ULTIMAKER ACADEMY

Aquaponic: Instructor Guide

Toolkit for Continuing Professional Development for Teachers

Aquaponic: a mini eco-system

Instructor Guide

Aquaponic: a mini eco-system

Picture 01

Getting Started

The tools and the process are the most important.

Drawing skills and designing skills of your students can be developed when they start working with an Aquaponic. Aquaponics is a process of combinging Aquaculture with Hydroponics. Some important aspects are:

- form,
- function and
- creation

The students also have to think about:

- design steps,
- functional requirements and
- technology for (distributed) manufacturing with 3D print.

Every student begins by answering some questions, like:

- What is the main function of the aquaponic?
- What are the design features that will support the basic function of the product?
- What is the ideal size, shape, and weight of the mini ecosystem?
- Which materials are the best to make this product?
- What is the best location to use the aquaponic?

Project brief

If you want to start this project, your first task is to develop some skills in using Maya 3D modelling software to create the basket for the aquaponic. After completing the basic product, the students are encouraged to create and design their own products and they have to apply their knowledge of the Maya 3D modelling software, to generate multiple concepts. With this project the students will increase their ability to work with the software, and they will develop the power of the design thinking process. They will also learn how to work with 3D printers.

Design considerations:

- Design goal: Is the aquaponic a practical design that could achieve its function?
- Design appearance: What does it look like? What is it made of? What are the measurements?
- Target: Who will be using the product? What is important to them?
- Mass production: Can the mini ecosystem design scale up to mass production?

Project Overview

This project is about the aquaponic (*see picture 01*) This project is fun and instructive. Aquaponics is a process of combinging Aquaculture (fancy word for fish farming) with Hydroponics (soil-less agriculture usually requiring a petroleum based nutrient solution for the plants). The idea of Aquaponics is to utilize the waste of fish (fish poop) to fertilize and nourish the plants within the system.

We feel that this way of producing food has a huge untapped potential and want to encourage innovation in this field.

Imagine that these developments will lead to a refrigerator or kitchen system that grows its own food! Desktop Aquaponics systems may be the catalyst to develop further interest in the subject.

Software: MAYA 3D MODELLING, MESHLAB
Time: 5-10 hours
Difficulty: BEGINNER
Subject: Mechanical Engineering, Maths, Biology, Science

Learning Outcomes

After this project, students will be able to:

- Demonstrate skills in using Maya 3D modelling software to create products for Mechanical Engineering.
- Create their own 3D products
- See how the product from Maya 3D modelling software will look like in real life.
- Demonstrate skills related to incorporating virtual and physical representations of mechanical engineered products into a variety of presentation formats that can include written essays, and oral and visual presentations.

Prerequisites

If you are not familiar with the Maya 3D modelling software, we recommend that you view the online tutorials, to increase your knowledge:
http://www.autodesk.com/products/maya/overview

Project Discussion Guide

Essential Project Conceptual Questions

- Why is the study of an aquaponic considered to be a valuable project for teaching Mechanical Engineering?
- Why do you build an aquaponic?

Essential Project Design Questions

- What type of material is used to the mini ecosystem?
- What are the design features the aquaponic should have to serve?
- What was wrong with the original product?
- What are the measurements of the product?

Teacher Preparation

- Be prepared to help the students with questions about how fish can breathe under water
- Show and teach students how to work with new software techniques.
- Show students how they can use the software Help feature.
- Make a list of videos and pictures where the students can take a look at when they need reference for their project.

Day-to-Day Plans

We divide the designing process in 7 phases.

- Understand
- Explore
- Define
- Ideate
- Prototype
- Refine
- Solution

Understand: Watch the students

To establish a solid foundation for the aquaponic, students need to have a clear understanding about the project and what is asked from them. The best point to start is to review the project design brief. The second action is to distribute the student pre-test and give students 10 to 20 minutes to answer the questions. Your next job is to facilitate a student discussion built around the pre-test questions.

Explore: Develop a knowledge base

In this phase you want students to develop an understanding of the function of the aquaponic. A good start is to form teams where students can discuss the project and the project design questions listed above.

Define: Clarify Requirements

This is a very important stage where the students have to establish the criteria for the project. You will need to understand specific parameters related to factors such as dimensions, materials used and construction techniques.

Ideate: Creativity

In this phase the students must base their design on the criteria that they have made in the previous stage. They have completed their research and they can justify why specific choices are made. Students can justify their choices in a number of ways, e.g.:

- sketches on paper,
- study models (out of simple materials) or by creating
- a mood board

Students will be able to communicate visually to others what they made en what they are going to refine in the next phase.

Prototype: Test

In this phase, students make a prototype of the product. They will print the part for their mini ecosystem. Students learn the skill to make their designs reality. Your job is to encourage students to assist each other in learning the software

Refine: Almost There

Almost done with the project. The students will criticize their prototype(s), and refine them to a better product. When the students are proceeding this phase, it is your job to remind them to keep reffering to the criteria they have established at the beginning.

Solution: Final Presentation

The last phase is also very important. In this stage you ask your students to give a presentation about how it helped them expand the four C's of their learning skills.

- Critical thinking
- Communication
- Collaboration
- Creativity

The presentation should be about the most important aspects of each of the previous phases. Students should be aware from the beginning of the project that the results in design phases 1-7 will culminate in a final presentation. Stress the importance of using tools to visualize and present in the same way professionals do. When time is limited, it is also possible to let students share their presentations electronically.

