MATH GAMES FOR TWO PLAYERS

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Abstract

In the article we introduce interactive mathematical games intended for two players or two teams of players. These educational games can be used for remarkable training mathematical skills in the class. These games bring joy, enthusiasm and originality to the education. The games are in an interactive PDF format.

Keywords: math interactive games, PDF, games for two players, Jeopardy, Triangle.

1 INTRODUCTION

It is well known that the impact of learning can be emphasized by using attractive methods and eye-catching teaching materials. One of favorable methods how to bring a breath of fresh air to the class is to organize a competition related to the subject. The authors of this article created a broad set of mathematical games which allow easily organize such a competition in a class and let two players or two teams of players to test their mathematical skills and compete with their classmates.

The teaching materials introduced in this article are based on the ideas described in the papers [1-3] and present a part of a project Stem4youth [4] located at the homepage http://www.stem4youth.eu.

2 DESCRIPTION OF GAMES

The authors of the article prepared a set of 50 Triangle games and 100 Jeopardy games for using in mathematical lessons. These games are free to download and use for students and teachers and cover all topics included in a typical secondary school curriculum (age between 15 and 19). The games are divided into 13 areas: Basics of math, Equations and inequalities, Functions, Exponents and logarithms, Trigonometry, Triangle trigonometry, Geometry, Analytic geometry, Complex numbers, Combinatorics, probability and statistics, Sequences and series, Differential calculus, and Integral calculus. The formulation of the questions and answers comes from a translation of a national project Matematika s radostí (The Joy of Math) [5]. In this project a database of 1800 multiple-choice questions in Czech language has been created by a team of secondary school lecturers, reviewed by the members of the team from Department of Applied Mathematics, VŠB-Technical University of Ostrava (authors of this article) and tested in classes.

It is said that a picture is worth thousand words and a video is worth thousand pictures. Therefore, the reader is encouraged to read the description of the teaching materials first and then follow the links with two short promotional videos. These videos show a typical workflow during the game and give you a quick overview about the main features.

2.1 The Triangle game

The game consists of 21 fields arranged in a triangular shape (see Fig. 1). Each hexagonal field is linked to a multiple-choice question. The player wins a field if he or she asks for the question linked to the field and gives a correct answer. The answers are graded automatically without assistance of a teacher or referee and without looking for the correct answer in an answer sheet. After an incidental incorrect answer, the other player has a possibility to win this field. If a field remains unanswered, it can be randomly assigned to one of the players.

The goal is to win fields which connect all three sides of the triangle. An important feature of the game is that the winning strategy does not include only a mathematical knowledge but also a careful choice of questions.

Video: https://youtu.be/B5L0tzuZTqY

2.2 The Jeopardy game

The Jeopardy game consists of 12 questions divided into four different categories (see Fig. 2). There are three questions of different difficulty in each category. The values of questions differ according to their difficulty – 100, 200 and 300 points. The players choose questions and by giving the answers they either win or lose the value of the question. The game finishes when all 12 questions are answered.

