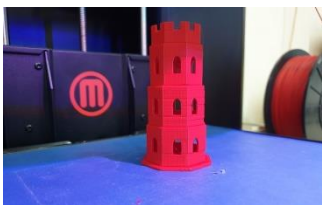


Integrating 3D printing into educational subjects to increase students motivation and creativity

Introduction

Biomimicry is a simulation of models, systems and elements found in nature in order to solve various non-standard manufacturing problems. In the fields of architecture and production, biomimics include the design of buildings and products that mimic nature's processes. It is a very modern solution to economic problems that will be developed in the future and will change many production processes. Biomimics develops new design thinking and is very important in the younger generations education process.

Pupils who learn about biomimic and their application options will be able to explore nature's models and will have the opportunity to create new nature inspired products, and structures with the engineering mindset. The methodological description includes also a lot of additional material to help students in the engineering and design processes to creatively fulfill their ideas in practice. The tasks are presented from the simplest to the more complex, learning something new at each stage. I posted the expected time to complete the tasks for my students but it is according to the individual's ability. The number of tasks is submitted for one schooling approximately 1 hour per week in the Tinkercad environment at about 36



academic hours a school year (time printing of the models is not included). All these works I carried out during one school year with 6 and 7 grade students during the non-scheduled classes. All students just have started learning how to use the

Tinkercad platform. I dedicated our first sessions to create an account for each student and to explain the basic printing technology. These skills are acquired while working, so, the theoretical part was alternated with the practical. The work focused

on practical use, ideas offered by students and other teachers. More talented students had the opportunity to perform more complex tasks, such as boxes with a lid, glasses and workroom modeling. In the photo we see the Gediminas Castle model, which was part of the Erasmus + project Life Is Math Around US.

Learning goals are:

- to analyze various symmetries in nature, understand their structure, and be able to represent practical models;
- to get to know the fractals, to be able to recognize them in nature, to explore and simulate them using 3D printing.
- to practise modeling and calculating in analyzing nature inspired patterns;
- to teach how to find ways to analyze nature's models and solve upcoming problems.
- Create and analyze prototypes.

This method can be implemented in small groups of students. Students can also work remotely. Students are encouraged to collaborate with each other using an online tool approved by your school, such as Zoom.

Stages of 3D technologies (additive manufacturing)

1. In the first stage of the manufacturing processes a digital model is created. For this purpose it is using CAD simulation. There are a lot of CAD programs that are complex for industrial modelling, Solidworks, Autodesk Fusion 360, SketchUp and tinkercad which is simple for beginners and teaching in schools. Tinkercad.com platform is very acceptable as it is online, simple and free. The platform has teacher access and educational materials. It has video tutorials and a large library. Students and teachers need to create their own access, a

teacher can register as an educator and get access for his students. This provides an opportunity to coordinate class work. Teachers can use some lesson plans <https://lessonplan.prd.tinkercad.com/assets/2021-06-18T20/2edec7e3.pdf>

2. A model in STL format. In this stage, the model is converted into STL (stereolithography) format. Also, it is possible to download stl files from internet storage such as Pinshape, GrabCAD or Thingiverse. Some of those models are for free, others - you have to pay for in the platform <https://www.thingiverse.com>. Students enjoy using models and this can be useful for a large complex project.

3. STL Model Analysis and Corrections: This step eliminates any errors in the STL file. Typical errors are missing triangles, unconnected corners and others. Also, the appropriate scaling is determined. With FDM printers, the STL file is imported into a special program (slicer program) where it is converted to G-code. G-code is a numerically controlled programming language understood by 3D printers.

4. Setting up the printing device. At this stage, the device is prepared for printing. It is useful to familiarize yourself with the user manual of Ender printers: <https://manuals.plus/lt/creality/creality-ender-3-3d-printer-manual#axzz7YonW7ga8>

Correct settings and control of the printer are set, the previous product is removed, and the print file and media are loaded. For beginners, I send: https://www.youtube.com/watch?v=_aDdTZLdync or <https://www.youtube.com/watch?v=M8bTi2C67nl> .