Differentiation

- Let students view some relevant videos in small groups.
- Show the students websites that can help them in the Define and Explore stages.
- Make small teams collaborate on the last four design phases. Some students will focus on the sketches and others will focus on digital prototyping.
- Let students evaluate others and themselves at the end of every phase.
- Give the students some examples of successful student presentations, so they can see what is needed to complete the project.

Non-Native Speakers

- Provide English dictionaries or electronic translation devices.
- Allow the student to create presentations in their primary language and have it translated later.
- Pair ELL students (English Language Learners) with students that speak English very well.

Special Needs Students

- Show the student prefabricated models.
- (Let assistants) Help the students in sketch modelling and help to create prototypes.
- Make it possible for the students to work with larger font sizes, speech recognition and alternative input devices.

STEAM Connections

Science

Make adjustments to the water filter by widening the filter. Do not make adjustments to the air flow. Find out if the water is pumped-up (lifted) higher or not. Why?
How much more air power do you need to reach the same water level with a wider filter?
Explain how Pascal's principle of communicating vessels and Gravity can be applied to lower the water level in the filter without touching the vase.

Technology

What does the choice of material tell you about the technology? What technologies can you use to manufacture all the parts? What are the pros and cons of the production techniques?

Engineering

What properties do the materials have, that make them well-suited to being used as an aquaponic? In which other applications is this material used? How would you manufacture this product if you did not have a 3D printer?

Art

How can you make the aquaponic in such way that it fits in a designer room? Which shapes, materials and colors do you use? What other kind of art can you make with a 3D printer?

Math

Explain the difference between measurements in liters and cubic liters. Also explain the Cubic Meters to Liters conversion. How many liters are in the whole Blomster vase (Air and Water combined)? How many liters Air and how many liters Water are in the system?
Exercise: Imagine an Aquaponic that can contain 10 liters of water. I have 1 cubic liter water.
Question: How many Aquaponic systems can I build?
The Air pump creates a water circulation in the vase. Assume we have 10 liters of water in the vase. The pump has a capacity of 5 liters per hour. How long does it take to circulate all the water one time?

Extra: Biology

Some questions to use the aquaponic in Biology class:

- Explain how fish can breathe under water.
- Explain how plants can purify air
- Explain how the water circulation will clean the water, while providing food for the plant.
- Explain how bacteria can be beneficial for our environment.
- Explain how water plants can live underwater
- What are the functions performed by fish?
- What and how do fish eat?
- How do fish excrete waste?
- Can I add a snail?
- Over time, algae might come into the system. Algae provide food for the fis. Explain how the excessive algae can cause problems for the whole eco system.

Extra: Scrapheap Challenge

Can you find ways to use some (or all) materials from a Scrapheap to build this Aquaponic system? This may lower the total purchasing costs. Hint: you may also want to visit an (online) Second hand shop.

Produce It

Activities where you have to produce something will take some time, but the benefits are worth it. When you ask former students what they remember about their schoolperiod, the answer often refers to something they made, wrote, or performed.

Assessment Processes

For each project students complete a self-evaluation and peer evaluation. These are accompanied by the teachers' evaluation.
The STEAM questions, Extension Ideas, and the Build It activity, offer students an opportunity to demonstrate what they learn in the process and apply the knowledge in new situation to increase the quality of their work and increase their scores.

Design Criteria Worksheet

In this challenge, students have to apply their technical skills to use Maya 3D modelling software to create a 3D model of the aquaponic. It is very important that you develop an understanding of all relevant design criteria. This chapter helps you with the developement by prompting a response to questions in four categories: Who, What, Where and Why.

Who?

- Who will buy the aquaponic?
- Who will use it?
- Who will have to be in the same room with it?
- Who will design it?
- Who will mass-produce the product?
- Who is involved with the discovery, extraction, and transport of materials used in the mini ecosystem?

What?

- What design features are crucial to the functionality?
- What materials will it be made of?
- What ways of manufacturing do you use?

Where?

- Where will the aquaponic be used?
- Will the product be used by more than one person?
- Where can the materials required to create the aquaponic be found?

Why?

- Why are you designing a mini ecosystem? What are the functions that it has to fulfill?
- Why are the specific materials you choose well-suited to produce this product?

Pre-Test

Discussion

What is an aquaponic system?

……..
……..

Why is the aquaponic created?

……..
……..

What are the design features the aquaponic should have to serve not only its primary functional purpose but other purposes as well?

……..
……..

Why should we print this product instead of melt in into a mold?

……..
……..

Survey
Fill the survey visualised in table *Aquaponic 1*
To what extent do you agree/ disagree with the following sentences:

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

	1	2	3	4	5
I understand what an aquaponic is, why it was introduced, and how people use it.					
I understand the most important functional features as well as other design features of the product.					
I understand the importance of appropriate material choice.					
I have used Maya 3D before and understand the program.					
I understand the seven phases of design thinking.					

Table: *Aquaponic 1*

Post-Test

Now that you have completed this project, reconsider the responses you provided in the Pre-Test for the following questions. When you are done, compare your results with your results of the pre-test, and describe how this project helped you in your developing process.

