The Logifaces Methodology

The Logifaces game consists of blocks constituting prisms with a triangular top and base and different heights at the corners. This leads to various slopes and areas of the sides of each block. The goal of the game is to form shapes with a continuous top surface. To create this, blocks with a similar side surface have to be selected and arranged accordingly. In the section on the Logifaces methodology the design and structure of the game will be explained in more detail. There is a broad variety of activities possible with Logifaces, which offer challenges with a wide range of difficulty. This wide range provides fun activities that are suitable for many age groups.

THE LOGIFACES GAME

Two different Logifaces sets were used in the exercise book including either nine or 16 elements. The elements are called blocks or pieces depending on the context of the exercise. The blocks are geometrical objects with equilateral triangles as bases and the heights of the corners can vary. This results in block sides with different slopes and area sizes, so called triangular based prisms and truncated prisms. In total, there are eleven different shapes. With each of the sets, as well by combining the sets to use 25 pieces, it is possible to create a larger equilateral triangle as a triangular tessellation with a continuous top surface. Figure 5 shows some of the Logifaces blocks and how they can form a continuous surface. Pieces have three height levels and should be assembled to form a continuous surface.

a) *b)*

Figure 5: *(a) Logifaces blocks assembled incorrectly to form a non-continuous surface (b) Logifaces blocks assembled correctly to form a continuous surface*

There are two solutions for solving the triangle with nine pieces, 22 solutions with 16 blocks, but 4942 solutions with 25 blocks. This seemingly simple task provides logical and creative challenges that can be used in a variety of exercises during maths classes, e.g. problem solving activities or relaxing the atmosphere of the lesson through an entertaining game. The broad variety of possible activities provides challenges with a wide range of difficulty level, as mentioned in [26]. Patterns play a significant role in early childhood education. With Logifaces, students can engage with patterns in at least three different dimensions, as listed in[27]:

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26 Erasmus+ 2019-1-HU01-KA201-061272

27 K. J. Carbonneau, S.C. Marley, J. P. Selig, (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. Journal of Educational Psychology, 105(2), 380.

- Structure: for example, prisms and truncated prisms
- Content: with their different materials, shapes and colours,
- and Complexity.

The connection of Logifaces to art is not restricted to the creation of patterns. Just like photographs consist of squared pixels as the smallest unit, three-dimensional models consist of triangles, since a triangle is the smallest possible way to represent a plane. A plane can also be called a face. This was the inspiration for its name and implies the idea of using Logifaces as the smallest unit to create three-dimensional artworks. Geometric abstraction also plays a role in art, in fine arts as well as in cultural arts and applied arts. The prime example of this is Cubism, which revolutionised the fine arts, painting and sculpture, in the early 20th century. It also influenced other movements in art and architecture that followed, like abstract art, futurism, suprematism, constructivism, De Stijl and Art Deco, just to name a few.

EXERCISES FOR ALMOST ALL OCCASIONS

An approach that reaches beyond the boundaries in the classroom is not only useful but also necessary, according to the European Union and many experts in the field. An interdisciplinary approach help foster key competencies and furthermore: we simply do not know the challenges students will face in the future, so we have to try to prepare them for anything.

Preliminary literature research was carried out in November 2019. This was used to create an overview about what to expect, which topics could be covered and which methods can be used in the Logifaces project. An interview was conducted with the developer of the game to understand its possible value for education and the features that could be used by teachers. To identify methods and collect data from multiple schools and at various events, we investigated how the Logifaces game was already being used by some teachers. Teachers entered their ideas for possible exercises in a spreadsheet table, which was created based on the gathered information. This table was later very helpful when constructing the content of our measurement tools.

The following data collection measurement tools were identified. Firstly we developed a questionnaire to be used after teaching with Logifaces in class (or at festivals if possible). Secondly interview questions were written for a survey with the possibility of giving open answers to determine multiple ways of using the game in multiple subjects. We will discuss the relevant findings later on. Thirdly we planned to observe classes, which was made impossible by the global Covid-19 pandemic.

