DIDACTIC GAME "POSSSIBLE CROSS SECTIONS"

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Abstract. The present article introduces the game "Possible Cross Sections", applicable to education on solid geometry. The idea of the game is to guess whether a figure could be a cross section of a particular solid. It is assumed that using a research approach the student would test his or her hypothesis and come to certain conclusions. The rules of the game and the didactic material can be modified and adapted according to the interests and abilities of the students and the goals, set by the teacher. A research version of the game is also on offer, in which students could enrich the didactic material in the form of a multidisciplinary project.

Keywords: game; mathematics; education; active method; game approach

1. Introduction

The modern world is highly dependent on technology, but together with the amenities it provides, the purely consumerist attitude of people of all ages to them. The common students in the 21st century are convinced that they do not need to study certain educational material since they can "find it on the Internet". The decline in interest and the low student achievements in the last twenty years has been diagnosed in a number of national and international studies. The analysis, presented by Rocard, shows that students are losing interest and desire to study mathematics and science. The report emphasizes the need for active research methods into education (Rocard, 2007). Studies, conducted by PISA (OECD, 2019), also show poor results in mathematics. Although the decline for Bulgarian students, reported in 2006, has been overcome, the results are still lower than the average. In addition, the number of students with the lowest scores (below the second level) is increasing, while the share of those with the highest levels remains almost the same.

The elements of solid geometry, on the other hand, are traditionally difficult for students. Spatial imagination and the ability to look at a particular solid from a different perspective and, accordingly, to operate with a plane drawing, are skills that very few students possess. Analytical and synthetic thinking skills are moved onto a higher level and this makes it very difficult for students. On the other hand, these skills have a strong applicable meaning.

Modern technology offers different capabilities for modeling three-dimensional objects. Software like GeoGebra, for example, has not only 3D modeling capabilities, but also a smartphone application that can be used to view 3D models with augmented reality. In modern education, it is difficult to afford not to take advantage of these opportunities, but we must not give up real models, which are inherently easier to be accepted by students. The best solution is to apply a variety of options for both visualization and modeling.

In this article, we will introduce a game that is applicable within the mathematics classes in 10th grade. It could also be used in extreme tasks in solid geometry - grade 12. The game is aimed at developing students' spatial imagination. The technology and materials for realizing the game are accessible to all and the time for it is not long, which allows it to be implemented in education. In addition to the user-friendly ability to apply the game, the article also offers another perspective – a research version. In this case, students are required to enrich the offered material with the help of mathematical reasoning and the use of dynamic models.

Didactic game "Possible cross sections"

User-friendly version

The idea of the above-presented game is for students to be able to guess whether a figure could be a cross section of a particular solid. The game assumes that the students will use their research approach to test their hypothesis.

Required materials:

– models of objects (pyramids, prisms, parallelepipeds, etc.), made out of material that fixates the bodies only at their edges;

– cardboard figures – most of them should be possible sections of the given bodies with parallel, inclined, and perpendicular planes. In these figures, it is necessary to cut the tips slightly, depending on the material, with which the objects are modeled, in order to allow the "cross sections" to fit into the three-dimensional models.

1. Each team has one object (cube, pyramid, etc.). Objects are distributed on a lottery basis between teams.
2. There are cardboard pieces on the table.
3. A team member selects a figure that could be an cross section of the body with a plane.
4. They show the other team members how the split plane must fit in order to get exactly this figure by placing the cardboard in the appropriate place in the object. It may be possible show several options.
5. If this can really be done, the team keeps the figure. If they make a mistake, they returns the figure, losing the right to one move by doing so.

   The team with the most figures wins.

In addition to play, the given material can also be used in lessons for new knowledge and for exercise in order to illustrate specific situations.

This game stimulates the students' spatial imagination and their ability to raise and test hypotheses. In the case of a wrong assumption, it is appropriate to have a conversation by commenting on what is missing from the selected figure so that it can truly be a cross section.

