Developing Mathematical and Technological Competencies of Students Through Remodeling Games and Puzzles

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Abstract

This paper presents and discusses teaching experiences in which mathematical and technological competencies of students are developed through games and puzzles. Elementary Students were encouraged to play some games in its physical form and then challenged to digitally recreate them. Also, a group of middle school students were motivated to do it reversely: start playing with an already existing digital game, remodel it using the software GeoGebra, and then print the pieces using a 3D printer and play the game in its physical form. Observations from this experience suggest that the activities improved students' geometric vocabulary and understanding of transformations. In addition, students had opportunities to work collaboratively to develop basic understanding of programming, and to creatively solve various problems that naturally emerged during the transition process.

Introduction

Playing and learning are natural parts of children's everyday lives. From a child´s perspective, these activities are not always separate [3]. The Bridges Conference offers a good opportunity for the public audience in Family Day to reinforce that learning can be strongly connected with playing. Two years ago in Finland we were happy to share a workshop with different materials that we called *Mathematricks: Surprising and Revealing*. Most of the materials were hands-on activities to physically explore, but some of them were also recreated in its digital format using GeoGebra, as shown in Figure 1. This offered an alternative perspectives and approaches with technology. A welcome surprise was that about one-year later, one of these digital tasks achieved more than twenty thousand views on GeoGebra Materials[1] platform.

Figure 1: *Mathematricks stuffs and related puzzle available in GeoGebra online platform* https://www.geogebra.org/m/xpRFvBAQ#material/wVHUUjhh

[1] An online platform targeted to the public in order to share digital education materials. More than one million worksheets are available on many different topics.

This sizable number of views offered us a clue that puzzles and logical games can attract many users and students and can be used as motivation for activities connected to STEAM (*Science*, *Technology*, *Engineering*, *Art*, and *Mathematics*) subjects. More merely than playing some already known games and puzzles, students can be encouraged to create and develop their own. They can also go further by improving already existing games based on their interests and designs. Geometric learning benefits were triggered by this approach, and we identified good opportunities to enhance not only mathematical, but also programming skills. Based on this assumption we have created a virtual book in GeoGebra Materials in which a wide ranging collection of such games can be found. This virtual book is intended to inspire other users – especially teachers and students – who can use them for their educational aims. The range of samples offers a diversity of game designs, varying from those that use basic commands such as dragging to others that require more elaborated logical syntax. One of these examples can be seen in Figure 2.

Figure 2: Book on GeoGebra Platform with one of its adaptions available in https://www.geogebra.org/m/xpRFvBAQ

There have been schools and initiatives which are working on the integration of games in education. Digital literacy, creative problem-solving and collaboration are outcomes which have been achieved through these gaming experiences according to Nussbaum [2]. Nevertheless, students do not seem to be restricted to a unique resource. The same author mentions some experiences in which students have designed and played with both digital and physical games.

From Playing to Making

Playing games and puzzles can foster strategic and critical thinking, while making them can foster creativity and assist in inquiry-based learning. When planning activities that involve the use of games it is important to take into account all these aspects, to get the most benefit that the game can offer. Experiences in this direction were tried recently in a private school in Calgary, Canada, where students not only played, but remodelled digitally already existing physical games. As the final outcome, a group of students used a 3D printer to creat their digital models physically. Students had to examine existing materials, either to test different strategies by playing or to grasp the code behind them. They also had to adapt them and create (or recreate) their own models.

In one of these tasks, a puzzle inspired by *15-puzzle*[2] was developed in an 4th/5th grade group combining GeoGebra, Prisma and IMGonline. While GeoGebra was used for geometric and logical development the other two apps were applied for image processing and as an artistic filter. As initial motivation for this activity, students took a virtual tour through an equatorian museum, where they could see a panel set by square tiles. This activity will be shared in a workshop at Bridges 2018 – *Creating Own Painting Puzzles: Math, Art, Games and Technology* – and for that reason we are not going into details in this paper.

[2] The 15-puzzle is a sliding puzzle that consists of a frame of disordered square tiles with one tile missing. The goal of the puzzle is to match the tiles by making sliding moves that use the empty space.

A previous activity developed with the same group involved playing the physical version of the game *Blokus*[3]. This task demanded extensive geometric constructions based mostly on squares and their elements such as sides, vertices, centroids, and so on. During the digital representation, a variety of strategies emerged. For instance, for constructing the board marks, at least two different strategies were used. While one of the students chose a sucession of circles with fixed ratio, another one just reflected the points conveniently. For the research team, it was rewarding to observe how students enjoyed comparing their solutions and how much their mathematics vocabulary improved throughout the exercise. In addition, building this game digitally, students became more familiar with symmetry tools in GeoGebra: reflection, rotation, and translation. They tested such features in diverse ways and learned mathematical concepts while interacting with the software. Figure 3 illustrates part of this activity, first playing and modeling digitally further. The pieces exhibited on (c) were designed by one of the students and have customed points to indicate the rotation and translation movements. They are represented by circles and rhombuses respectively. Also, the process of construction allowed students to create new pieces and opened to discussions regarding the symmetry of them.