What is an aquaponic system?

……..
……..

Why is the aquaponic created?

……..
……..

What are the design features the aquaponic should have to serve not only its primary functional purpose but other purposes as well?

……..
……..

Why should we print this product instead of melt in into a mold?

……..
……...

Describe how your response to this question changed as a result of your experience with this project.

……..
……..

Survey
Fill the survey visualised in table *Aquaponic 2*
To what extent do you agree/ disagree with the following sentences:

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

	1	2	3	4	5
I understand what an aquaponic, why it was introduced, and how people use it.					
I understand the most important functional features as well as other design features of the product.					
I understand the importance of appropriate material choice.					
I have used Maya 3D (before) and understand the program.					
I understand the seven phases of design thinking.					

Table: *Aquaponic 2*

Pre- and Post-Test Evaluation Rubric

See the tables *Aquaponic 3-11*

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Pre-Test	Great care was taken in reading and answering all questions. Maximal engagement in group sessions. A leadership role assumed.	Care was taken in reading and answering all questions. Demonstrated a willingness to engage in group discussions.	A minimal amount of care was taken in reading and answering all questions. Minimal engagement in group discussions.	No care was taken in reading and answering all questions. No engagement at all in group discussion.
Post-Test	Great care was taken in reading and answering all questions. Maximal engagement in group sessions. A leadership role assumed..	Care was taken in reading and answering all questions.. Demonstrated a willingness to engage in group discussions.	A minimal amount of care was taken in reading and answering all questions.. Minimal engagement in group discussions.	No care was taken in reading and answering all questions. No engagement at all in group discussions.

Table: *Aquaponic 3*

Prerequisite Skills Preparation Evaluation

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
How-to Videos	The videos are used with great care to develop the skills that are necessary for the project.	The videos are used with care to develop the skills that are necessary for the project.	The videos are used with a minimal amount of care to develop the skills that are necessary for the project.	The videos are used with no care to develop the skills that are necessary for the project.
Collaboration and Participation	The student made exceptional effort to work with other students to improve competecies with the prerequisite skills	The student made reasonable effort to work with other students to improve competecies with the prerequisite skills	The student made minimal effort to work with other students to improve competecies with the prerequisite skills	The student made no effort to work with other students to improve competecies with the prerequisite skills

Table: *Aquaponic 4*

Understand Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Project Videos and Brief	The project videos and project brief are explored with great care	The project videos and project brief are explored with care	The project videos and project brief are explored with minimum amount of care	The project videos and project brief are explored with no care
Design Journal	In the Design Journal you can clearly see that the student attempted to improve the understanding of the project.	In the Design Journal you can see that the student attempted to improve the understanding of the project	In the Design Journal you can just see that the student attempted to improve the understanding of the project.	In the Design Journal you can not see that the student attempted to improve the understanding of the project.
Collaboration and Participation	The student made exceptional effort to clarify their understanding through discussion with others.	The student made effort to clarify their understanding through discussion with others.	The student made a minimum amount of effort to clarify their understanding through discussion with others.	The student made no effort to clarify their understanding through discussion with others.

Table: *Aquaponic 5*

Explore Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Deeper Inquiry	The student made exceptional effort to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made effort to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made a minimal amount of effort to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made no effort to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions..
Design Journal	In the Design Journal you can clearly see that the student made excellent evidence of designing exploration. All the notes and sketches show an exceptional grasp of the project and the aspects that will have an impact on their own work	In the Design Journal you can clearly see that the student made evidence of designing exploration. All the notes and sketches show a grasp of the project and the aspects that will have an impact on their own work	In the Design Journal you can clearly see that the student made a minimum amount of evidence of designing exploration. All the notes and sketches show a minimum amount of grasp of the project and the aspects that will have an impact on their own work	In the Design Journal you can clearly see that the student made no evidence of designing exploration. All the notes and sketches show no grasp of the project and the aspects that will have an impact on their own work
Collaboration	The collaboration is excellent. The students listens very well and supports the other students.	The collaboration is good. The students listens well and supports the other students. He does not create conflicts.	The collaboration is fair. The students listens sometimes and supports the other students, but sometimes isn't a good team member	This student never listens and never helps other people. The student is not a good member for the team.

Table: *Aquaponic 6*

Define Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Design Criteria Worksheet	The student made exceptional effort to use the worksheet to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made effort to use the worksheet to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made a minimum amount of effort to use the worksheet to expand their understanding of the challenge, the factors that are part of the project, or the types and quality of solutions.	The student made no effort to use the worksheet to expand their understandin g of the challenge, the factors that are part of the project, or the types and quality of solutions.
Design Journal	From the design journal becomes very clear that the student has identified the critical criteria for their project	From the design journal becomes clear that the student has identified the critical criteria for their project	From the design journal becomes just clear that the student has identified the critical criteria for their project	From the design journal becomes not clear that the student has identified the critical criteria for their project
Collaboration	The collaboration is excellent. The students listens very well and supports the other students.	The collaboration is good. The students listens well and supports the other students. He does not create conflicts.	The collaboration is fair. The students listens sometimes and supports the other students, but sometimes isn't a good team member	This student never listens and never helps other people. The student is not a good member for the team.