It is especially important to set the temperatures correctly depending on the media used. The temperatures are indicated on the packaging box. For more information you can visit <https://www.youtube.com/watch?v=FPumsgvBt00>

5. Printing. The printing is usually done automatically and takes hours or days. It is necessary to check from time to time for errors during printing. A very important moment is the calibration of the device.

<https://www.youtube.com/watch?v=IYmFXrmC5p0>

6. Processing. The final processing of a printed item can vary greatly depending on the printing technology and materials used. In schools, we use materials from which the model can be used immediately after printing. Also in schools, students can polish and paint their models.

I present some tasks which I accomplished working with our student's club in the first 3D learning year. These tasks are uncomplicated and intended from 6th to 8th grade students. After the theoretical introduction about three-dimensional printing and where it can be used, I presented the 3D printing technique and materials that are available in our school. I demonstrated a printing process and explained all technological stages. Students started work from the first steps in the tinkercad environment. The students created their accounts and became acquainted with the main functions. The first task was to create rectangular parallelepipeds in different dimensions. Those parallelepipeds had one or two similar dimensions, for example 2x5x4 and 3x5x5 or 2x5x1 centimetres. When we printed all of them we had a set of rectangular parallelepipeds from which it was possible to design buildings or structures. It was the first evidence that three dimensional printing may be helpful to get the desired toy or model. We have made the simple game constructor. Our collective teamwork was very valuable.

Key chain with the first letter of the student's name.

Subjects/area: engineering, ergonomics, design.

Duration: from 1 to 3 academic hours.

The task: to create a model on the tinkercad platform and get it as a stl file. With the teacher's help, send the file for printing. Print the model.

Pupils' abilities: spatial sense, creativity.

Required tools:

1. A computer with connected 3D printer, installed software and internet connection;
2. Tinkercad environment access for the student.



Students can create key rings in different shapes. The main parts of the pattern are the letter and the ring for fastening. Both of these parts are found in base forms. It teaches how to align two models with a special tool and combine them into one model. Advanced students can be given a chance of making pendants of more complex shapes. My students created pendants with the letter π that were distributed to the students to celebrate what is called international “ π day” at school.

Students save the prepared file in their tinkercad account and download it to their computers as an stl code. Then use the software of the available 3D printer (MakerBot Desktop Software, 3D Slicer or Creality slicer or others). In the beginning, it is advisable for the teacher to do these preparatory works. When using Ender type printers, the file must be saved in gcode format. Markerboot replicator printers read stl files. Pay attention to the type of filament selected and the printing temperature, which is stated on the product box.

Capacity for pencils or other small items.

Subjects/area: engineering, ergonomics.

Duration: from 3 to 5 academic hours. Working time depends on the individual ability of the students and the complexity of the model created.

Task: To create stl file in the tinkercad environment. Send the file to the computer and print model with 3D printer.

Students' abilities: sketching skills, a certain spatial sense, creativity.

Required tools:

1. a computer with a connected 3D printer and installed software and the Internet;
2. tinkercad environment access for the student;
3. drawing notebook;
4. scissors, knife, glue.

At first, students draw sketches on paper. Discuss the shape and size with the teacher. Transfers the models to the tinkercad.com environment and adjusts the dimensions, prepares the media for printing. Students can create containers of various shapes to store pencils and others small items. The simplest model is a roll-shaped pencil case which can be found on the right side of the tinkercad platform. At the beginning, it is suggested to use the shape of a roll or cube and transform it. Save and download the prepared file to your computer with the stl code. Then use the software of the available 3D printer (MakerBot Desktop Software, 3D Slicer or Creality slicer or others). When using Ender type printers, the file must be saved in gcode format. Markerboot replicator printers read stl files.

Modified cube.

Subjects/area: engineering, ergonomics and math.

Duration from 3 to 5 hours.