Like in the Triangle game, the questions are multiple-choice questions and the answers are graded without participation of a teacher.
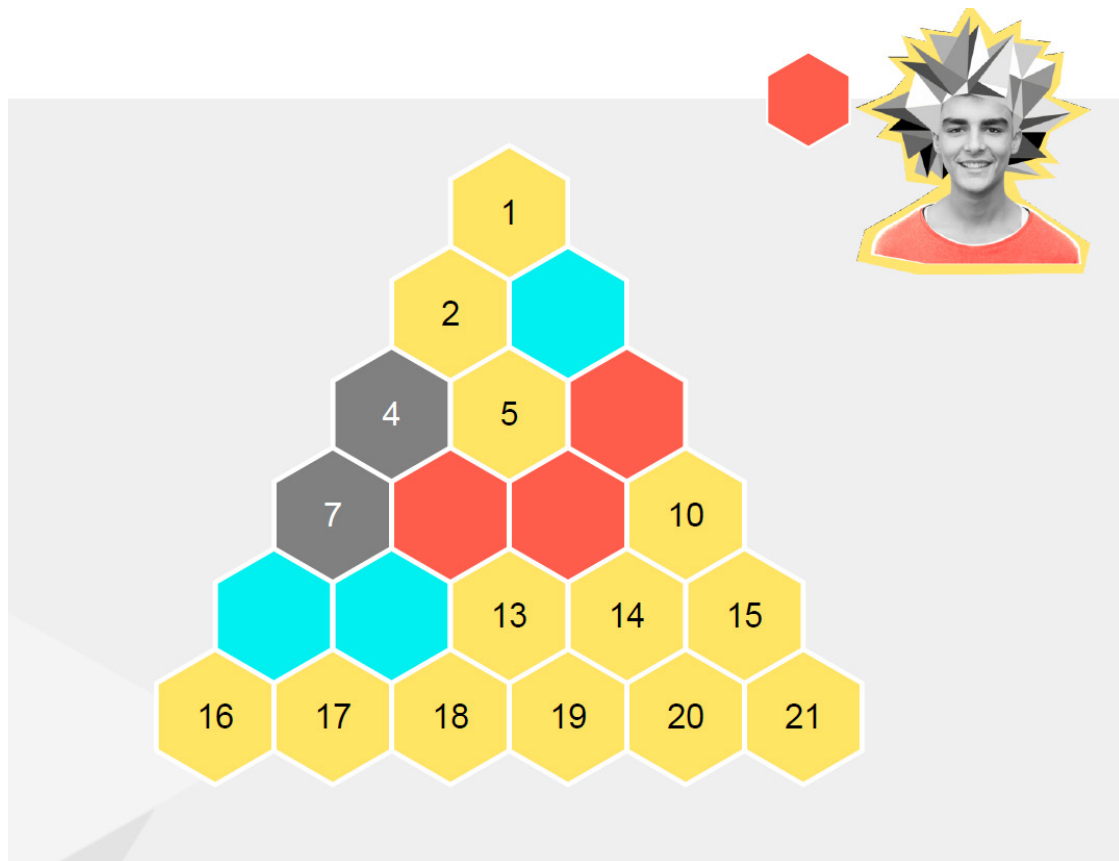
Video: https://youtu.be/CshXIx2D5NA

Figure 1. Triangle game

3   BENEFITS FOR TEACHERS AND STUDENTS

The interactive Triangle and Jeopardy games have many benefits for teachers and students. Let us highlight some of them:

- Materials cover thematically all secondary school curriculum.

- All types of games have uniform and simple controls and attractive graphics.

- Thanks to the use of the TeX typesetting system, the mathematical expressions reach high typographic quality and are easily readable.

- All the materials can be accessed with free software (Adobe Reader) and used offline with no Internet access.

- The evaluation (the number of correct answers etc.) is shown after finishing the game. A student can go through all the questions again and revise the answers.

- The Triangle game never turns into the same competition. The file includes a database of questions which exceeds the number of the fields. These questions are assigned randomly to the fields on board when the game is opened. Consequently, the same group of students can

repeatedly work with the same game without fear of repeating questions. Not only the questions, but also the order of the answers is randomized.

- The questions for the Jeopardy game are fixed but the order of the answers is randomized each time when the game starts.

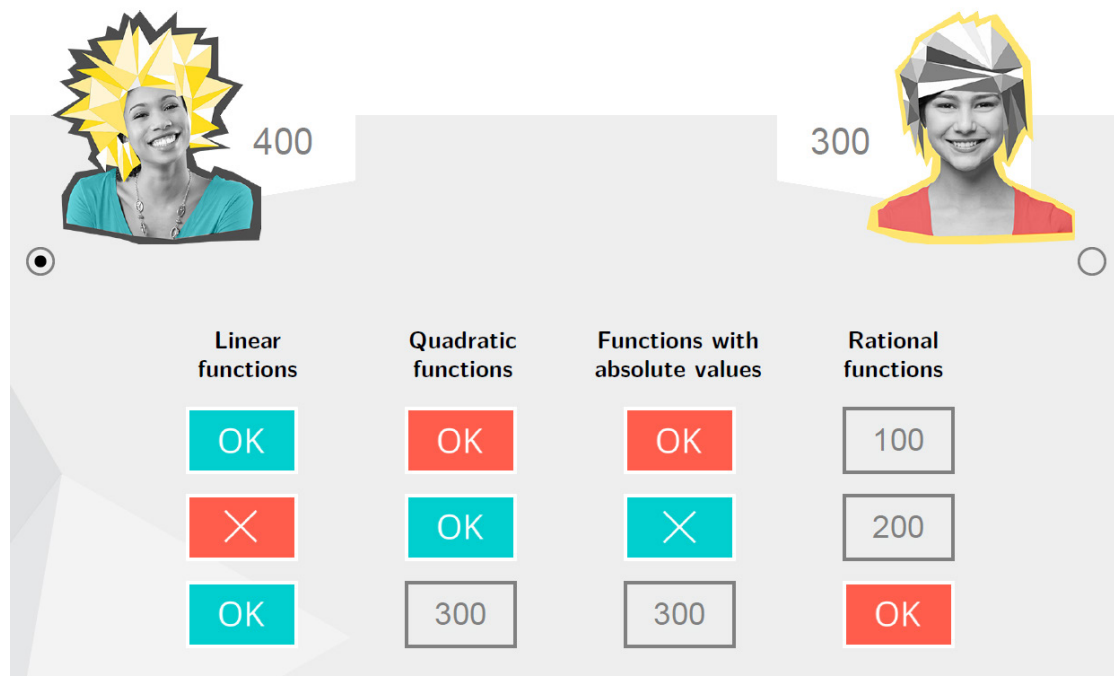- All these games are free to download on the STEM4youth project website.