Table: *Aquaponic 7*

Ideate Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Ideation	The student made excellent effort to create concepts and solutions.	The student made effort to create concepts and solutions.	The student made a minimum amount effort to create concepts and solutions.	The student made no effort to create concepts and solutions.
Design Journal	From the design journal becomes very clear that the student has explored multiple design solutions.	From the design journal becomes clear that the student has explored multiple design solutions	From the design journal becomes just clear that the student has explored multiple design solutions	From the design journal becomes not clear that the student has explored multiple design solutions
Collaboration	The collaboration is excellent. The students listens very well and supports the other students.	The collaboration is good. The students listens well and supports the other students. He does not create conflicts.	The collaboration is fair. The students listens sometimes and supports the other students, but sometimes isn't a good team member	This student never listens and never helps other people. The student is not a good member for the team.

Table: *Aquaponic 8*

Prototype Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Prototype Development and Testing	The student made excellent effort to visualize and test prototypes.	The student made effort to visualize and test prototypes.	The student made a minimum of effort to visualize and test prototypes.	The student made not effort to visualize and test prototypes.
Design Journal	From the design journal becomes very clear that the student has documented and evaluated prototype(s).	From the design journal becomes clear that the student has documented and evaluated prototype(s).	From the design journal becomes just clear that the student has documented and evaluated prototype(s).	From the design journal becomes not clear that the student has documented and evaluated prototype(s).
Collaboration	The collaboration is excellent. The students listens very well and supports the other students.	The collaboration is good. The students listens well and supports the other students. He does not create conflicts.	The collaboration is fair. The students listens sometimes and supports the other students, but sometimes isn't a good team member	This student never listens and never helps other people. The student is not a good member for the team.

Table: *Aquaponic 9*

Refine Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Refine Solutions	The student made excellent effort to refine ideas. The solutions are very closely aligned to the design criteria.	The student made effort to refine ideas. The solutions are aligned to the design criteria	The student made a minimum amount of effort to refine ideas. The solutions are somewhat aligned to the design criteria	The student made no effort to refine ideas. The solutions are not aligned to the design criteria
Design Journal	From the design journal becomes very clear that the student has significantly enhanced the design through the use of the software	From the design journal becomes clear that the student has significantly enhanced the design through the use of the software.	From the design journal becomes just clear that the student has significantly enhanced the design through the use of the software.	From the design journal becomes not clear that the student has significantly enhanced the design through the use of the software
Collaboration	The collaboration is excellent. The students listens very well and supports the other students.	The collaboration is good. The students listens well and supports the other students. He does not create conflicts.	The collaboration is fair. The students listens sometimes and supports the other students, but sometimes isn't a good team member	This student never listens and never helps other people. The student is not a good member for the team.

Table: *Aquaponic 10*

Solution Phase Evaluation Rubric

	Excellent *4 points*	Good *3 points*	Fair *2 points*	Poor *1 points*
Preparation of Presentation	The student made excellent effort to make a perfect presentation.	The student made effort to make a good presentation.	The student made a minimum amount of effort to make a presentation.	The student made no effort to make a presentation.
Communication and Team Dynamics	Maximal effort was made to help the team conduct the final presentation.	Effort was made to help the team conduct the final presentation.	A minimum amount of effort was made to help the team conduct the final presentation..	No effort was made to help the team conduct the final presentation.
Presentation Content	The student made exeptional effort to create and present a solution that is aligned to the criteria for the project.	The student made effort to create and present a solution that is aligned to the criteria for the project.	The student made a minimum amount of effort to create and present a solution that is aligned to the criteria for the project.	The student made no effort to create and present a solution that is aligned to the criteria for the project.

Table: *Aquaponic 11*

INSTRUCTIONS

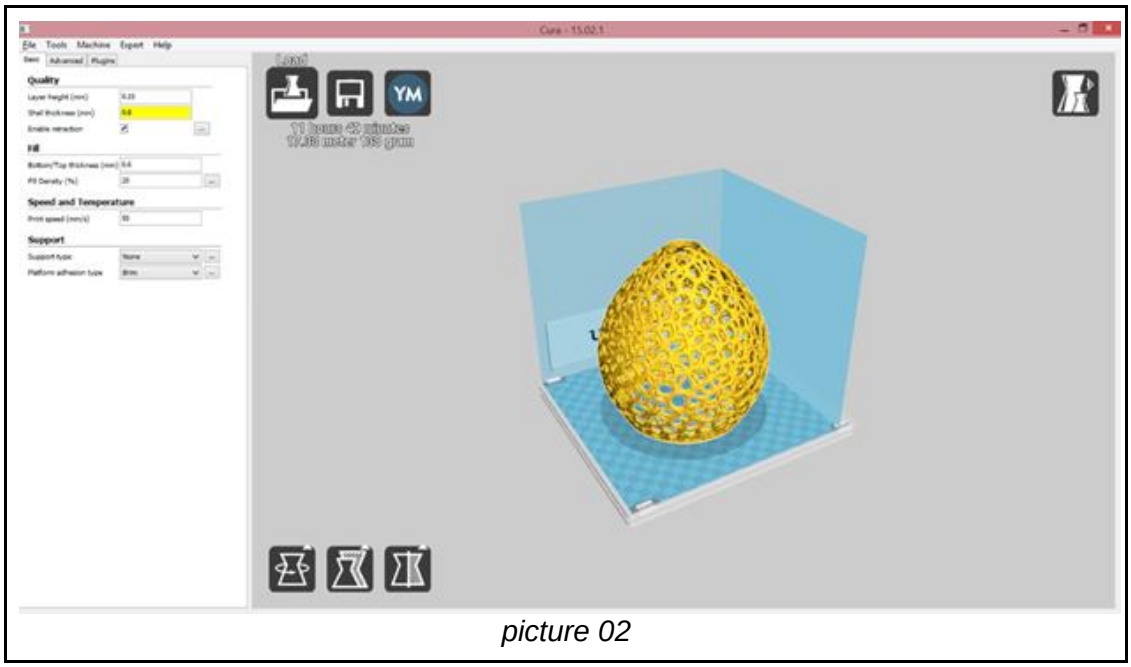
Bill of material with a total retail price of less than 99 euro's.