Task: create 3 cubes for a maths game. Two cubes are identical, the numbers 10, 25, 50, 100, 200, 500 are written on their walls. One cube has arithmetic operations +, +, x, x, -, -. Create stl. file in the tinkercad environment. The working time depends on the students' individual abilities and work skills. In the photo you can see a set of cubes intended for students who study under to the adapted program.

Students' abilities: sketching skills, creativity and certain spatial skills.

Required tools:

1. a computer with a connected 3D printer and installed software and the Internet;
2. tinkercad environment access for the student;
3. drawing notebook;
4. scissors, knife, glue.

At first, students draw sketches on paper. Discuss the numbers and cubes size with the teacher. Transfers the models to the tinkercad.com environment and adjusts the dimensions and prepares the media for printing. The preparation and printing are straightforward. Students can work independently under the supervision of the teacher.

Description of the game:

The essence of the mathematical game is the training of mental calculation and the completing understanding of the rules of multiplication by 10, 25, 50, 100 or 200. 4-6 players can play. They have to write down their answers. 3 dice are rolled: two with numbers and one with arithmetic operations. Players take turns rolling the dice and perform the unfolded arithmetic operation mentally and writing down the

answer. Rolling 10 times in a row. The answers are added up, and whoever rolls the highest sum wins. In the picture you can see several cubes with one "empty" wall. If a player digs out such a wall, he misses his turn.

Students can make cubes for learning a multiplication table or numbers up to 20, which are suitable for students with special needs. In the photo, you can see colored cubes for teaching the multiplication table.

Students can also create number of cubes for learning a foreign language. In this case, the English teacher recommends several sets of English words, which 6 words in each set. The essence of the game is that after rolling 2 or three cubes, you need to come up with an English sentence with these words. It is most interesting to play when there are many different cubes with different words. Then the player simply chooses the cubes themselves and rolls the words. The game is suitable for use during lessons. In the photo you can see one of the cubes for making English sentences.



In the www.tinkercad.com environment, students are taught to insert text into an object, align surfaces with a ruler and a special tool. Students operate with material and holes, learn to rotate, flip, and clone an object. It is a job that requires the skills of working with objects and strategic thinking.

One of the simplest ways to connect two-dimensional images with three-dimensional forms is a conversion of 2D paintings to the 3D objects by some steps:

1. Students draw their design on white paper using black color.
2. Paintings should be bright, fill it with the color without tiny lines and no shadows.

3. Drawings are digitized, saving them in jpg format. Points 1 and 2 can be skipped and the design can be created using any graphic editor.
4. The aim is to get the design in svg. format. The www.vectorizer.io can be used or any internet converter.
5. Depending on the software or website which you use to convert your design you can find a tool which allows to convert in stl. format. I recommend to open your file and check, clean, adjust it in tinkercad.com and then send it into your computer in stl. format.



6. No cost distributed svg. files can be downloaded from the website <https://lt.jf-staeulalia.pt/collection-free-svg-images> . But let's not take away the joy of creativity from the students. They are perfectly capable of constructing logos, stamps, signs suitable for three-dimensional printing. In the photo we see a drawing suitable for conversion and printing.

▪ **Snowflakes for the outdoor Christmas tree.**



The products are ideal for outdoor use, they do not fade, they are not afraid of precipitation.

Subjects/field: engineering, ergonomics, geometry, design.

Duration: from 4 to 6 hours.

Firstly, it is advisable to introduce students to fractals and rotational symmetry.

Task: to create a symmetrical snowflake using cloning and rotate tools on tinkercad.

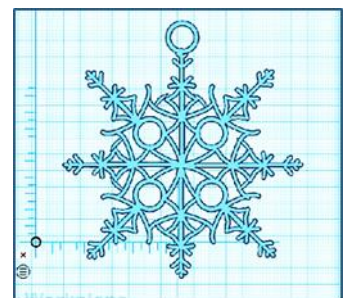
Students' abilities: sketching skills, certain spatial sense, creativity and geometric knowledge of symmetry (being able to calculate the angle, when rotating a figure complete a circle).