Figure 2. Jeopardy game

4   SHORT USER'S GUIDE

Using the games in the class does not differ from a typical slideshow presentation. Teachers can present the games on an interactive whiteboard or use data projector and screen. In the first case, the whiteboard turns into a playing area and the students can directly mark their answers. An alternative is to use a computer or laptop and present the materials using a screen and data projector. In this case, the students answer questions and either the teacher or referee mark their answers on computer. Since the game can be controlled just by a mouse, a wireless mouse turns into a valuable assistant.

The materials are good for home practice too. Thanks to the interactivity and catchy graphics, the practice is funnier than a regular homework or exercises. The fact that the learning mathematics may take the form of interesting competition also motivates the students to learn together with their classmates. This could lead to another benefit of the materials, since this approach does not only enhance skills of weak students but has a benefit also for good students. These good students explain the answers to their classmates and learn to formulate their ideas and knowledge clearly and in an understandable form.

Running the game does not need any extra effort from the players or referees. The file opens in the Adobe Reader (see also hereinafter). The operator selects the faces for the players or teams and starts the game by clicking a start button. After this, he or she selects questions and marks the answers. The time to find the correct answer is not limited in the games, since it may vary according to the user preferences. Anyway, a suitable external device or smartphone application can be used to limit the time for each question. Intended or unintended changes of the active page are blocked when the active question is displayed. This prevents cheating as well as unintended skips to another place in the game.

5 UNDER THE HOOD

Each game is a single PDF file. This simplifies the distribution and utilization of the games. Thanks to the PDF format, there is only a minor system requirement to run the games: the installation of Adobe Reader. This requirement can be satisfied easily on any common IT platform.
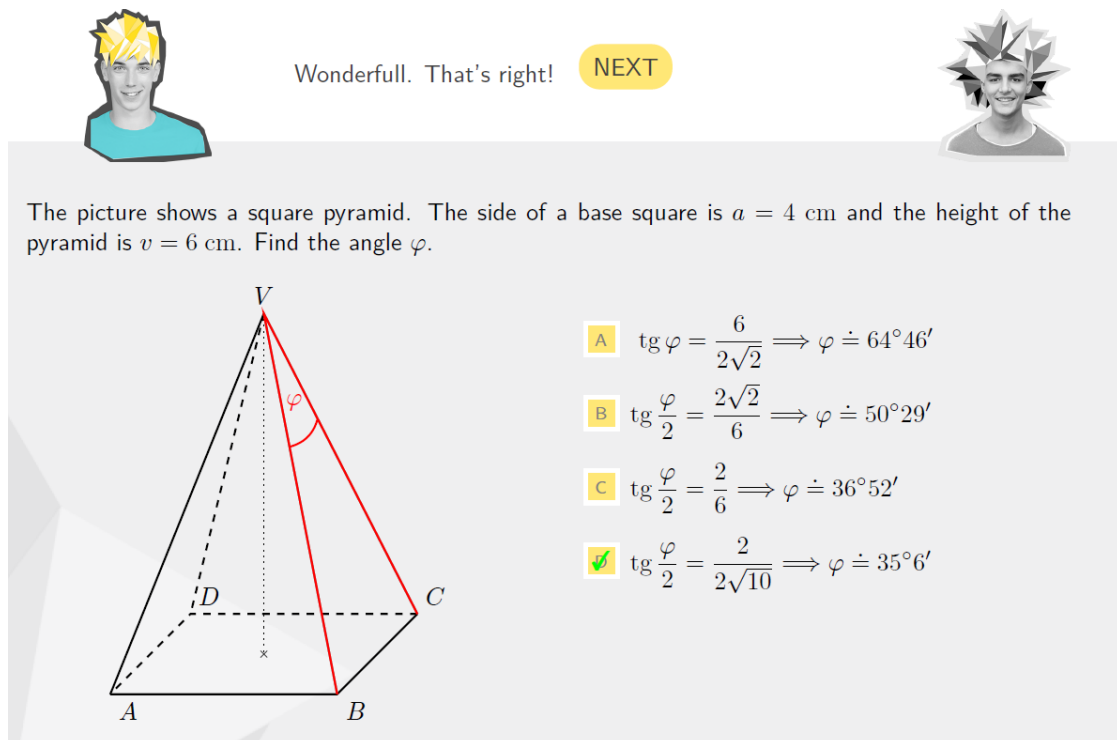
Since the games are just ordinary PDF files, one file per game, the user may easily copy and redistribute the files. The user may also utilize the directory structure in his or her operating system and sort the materials according to his or her needs. The name of each file/game can be also changed arbitrarily. Thus, prefixing the name may be used for sorting purposes.