- Ikea vase Blomster (39,93 euro)
- Air pump with 2 tubes and 2 regulators for the tubes (25 euro)
- Air stones (3 euro)
- Fish food (5 euro)
- 2 Fantail Fish (5 euro each)
- Plant Basilicum or Mint (3 euro) and hydro clay pebbles or
- Hydro culture Plant (15 euro)
- Water plant (2 euro)
- PLA (4 euro)
- Extra: Mini oxydator (15 euro)

Download the files Basket and Biofilter on YouMagine.com. Follow instructions below.

How to adjust the printer settings for the Basket?

Open the .stl with Cura. The best print results are created when you print the basket upside down. So, the widest opening should face downward. (*see picture 02*)



picture 02

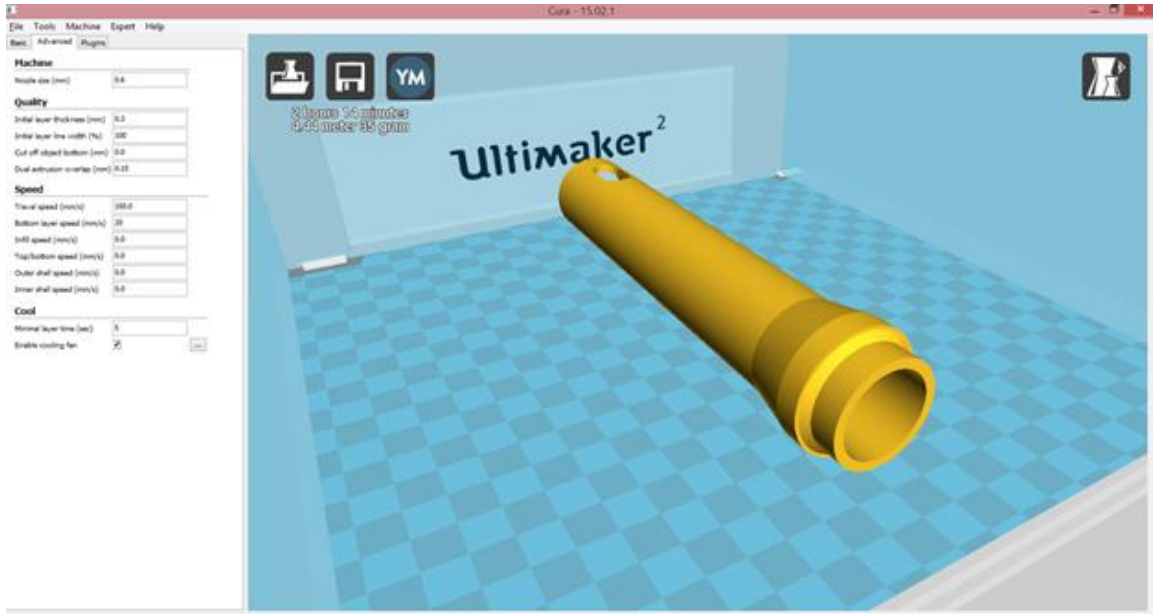
Set your basic setting to:

- Layer height 0.15 mm
- Shell thickness: 0.8
- Fill density 20
- Printspeed 20

If you prefer to print without brim, you might want to use glue for a good attachment to your heated bed.