Required tools:

1. a computer with a connected 3D printer and installed software and the Internet;
2. tinkercad environment access for the student;
3. graphic editor online converting files from jpg to svg format; drawing notebook or graphic editor, if drawing will be done on a computer;
4. scissors, glue.

Students can create different shapes of snowflakes starting with a 30° circle cutout. Other angles with a multiple degree of 360° can be used. In the beginning cutout, a snowflake fragment is made, which is rotated until the entire circle is completed. Students draw sketches on paper. Discuss the shape and size with the teacher. Transfers models to tinkercad.com environment and adjusts dimensions, clones and prepares media for printing.

In the tinkercad environment, we can find a great tool for freehand drawing. We created the snowflake detail with this tool, then cloned and rotated it. This method took more time, students took 3 hours. In the photo you see a snowflake, the original fragment of which was drawn by hand, then cloned and rotated around the center of symmetry.



Candlestick

Subjects/field: engineering, ergonomics, design, mathematics.

Duration: from 4 to 5 hours. The time depends on the individual abilities of the students and the complexity of the model.

Task: create stl. file in the tinkercad.com environment. The time depends on the individual abilities of the students and the complexity of the model.

Students' abilities: sketching skills, basic skills of working with a graphic editor, a certain spatial sense, creativity, ability to calculate rotation angles.

Required tools:

1. a computer with a connected 3D printer and installed software and the Internet;
2. tinkercad.com environment access for the student;
3. graphic editor capable of converting media from jpg to svg. format;
4. drawing notebook;
5. scissors, glue.

Students can create containers of various shapes to store small items. The simplest model is a roll-shaped pencil case. Advanced users can create an eye-catching pencil case, which is created by cloning and rotating a simple part around circle.

At first, students create sketches on paper or work on the computer. Discuss the shape and size with the teacher. Transfers the models to the tinkercad.com environment and adjusts the dimensions, prepares the media for printing. At the beginning, it is suggested to use the shape of a roll or cube and transform it.

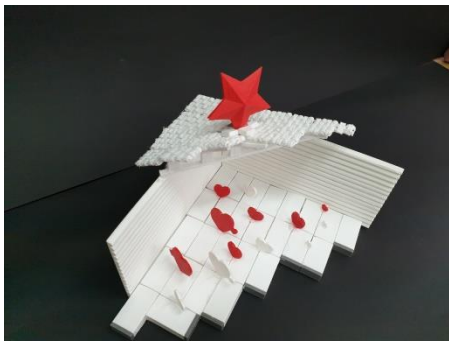
- **Other tasks are a pendant, button, happiness horseshoe with pin, towel pendant, photo stand, silencer, candle holder and other simple items that the students choose at their own discretion.**

It is possible for successful integration with other school subjects, like maths,



physics, biology etc. For example, the task linked with maths is to print an old Lithuanian measure of volume „Kvorta“. Here it needs an explanation. In Lithuania were two measures, one large and another small. Large "kvorta" was

1,7 litres, small was 0,7 litres. A task to print small "kvorta" was formulated for students. The problem was to count the dimensions of the roll which holds 0,7 litres. The task is suitable when students are familiar with the roll volume formula. In the picture seen "kvorta", which was created by my students. A superposition of text requires more skills in tinkercad management. The educational material suitable for the task is available on the tinkecad platform.



Another successful example. Students love to construct, so, in the beginning we printed details for construction: bricks, windows, doors, spars, stairs, etc. All these details are simple, found in the basic forms, the students had a task to clone the form and align the lines. We printed 20 tiles at once. We constructed various buildings from the printed

details. In the photo, you can see a stylized Bethlehem constructed by high school students for the country's Christmas competition.

Students also make souvenirs for school guests or to commemorate certain occasions. These small souvenirs make the school unique, with its own face, and students gain more self-confidence in creativity and science, pride in their work and achievements.