The PDF format allows to enjoy the high-quality vector graphics, professional typography for both, plain text and mathematical expressions and perfect positioning of any element on the page. This results in catchy outputs with professional look. Finally, the PDF specification includes interactive JavaScripts and layers with controllable visibility. This allows to build interactive materials which have full usability even without Internet access.

The tools used to prepare the electronic form of the games were
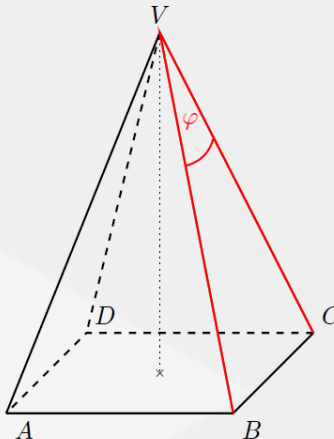
- pdfLaTeX [6],
- AcroTeX eDucation bundle [7],
- Custom macros to enhance pdfLaTeX and AcroTeX,

that are briefly introduced below. Description of JavaScripts and layers can be found in the article Math Games for One Player [8].

The picture shows a square pyramid. The side of a base square is $a = 4$ cm and the height of the pyramid is $v = 6$ cm. Find the angle φ.

A. $\operatorname{tg}\varphi = \dfrac{6}{2\sqrt{2}} \implies \varphi \doteq 64°46'$

B. $\operatorname{tg}\dfrac{\varphi}{2} = \dfrac{2\sqrt{2}}{6} \implies \varphi \doteq 50°29'$

C. $\operatorname{tg}\dfrac{\varphi}{2} = \dfrac{2}{6} \implies \varphi \doteq 36°52'$

✓ $\operatorname{tg}\dfrac{\varphi}{2} = \dfrac{2}{2\sqrt{10}} \implies \varphi \doteq 35°6'$

Figure 3. Sample question from the Jeopardy game

5.1 pdfLaTeX

The essential authoring tool for the games is the pdfLaTeX typesetting system. This tool is a member of the family of programs built on the top of TeX typesetting system. TeX has been written in 1978 as a software which allows to typeset mathematical publications. In a modern terminology, the TeX language can be described as a text markup language focused on typography and mathematical expressions. Since it is highly customizable and allows to write custom macros, TeX is often viewed as a programming language. Despite its age, the TeX language appears till now as the only viable method how to write mathematical expressions effectively. For this reason, it is used by professionals worldwide. The typical workflow is slightly different from typical word processor, but still simple and

straightforward. Really, when the document author prepares the text, he or she does not see the mathematical expressions as they appear in the final form, but describes (using commands and special formatting marks) the structure of the expression. The final appearance of the document is created by the postprocessor. The postprocessing of the input text and formatting the output took minutes when TeX has been created in early 80's, but takes only a fraction of second today.