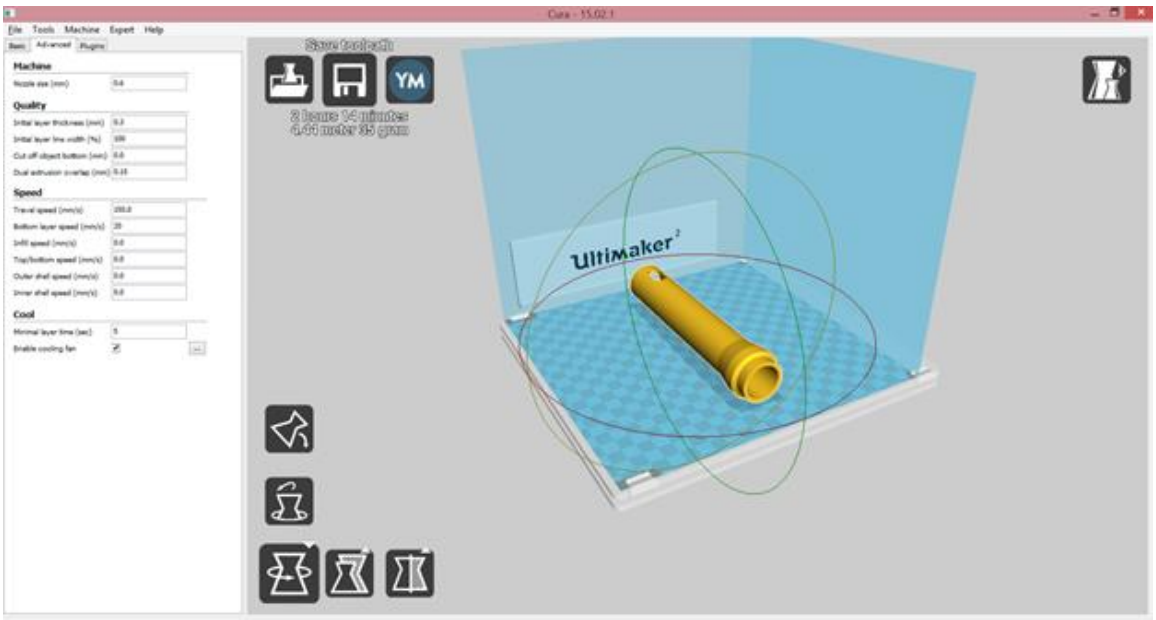
How to adjust the printer settings for the Biofilter?

Open the .stl with Cura. The best print results are created when you print the filters in vertical position. When you open the .stl the result will probably look like this (*see picture 03*)



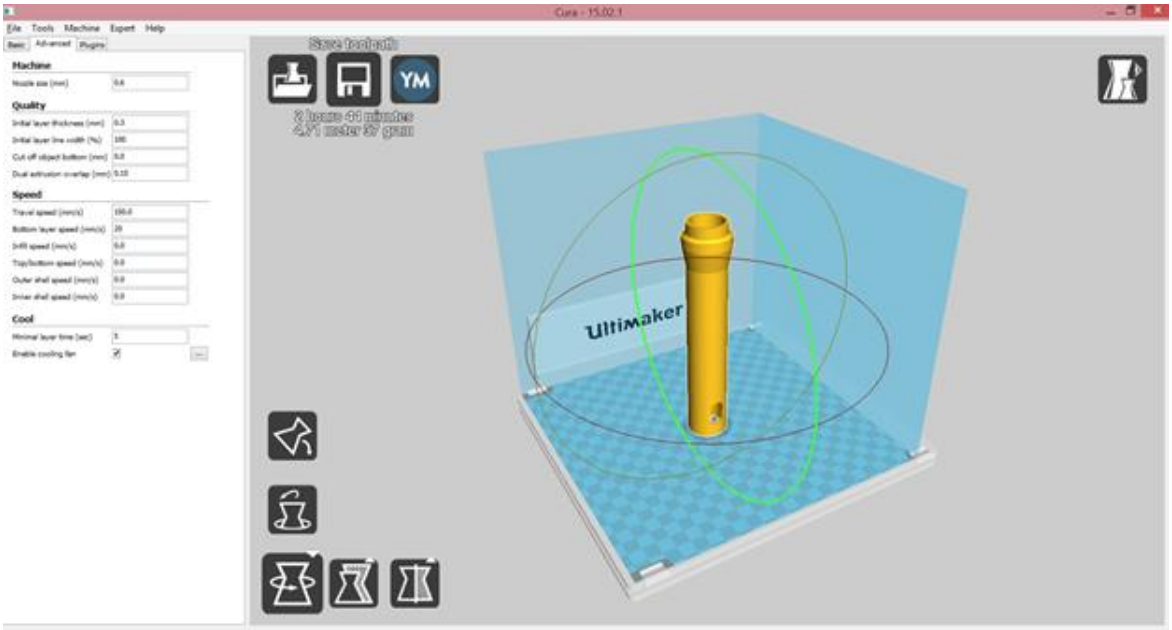
picture 03

Click on the object. In the left corner, a Rotate button will appear. (*see picture 04*)