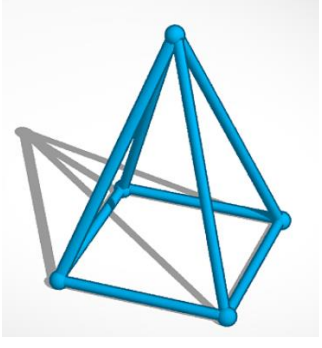

Figure 1. Model of a pyramid

The models can be made in a different manner – with sticks and modelling clay, from wood or through 3D printing (Fig. 3), depending on the capabilities and the didactic goals of the teacher. The model, presented in fig. 2 is appropriate for printing and is created within the spectrum of *the Information and Communication Technology within Science, Education, and Security project.*

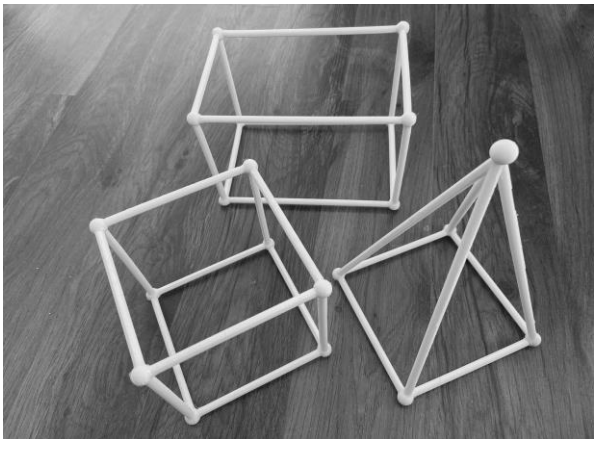

Figure 2. 3D-printed models

It would be appropriate for the teacher to have at least a model of a cube, a parallelepiped, a pyramid and at least 20-30 different cardboard figures. At a later stage, students can enrich the kit themselves.

Cardboard figures are good for containing distractors. When working with unmotivated students, these distractors may be weak – there should be particularly large, circular, and other cards. The idea is that when choosing a wrong figure, a heuristic conversation can take place, in which the student will come to the conclusion that the selected figure is not appropriate. When working with prepared and motivated students, these distractors should be stronger, focusing primarily on form and reasoning in order to concentrate on the number of cross sections and the cross section angle.

Research version

The presented game can have many more didactic possibilities. Students may be asked to enrich the material by creating their own object models and correspondingly select appropriate shapes to complement the cardboard figures with possible cross sections. This task can be designed as a multidisciplinary project. Its complexity may vary depending on the interests of the students and the capabilities of the school. It may affect:

– 3D modeling by using an accessible and lightweight platform such as Tinkercad (https://www.tinkercad.com/). Here, students will be able to easily create their own online models that can be printed out with a 3D printer. Unfortunately, not many schools have such a printer. The problem can be solved by using a relatively inexpensive 3D model printing service, offered by a number of companies.

– An alternative to 3D printing is the creation of models with readily available materials – sticks, spikes, pencils, modelling clay or metal (Velcheva, 2018), in which case it is appropriate to use Technology and Entrepreneurship classes and to cooperate with older and younger students.

– Finding the right cross sections and preparing them for printing. This task can be fulfilled entirely through mathematical calculations, but in order to facilitate the students' work, a research approach can be applied and a dynamic model can be created in software such as GeoGebra. In it, with the help of a model, created through 3D printing or readily available materials, and a selection of various planes, students will easily be able to choose interesting cross sections. Example in Fig. 2. Accomplishing the task in this way will also prepare students for the implementation of a research approach that can be used in Extreme Tasks in Stereometry, grade 12.

