is in the form of a game. Creative mode can facilitate the user can create music, record and play the music. This functionality teaches children to learn the piano keys better, and to accept them in a creative way.

C. Interface models and metaphors

The development of the game interface is based on the interface metaphors of fuzzification, gamification and metaphorization.

Fuzzification is the reduction of information load by presenting data to a person in a more understandable and acceptable form [28]. The essence of the fuzzification is the information provided to the consumer using abstract but acceptable and naturally understandable concepts.

Gaming is the integration of game elements into the interface [29]. Gameplay increases the attractiveness of the user interface, instructs the user to perform certain routine but necessary actions, encourages the user to come back and make the process of communication with the system enjoyable. Gamification is introduced through gamification patterns [30], which capture the reoccurring templates of game interfaces.

Metaphorization is used to represent abstract concepts, to use real-world objects that the user directly or intuitively relates to these concepts [31]. The essence of metaphorization is to illustrate an unknown concept (object or process) by using a well-known and understandable symbol that does not directly relate to an illustrative concept, but intuitively associates with an illustrative concept. Metaphors in user interfaces increase interface visibility, usability, help the user to create a mental model of the system, and contributes to enhancing connectivity.

D. Description of Game World

The action at each level takes place in different environments:

First environment (main menu, see Figure 1) - in the menu environment, there are five zones painted in different colors, depicting animals or human silhouette, surrounded by four musical notes. At the bottom of each colored box is the line of the same color, but a brighter tone. At the bottom of the image is a part of the settings icon, which, by clicking, will open the entire settings window, and the image will be dimmed for it. The entire center of the image, in the oval zone, depicts a landscape with two different houses, sky, and meadow. There are two cows in the meadow. The oval area also features clouds, a smiling sun, a rainbow, trees, and flowers.

Second environment (sheep level, see Figure 2) - piano keys (5 black and 7 colored) are shown at the bottom of this environment. Above each colored key stands the sheep. Each colored key has a gray background. In the left corner, a gray, translucent button with an arrow to the left is depicted, symbolizing the action - back. In the upper right corner are two gray transparent buttons: one button is with an arrow rotating round, and the other one has a question mark. The landscape above the piano keys features a rotating mill, a blazing river and a light rainbow. There is also a meadow, and a sky showed in the
level. On the right side of the image there is a fence with a house and a tree.

Third environment (dog level, see Figure 3) has five black and seven colorful piano keys in the bottom of the environment, as in all levels. Above each key stands the dog. The left corner of the level is a gray, translucent button with an arrow to the left, indicating the back key. Above the piano keys, there is the moon depicted, with changing phases, a starry sky, a meadow, trees, stones, and a dog hut.

Fourth environment (cow level, see Figure 4) presents a landscape view of the farm. At the bottom of the screen, as in the other levels, the piano keys are displayed. Above each keypad, a cow figure stands. Also, as in the abovementioned levels, there are three gray transparent buttons in the upper left corner and in the upper right corner. At the level above the piano keys there is a farm, a silhouette of the house, in the distance one can see trees, flowers, grass, heaven, and sky-high clouds.

Fifth environment (cat level, see Figure 5). At this level, the action takes place in the living room. As in the above levels, there are piano keys above which there are seven cat figures on this level. There are also three gray, translucent control buttons in this level. Above the piano keys there is a sofa in which the color changes when clicked. The colors of the sofa are seven, the same as the number of the piano keys, thus providing a meaningful association. The floor also features a wall decorated with geometrical shapes and flowers. On the wall there is a picture hanging that features a bird that looks up on a branch of a flowering tree. In the room there is also a table, a cake with seven burning candles, a cat's bed, and a cat bowl.

Sixth environment (creative level, see Figure 6) - as in the above cases, it shows the piano keys and the control buttons. This environment imitates a children's play piano with two speakers in its upper corners. Above the piano keys there are five buttons featuring the images of animals and pianos. At the top, in the middle, there are three more buttons with recording, playback and silence icons. The background for all buttons is moving from one color to another. From the speakers, white semi-transparent lines, which give rise to light imitation, shine. Also there are stars, which flash in different colors one by one.

E. Game mechanics

When a player enters the first level of any animal, first of all a sound is played that tells you what to do to get the player to level. At the same time, a picture of the hand is displayed on the screen, indicating the selection of the button. At the end of the helping stage, sounds are played that the player will have to repeat. When other levels (second, third, fourth) are triggered, the melody that a child needs to repeat will be heard immediately. When playing each sound, the piano key that corresponds to the sound flashes. Piano keyboard keys are inactive until a ringtone sounds to be played complete. When the ringtone ends, the piano keys become active.

Pressing one of the piano keys sounds its sound, launches the animation of the animal up-front of the button, and checks whether this key should have been pressed to repeat the melody. When a child presses the wrong key, an error sound is played, and the button, with the circle pointing arrow, starts to spin around its axis. The player can press the rotary button to hear a ringtone to repeat, and the level starts again. One after another, when pressing the correct keys, at one of the levels no. 1, 2 or 3, the animation of the balloons appears on the screen and the greetings are heard thus providing an encouragement and gratification for a child, acknowledging his/her successful effort. After the balloon animation, the player moves to the next level. After pressing the correct keys and at one of the levels no. 4, the animation of the balloons appears on the screen, the greetings are heard, the buttons that were previously turned on are inactive, and the 2 buttons appear on the screen - a button with a circle leading arrow and a button with a depiction of the home image.