The literature review was later refined towards a wider variety of topics and a more detailed picture. The research fields were manipulatives, problem solving, teacher beliefs, open learning, geometry, and methods in the teaching subjects of art, physics, mathematics and information technology. We found a great many studies and collated them. Though the literature review is an on-going process, the basis was defined at the time and is only updated

whenever new research is found to be useful. With this in mind, many teachers created exercises to use Logifaces in their lessons. Here is one example of a lesson that took place in ninth grade in Vienna.

In a 9th grade (±14 year old pupils) computer science class the teacher used Logifaces in an interesting way. The task was to use Excel to write a program that checks whether two Logifaces blocks fit together or not. It was conducted in pair work or in small groups of three. Each student could use a computer, had access to the Internet for research and each group received a Logifaces set (16 pieces). The classes were held twice, one double lesson each (2x50 minutes) with a total of 41 students participating in the educational experiment. There were always two teachers present during the lessons.

Here are some of the things the students said:

> *The good thing was that you had to think for yourself before working.*
>
> *You learn exactly the things you need to solve the problem - otherwise we would probably not have learned these things.*
>
> *It's fun to experiment with the stones and the program - and you can also check if the program is correct.*
>
> *It's good that you can think for yourself and have time to think.*
>
> *It is good that there are several solutions and that you do not have to look for only one solution.*

USING LOGIFACES FOR ONLINE AND HYBRID TEACHING

Online and hybrid teaching gained importance during the Covid-19 pandemic. However, Logifaces blocks are physical manipulatives and, therefore, using them in online or in hybrid teaching situations is challenging. Students would need a locally available set of blocks to be able to participate. However, virtual manipulatives and emerging technologies, such as Augmented Reality and 3D printing, can help with the transition between virtual and physical worlds.

3D modelling and printing has the potential to help develop and train STEAM skills in students and help teachers in their lessons and teaching process. In addition to skill development for the students' later careers, it is not only valuable to understand this technology but it also supports the development of skills. In particular, skills that can be used for educational purposes and can provide teachers with tools to motivate students to consider career paths in STEAM education. Using 3D modelling and printing, three dimensional thinking, problem solving competencies and more skills can be developed in STEAM classes, such as an understanding of the connection between the virtual and physical worlds as well as between 2D and 3D representations. 3D modelling and printing can therefore open up new possibilities to teaching these skills and help transport concepts from, for example, mathematics[28]. The

28 D. Lieban, M. Barreto, S. Reichenberger and Z. Lavicza. (2018). Developing Mathematical and Technological Competencies of Students Through Remodeling Games and Puzzles. In Bridges 2018 proceedings. http://archive.bridgesmathart.org/2018/bridges2018-379.pdf.

GeoGebra app was created to help the creation of a personalised Logifaces block for printing. Some pieces were created and tested. This GeoGebra resource may represent a basis for activities in schools. Logifaces pieces using GeoGebra: this GeoGebra resource contains the information and tools of the workshop https://www.geogebra.org/classic/ymmmehdf.

The free GeoGebra platform, which was mentioned briefly above, allows the creation of maths-based applets for creating graphs, investigating geometrical objects, using algebra and more purposes such as 3D modelling. 3D models can be downloaded in a 3D printable format meaning a GeoGebra applet can be used to create exercises and support activities. One example of an activity inspired by the Logifaces game is the creation of personalised prism-based blocks. Such blocks can either be created by using an applet developed by the authors, where each side can be manipulated by a student, as can be seen in Figure 6.