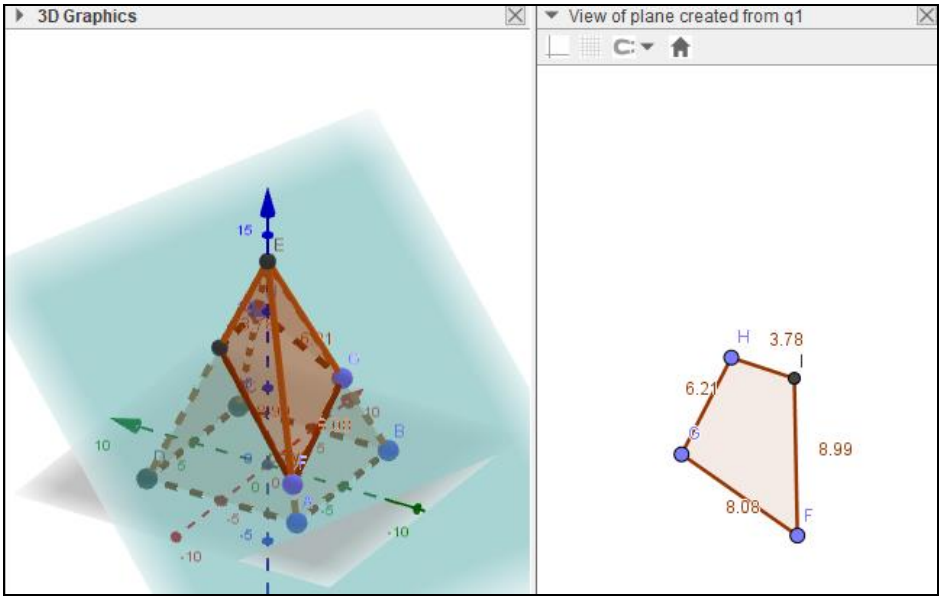

Figure 3. Selection of cross sections

Place in education of "Possible intersections"

We can view the given material both as a visual tool and as a game. We can generally call it an educational toy that can increase the motivation and interest in mathematics (Pavlova, 2017). The game takes place mainly in grade 10, but younger students may be provoked to play it. There are a number of attempts in mathematical education to introduce games to the classical teaching methods. Stariradeva offers a detailed overview of the possibilities for the application of gamified education in mathematics classes in her dissertation "Game Computer Models in Modern Learning" (Stariradeva, 2018).

According to Trybus, gamified education refers to the application of certain game principles in real life situations for participants (Trybus 2015). This definition can be useful in solving cases and applying research and project methods by applying role-playing games. This approach is fruitful, but it requires a lot of study time and serious preparation. In this aspect, the game "Possible intersections" concerns a purely mathematical model and is not tied to a real-life situation.

Another important aspect is the game type – whether it's a video game, a board game or a purely didactic one. It is important for each type of game how exactly it can be used for educational purposes. In order to receive truly effective and motivating education, the teacher must have a number of competencies. In (Stariradeva, Marinova 2015), an analysis of the digital competences of the modern teacher has

been made. It is the good handling of modern technologies and the knowledge of the psychological features of the newer generation that is the key to the successful application of video games in mathematical education. Based on this analysis, the Possible Cross Sections game, in its research version, requires the mathematics teacher to be trained in working with dynamic mathematical software and to have 3D modeling skills with specific software.

Polshikova offers a classification that divides games into business, travel, competition, and role-playing, dividing business into study and research (Polshikova, 2005). Applying this classification, the game "Possible Cross Sections" falls into the business group, but in its didactic value it could be classified as education and research.

According to Kovalenko's classification, the game is an artificial, result-driven didactic game (Kovalenko, 1990).

In this article, we look at the didactic educational game as a support tool for traditional mathematics teaching. Research (Ke, Xie, K. & Xie, 2016) shows that the cognitive power of play with a duration of 17 minutes is strongest in the first 7 minutes and then the application of knowledge increases. Using these results, we would recommend that the proposed user-friendly version of the game be 10-20 minutes long. For its part, the research version is project-based and requires significantly more time, in mathematics, information technology, and entrepreneurship classes, as well as in the form of homework.

The rules of the game, as well as the didactic material itself, can be modified and adapted for different types of students – weak, unmotivated, bilinguals with difficulty in using the official language, but can also be used with students with a strong interest in mathematics. The games were tested in the framework of project No. 2019-1-PL01-KA201-065002: Game based learning for the development of problem solving skills.

Conclusion

The presented game is easy to implement and it aims to develop both spatial imagination and a range of mathematical knowledge, skills, and competences. Through the game-based approach, we aim to increase students' interest and overall attitude toward mathematics. The implementation of gamified education is possible in different types of lessons, but is most appropriate in exercise lessons. It should be remembered that if theoretical knowledge is not mastered, it will not be possible for them to be consciously applied in practical tasks, even in the form of play.

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