Once the player clicks the arrow button (level button #1), the level is repeated again, and once the player clicks the button with the home image, it returns to the main menu.
At the user level and clicking on one of the animals, the sound of an animal is played corresponding to the note, which is indicated by the key under the corresponding animal.

There are educational objects, which, once clicked, have certain functions performed when the learning sounds are activated. For example, when clicking on sofa, it changes its the color to one of seven colors (red, orange, yellow, green, blue, blue, violet) and the name of that color is given. Clicking on the moon shows its name and it changes to another image depicting one of the four moon phases (new moon, first quarter, full moon, third quarter).

By pressing one of the sound buttons, with the pictured animal or piano, the piano key sounds are replaced by the sound of the animal shown on that button, or the piano's sound. These sounds are of a different pitch, adapted to each piano key.

IV. EVALUATION OF PEDAGOGICAL USABILITY

Considering that most of preschool children can not read, it is difficult to evaluate the pedagogical usability of the game using the traditional survey based approach. According to [32], usability is a characteristic related, among others, to the use of the product, user experiences or user expectations. Here we evaluate the pedagogical usability of the educational game in terms of the usability attributes, which are measured through subjective effectiveness of the pedagogical aspects of digital learning material [33]. However, since the target of the game are preschool children, complex questionnaires such as 56-item Pedagogically Meaningful Learning Questionnaire (PMLQ), which relate the learning experience to formal teaching programs, do not fit here [34].

Here we use the Child-Initiated Pretend Play Assessment (ChIPPA) [35], which has been created to assess children of 4-7 years of age. Three play items are measured on the ChIPPA: the elaborateness of child’s play action (Percentage of Elaborate Pretend Play Actions (PEPA) score), the ability of the child to substitute objects during playing (Number of Object Substitutions (NOS) score), and child’s imitation of the examiner’s modelled actions (Number of Imitated Actions (NIA) score). PEPA measures both the complexity and level of self-organization of a child’s play ability [36], and is calculated as the number of elaborate (i.e., meaningful) play actions divided by the total number of actions performed by the child during each 15-minute session of the ChIPPA, multiplied by 100. The ChIPPA assessment consists of three 5-minute long sessions of conventional play followed by three 5-minute long sessions of play with the educational game.

The summary of ChIPPA sessions is presented in Table 1. The sample comprised 9 preschool children ages 4 to 7 years old (6 boys and 3 girls) years old. The assessment was made by their parents, who are also the authors of this paper. The bias of the study was limited, since the assessment was performed by four different examiners. The ethical procedures were adhered to.

We have observed the reactions of the Lithuanian children to the play materials to check if they have understood the purpose of the play and responded to the actions of the game in a meaningful way. For example in the conventional game play, the children can imagine that the toy animals are alive and they can take animals to walk outside of the farm in the fields. In the musical game, the children imagined that the cows sing and produced musical sounds. The results of the assessment were as follows: PEPA (conventional game) = 85.55, and PEPA (digital game) = 84.46. The results indicate that the children interaction with the musical game was meaningful.

<table>
<thead>
<tr>
<th>ChIPPA play session</th>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional imaginative play session (play materials: animal figures from PLAYMOBIL Farm Set)</td>
<td></td>
</tr>
<tr>
<td>First 5 minutes</td>
<td>Present the toys (cow figure is withheld). No play directions are given.</td>
</tr>
<tr>
<td>Second 5 minutes</td>
<td>Examiner produces the cow figure and models five play actions (go to house, go to fields, eat, sing, say hello).</td>
</tr>
<tr>
<td>Third 5 minutes</td>
<td>No instructions are given. The child is encouraged to play</td>
</tr>
<tr>
<td>Digital game play session (play materials: electronic educational game)</td>
<td></td>
</tr>
<tr>
<td>First 5 minutes</td>
<td>Present the digital game (the “cow” level is not shown). No play directions are given.</td>
</tr>
<tr>
<td>Second 5 minutes</td>
<td>Examines shows the cow level and encourages playing.</td>
</tr>
<tr>
<td>Third 5 minutes</td>
<td>No instructions are given. The child is encouraged to play</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this paper, we have described the development of the educational music game for preschool children aiming to motivate their learning abilities. The game targets Lithuanian preschool children, which do not speak English. The game belongs to the memory type games and helps children to learn the basic knowledge about the piano keys and the associated musical notes. The game was developed based on the principles of Digital Game Based Learning (DGBL), self-determination theory (SDT), immersive learning and TPACK (Technological Pedagogical Content Knowledge), and employed the gamification patterns for motivation reinforcement. The game was evaluated by preschool children using the Child-Initiated Pretend Play Assessment (ChIPPA) assessment, and the results were good.

Considering the availability and wide-spread use of digital technologies even among young children there should be a reconceptualisation of young children learning in early childhood settings as children under six years of age are actively engaging with digital technologies in playing and learning at home and this cannot be missed by preschool education system. Preschool educators should re-examine the way children learn. The developed educational musical game presented in this paper and associated study is a step in this direction.
REFERENCES