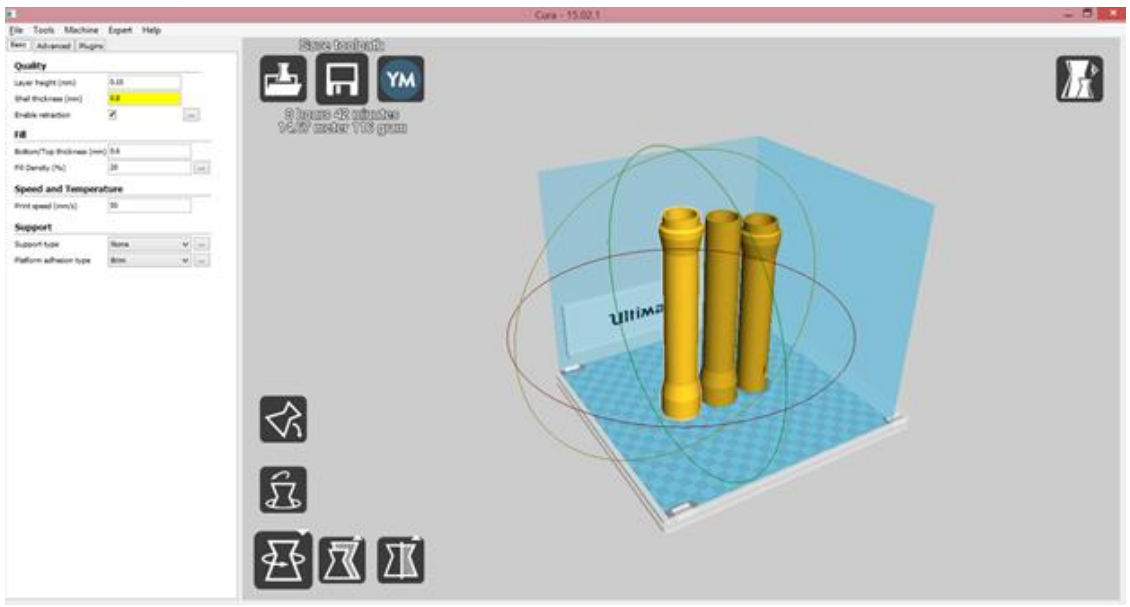
picture 04

Click on this button to flip the objects in its vertical position. The result will look like this. (*see picture 05*)



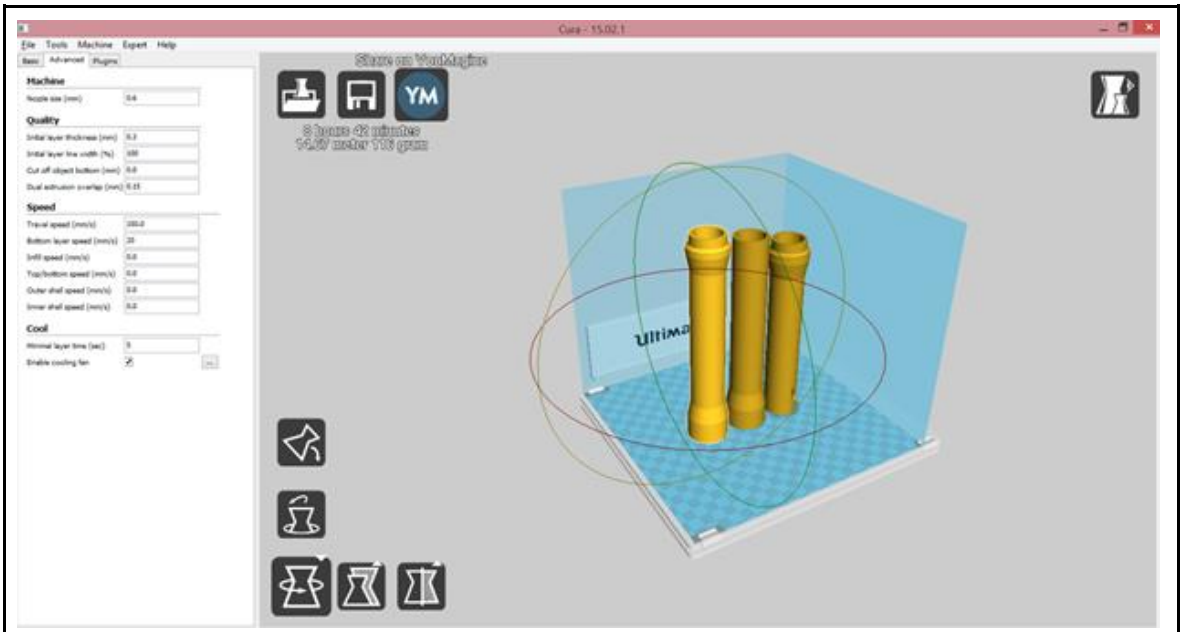
picture 05

The Biofilters has 3 parts. You can print the parts one-by-one, or you can import all parts into Cura and print all tubes at the same time. For good printer setting, use the following Basic Settings (*see picture 06*)



picture 06

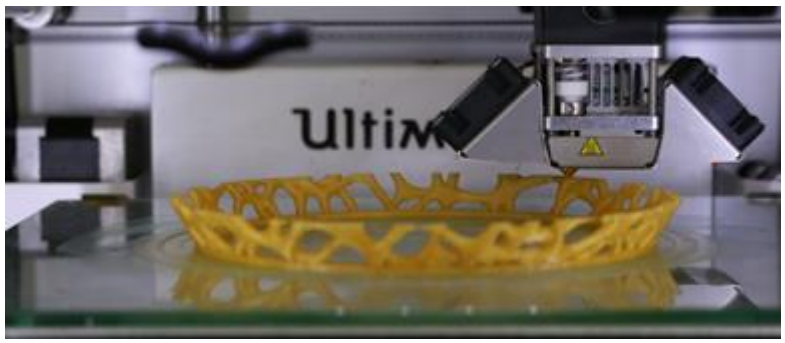
For good printer setting, use the following Advanced Settings (see picture 07)