(a) (b) (c)

Figure 3: *From physical model to digital model, students working collaborativelly*

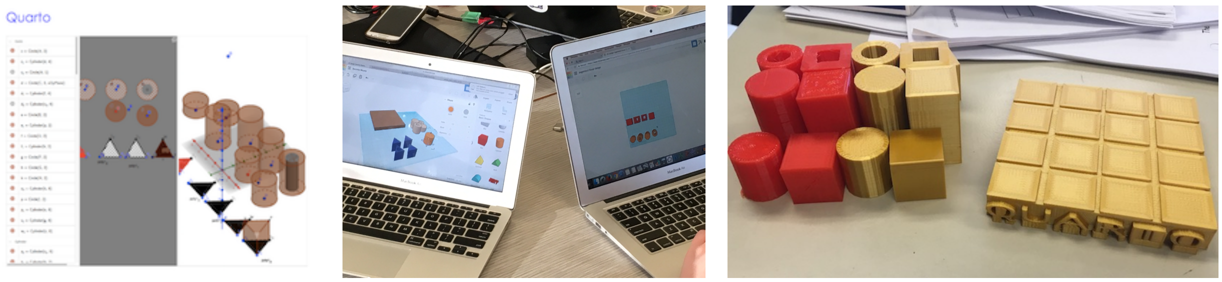
During an elective Choice Friday[4] course, two grade 8 students used GeoGebra, Tinkercad and 3D printer to make their own game. Students were introduced to the strategic game *Quarto*[5] and asked to create this game in a digital form. The main goal was to introduce them to the geometric modeling and develop basic coding skills. During the first four meetings (45 min each), students designed the game using GeoGebra. They then created the board and the pieces either in 2D (as the top view) or 3D views. For the first version the pieces could only be moved by dragging them, instead of clicking. In order to move the pieces without distortion students had to learn some basic principles of geometric constructions. Once the game was finished in GeoGebra, students remodeled it using Tikercad. This software was chosen due to its friendly interface and easy connection to the 3D-printer. Both resources were meaningful and complemented each other. On the one hand, GeoGebra provided features that allowed students to create more precise geometric constructions and connect this tool thoughtfully with their mathematical learning. On the other hand, Tinkercad offered a larger range of predefined solids and it worked in a way that favored a more intuitive manipulation of the objects as well as aimed at assisting the manufacturing

[3] In this game, the players have to fit the blokus pieces on a square-board in a proper way in order to play as many pieces as possible respecting the rules.

[4] A concept adopted by Renert School, in Calgary, on which students attend workshops instead of regular classes every Friday. The workshops are offered by the school teachers team and the range of topics include STEAM subjects, languages and intrapersonal development. Each student chooses her/his own program.

[5] In this game, two players take turns choosing a piece which the other player must then place on the board. A player wins by placing a piece on the board which forms a horizontal, vertical, or diagonal row of four pieces, all of which have a common attribute (height, shape, color, with or without hole). There are 16 unique pieces available in the beginning of the game (two possibilities for any of those four attributes).

process. This reflects the distinct nature of the objectives of each resource. Mathematical discussions came out in different levels during the development of the game. As a particular example, one of the students decided to use equilateral triangle prisms instead of squares. His choice also became his first challenge: find the center of the triangle in order to make an inner circle representing the hole. Some explorations with the tools in GeoGebra guided the student to the angle bisector and to the precise solution. Nevertheless, when he tried in Tinkercad, he found only the grid as a support, not being able to use the same tools and strategies he used in GeoGebra. As a consequence, he changed the shape of the pieces again, choosing this time the square prism as a piece. Part of this process is represented in Figure 4.



(a) (b) (c)

Figure 4: *Modeling the game Quarto on two platforms: (a) GeoGebra, and (b) Tinkercad; with the final 3D-printed model in (c); a model of this game can be accessed at* https://www.geogebra.org/material/edit/id/6813379

Discussion

In addition to the comprehension of the rules, which is the first learning aspect of playing, other competencies can be seen from the use of games as a teaching and learning tool. Social attitudes such as resilience, self-expression, and colaboration can be improved when playing. Some of these competencies were identified by a group of Psycologists, Musicians and Teachers/Educators in a workshop in Brazil [1]. Moreover, when used as described in this paper, mathematical and technological skills can also be developed and improved.

From this experience, we also found that the use of games as a teaching tool can be adapted as much as desired for learning/teaching differentiation. This shows another great value in using games in education. Currently we are considering to extend this teaching experiments to different learning environments and classroom settings. One idea is to add other more accessible technologies such as smartphones and tablets to complement the activities. Through this, we believe that a greater number of students could be reached and engaged to such learning process we described in this paper.

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