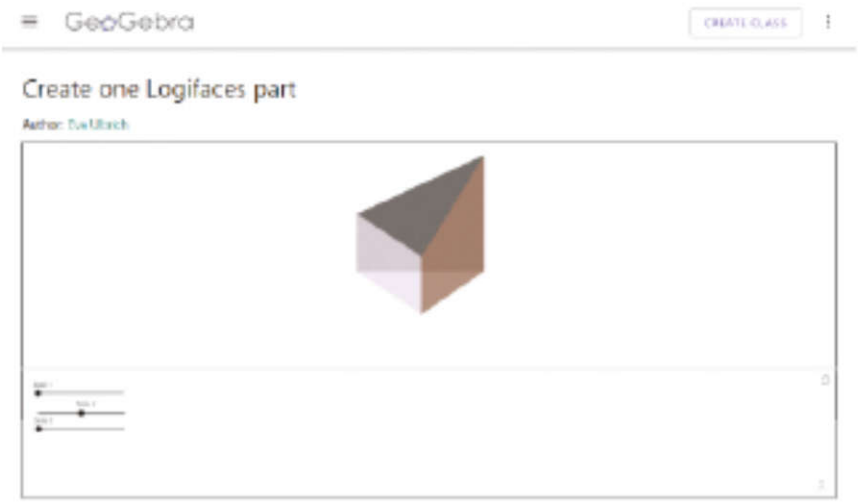

Figure 6: *Creating one Logifaces block with two sides set to low and one side set to medium height*

For more complexity and more advanced training of mathematical skills and computational thinking the GeoGebra functionality can be used in the classic version of Logifaces. For example by drawing a polygon and extruding it to 3D. The created block with features also used in Logifaces can then be downloaded and used to introduce students to 3D printing.

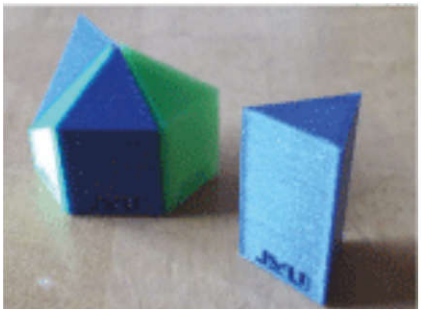

Figure 7:
Example blocks similar to Logifaces created by the applet in and downloaded from the GeoGebra and 3D printed using the Fused Filament Fabrication technology

A workshop concept was created to develop maths, art, and social skills using Logifaces. The aforementioned skills described by the European Council and the motivation created and the exercise possibilities using the Logifaces game can be combined into this workshop idea. Initially, students are asked to imagine and draw the side areas with the triangle corners at different heights. Later, the students can play with the GeoGebra applet, which allows the Logifaces-like blocks to be freely rotated. Then they are asked to investigate how setting the sides to the heights they thought of before changes the surface of the other sides of the prism.

A shape is presented to the students that has to be filled with blocks to create a continuous top surface. The students are asked to find out which blocks fill this shape. Next, they are asked to create prism blocks themselves and to download them for production. They can either use features of the GeoGebra tool by themselves constructing their previously drawn block or by creating a version of their block using the applet. Now, the students are asked to load their prisms to a 3D printer to produce their solutions and put them to the test. This step can take some time so we recommend that only small blocks be produced. High blocks should be turned to one of the side surfaces to avoid knocking them over during production and to have them finished at the same time to avoid unnecessary waiting time. Additionally, the students can find other shapes that could be formed by their solution.

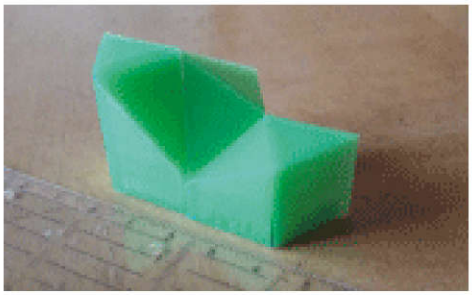

Figure 8:
Example printouts with a ruler showing blocks with a maximum height of 3 cm

Skills in mathematics, digital and technology based competencies, as well as communication and cultural awareness and expression can be taught through these steps. The students may also be able to use the produced manipulatives for other exercises revolving Logifaces, for example, by combining the mathematical activities with art, such as adding drawings to the shapes produced with Logifaces.