Since TeX is a kind of a special program language, various extensions are possible and therefore many extensions appeared till now. One of the most widely accepted extension is the LaTeX typesetting system which is nowadays a standard in academic publishing among mathematicians. A modification which writes the output as the PDF file is pdfLaTeX. This software can be used for free and has many advantages compared to the mainstream commercial or open source word processors.

There is no other software available which can be compared with TeX and LaTeX regarding the quality of the output of mathematical expressions. No doubt that this is caused by the fact that TeX has been designed by a mathematician and an excellent programmer to write mathematical publications.

The fact that the LaTeX files are plain text files allowed to utilize the potential of text manipulation programs, such as version control systems, search and replace regular expressions across multiple files and other high-level utilities which are invaluable in programming tasks. This approach allows the simultaneous work of several members of the team without the fear of collision, loose of changes or data damage. More specifically, we used *Mercurial* for version control and file sharing, *aspell* as a spellchecker, *grep* for regular expression search and *sed* for search and replace in a single file or multiple files.

Further, the fact that LaTeX is a programming language opens the door for custom extensions. These extensions allow us to simplify repeated tasks and solve even complex tasks using predefined commands. The extensions are usually distributed as bundles of commands and procedures. One of the essential bundles is described below.

5.2 AcroTeX eDucation bundle

AcroTeX eDucation bundle was written by D. P. Story to enjoy the full features of the PDF format, such as document level JavaScripts, PDF forms, buttons and checkboxes. Really, each game is in fact an elaborated PDF form which is written across multiple pages and has an ingenious method of navigating between pages and hiding or unhiding objects on the page. The AcroTeX eDucation bundle is designed to prepare the interactive quizzes and it was the first attempt to bring the world of interactive PDF to the mathematics education. The AcroTeX homepage [7] contains a comprehensive showcase of the bundle capabilities. The ideas introduced in AcroTeX form the core of the functionality of our games. However, after a short time period it turned out that the AcroTeX alone is not sufficient for our purposes and it will be necessary to extend the capabilities of AcroTeX as we describe in the next paragraphs.

5.3 Custom macros

The work on the database of questions started as writing a bunch of files (one file per question) based on a common template in AcroTeX notation. However, for customizing and tweaking purposes we soon realized that it is fruitful to add an additional layer between our text input and AcroTeX commands. Thus, we created macros which (from the point of view of the user typing on keyboard) simply mark the start and the end of the question and an envelope for each possible answer in multiple-choice question. This was optionally accompanied by one or few more commands which influenced the formatting such as the position of the answers with respect to the question or the position of a picture included in the question and the surrounding text. This approach turned out to be very flexible and allowed to influence all the questions simultaneously by editing the commands in this new layer. A similar approach has been used to draw images: new layer on the top of drawing capabilities guarantees fast drawing of the images and their uniform look. Among others, since the images are coded directly inside the questions and no external program is required to edit the images, the process of fixing potential errors is simple and fast.

Originally, we supposed to write the educational games on the top of AcroTeX eDucation bundle. Unfortunately, this approach appeared to be insufficient. Among other, the methods used in AcroTeX do not allow the possibility to change the order of possible answers for each question. Therefore, it was necessary to rewrite almost all the internals of AcroTeX from scratch. Further, the PDF files

created by the original AcroTeX contain some JavaScripts which are today considered as insecure and some email clients, such as Gmail, block these PDF files and do not allow to send the PDF files as an attachment. This was an important drawback which would prevent the impact and spreading of our materials. Therefore, we fixed the corresponding parts and removed the code which could be used to compromise the resulting PDF file.

The unique fact that the text can be written together with typographic marks speeds up the typing of math formulae. For a skilled writer this presents an important feature. The fact that the text must be postprocessed to check the final output is a minor disadvantage. Really, the computers are so fast nowadays that the delay between the text input and preview of the final document is a fraction of second. Thus, the advantage of WYSIWYG text processors was lost, and all the advantages of text batch processing (such as version control and fast input of mathematical formulae) remain.

6   SUMMARY

The authors of the article created a comprehensive set of teaching materials which can be used to make math classes more attractive. These materials are designed as educational games and can be smoothly included to the classes. The programing approach to create text documents may appear to be ineffective and uncomfortable. However, the opposite is true. We described the tools available to create these PDF games and emphasized the advantages from utilizing these tools rather than classical approach based on writing texts on WYSIWYG word processors.

ACKNOWLEDGEMENTS

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