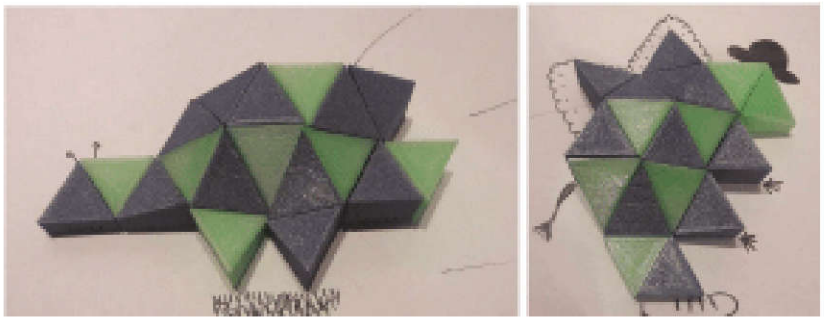

Figure 9: *Logifaces blocks arranged into various shapes and decorated with drawings*

Furthermore, the skills gained can be used for a follow up workshop where students are asked to develop their own mathematical puzzles, such as printable cube puzzles. This follows the European Council's recommendation for the development of competencies that foster entrepreneurship.

THE ROLE OF ART IN THE EXERCISES

Art may also be viewed as a fundamental element in holistic skill development education. In connection with the European Council requirement for European citizens to be able to communicate and be culturally aware, interdisciplinary knowledge about understanding and embracing various cultures also includes art. STEAM fuses the sciences and the arts, combines logical and intuitive thinking and brings together systematic exploration and revealing insights[29]. The STEAM education methods include experimenting, being open to change, improvisation,

29 Colucci-Gray, L., Burnard, P., Gray, D., and Cooke, C. (2019). A critical review of STEAM (Science, technology, engineering, arts, and mathematics). Oxford Research Encyclopedia of Education. https://doi.org/10.1093/acrefore/9780190264093.013.398

and creating freely. The resulting new structures, in turn, aid development and construction of personality[30]. As such, STEAM education can be thought of as a compound way of gaining knowledge. Science and art can be seen as being connected by STEAM education methods – openness to change and creating freely can be trained through art lectures as well as within all other subjects, especially in an interdisciplinary STEAM approach. This, in turn, helps students achieve the European Council skills.

a) *b)* *c)*

Figure 10: *Using Logifaces as inspiration and as a part of artistic projects*

Besides tactile experiences we also investigated integrating whole body movement into Logifaces exercises, based on the following considerations:

1. Whole body experiences are an integral part of learning[31], so by getting involved in whole body movement connected to Logifaces tasks students are able to internalise the quality and structure of the Logifaces pieces and constructions at a deeper level, and so they become more efficient when carrying out other Logifaces tasks, and are able to internalise and connect the knowledge they obtain in any field through engaging with Logifaces.
2. Physical activity has physiological effects (e.g. increasing the supply of oxygen to the brain) and psychological effects (e.g. increasing motivation) that enhance learning[32], so movement may act as a catalyst to reaching the educational objectives of Logifaces tasks.
3. Engaging in an adequate amount of physical activity is crucial for physical and mental health[33], meaning that integrating movement into Logifaces tasks has health benefits for students.

The innovation of Logifaces lies in the fact that it takes the process of digital design from the screen and places it in tactile reality, bridging the gap between immaterial shapes and solid physical reality. Correspondingly, the range of methods embraced by art education has widened to include 3D modelling and digital creation, for example, which means that new interdisciplinary connections are formed.

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30 I. Nahalka (2013). Konstruktivizmus és nevelés. Neveléstudomány 2013/4. http://nevelestudomany.elte.hu/downloads/2013/nevelestudomany_2013_4_21-33.pdf

31 M. Johnson. (1991). Knowing through the body, Philosophical Psychology, 4:1, 3-18, DOI: 10.1080/09515089108573009

32 C. Bedard, L. St John, E. Bremer, G. Jeffre, J Cairney (2019). A systematic review and meta-analysis on the effects of physically active classrooms on educational and enjoyment outcomes in school age children. PLoS One, 14(6), DOI: https://doi.org/10.1371/journal.pone.0218633

33 V. Beserra, M. Nussbaum, M. Navarrete, D. Alvares. (2021). Teaching through dance: An opportunity to introduce physically active academic lessons, Teaching and Teacher Education, 106 / 2021, DOI: https://doi.org/10.1016/j.tate.2021.103450