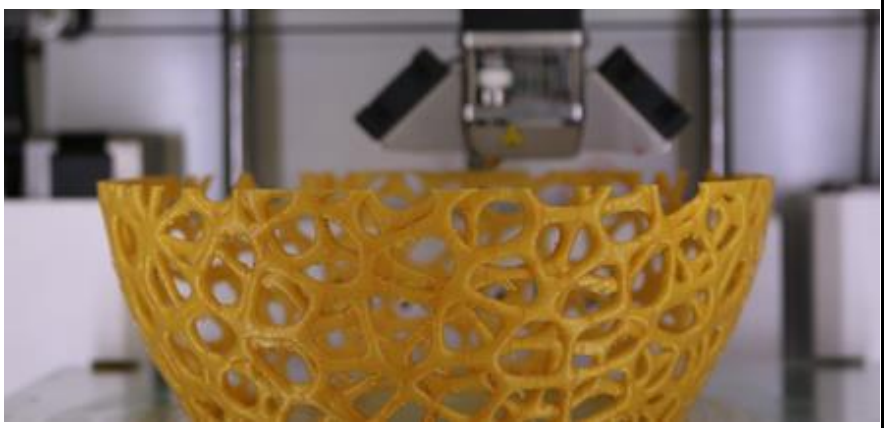
picture 07

Print results

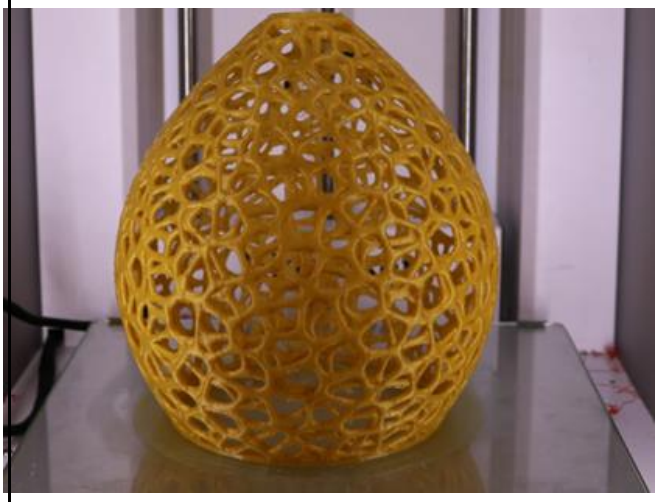
Some of our print results are visualised in the pictures 08 -13.



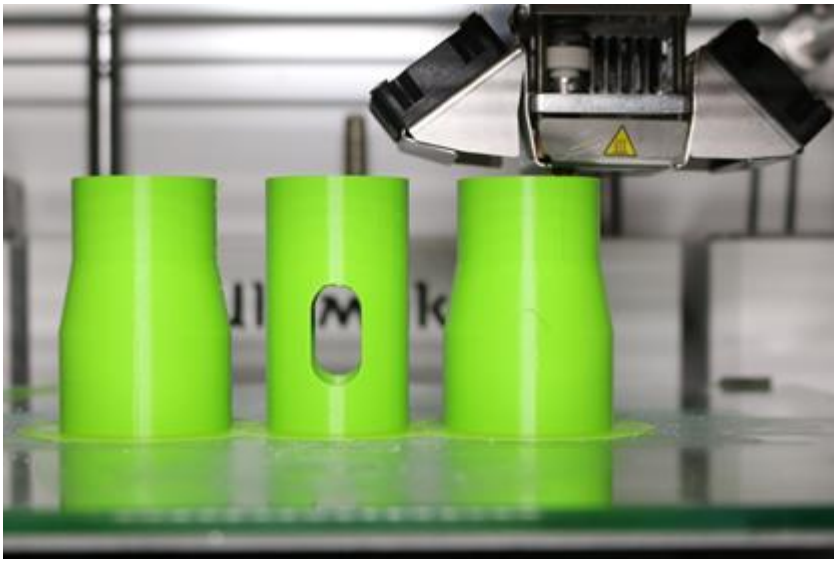
picture 08



picture 09

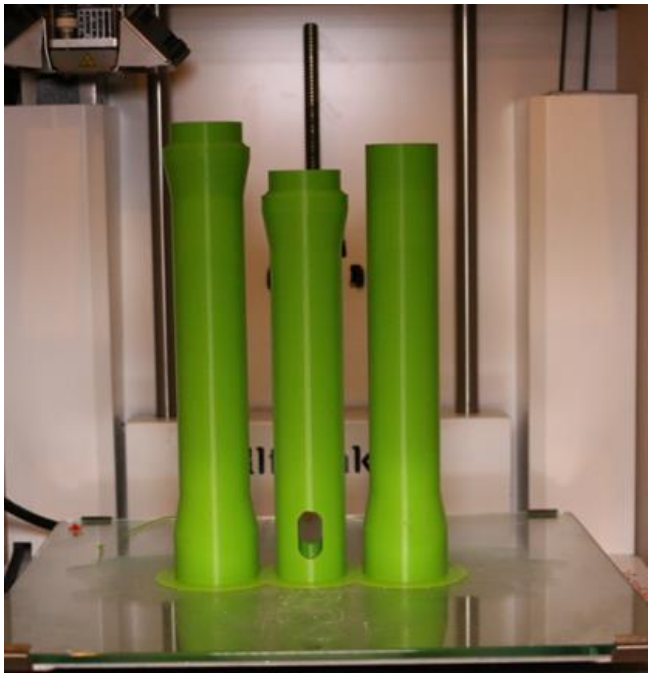


picture 10



picture 11

picture 12



Picture 13

Last minute purchase and animal care

Make sure that all parts of your Aquaponic are ready, before you purchase the fish. Your fish can be carried in a plastic bag filled with water from the retail store to your school. Please release the fish as soon as possible from the small transportation bag, into the Aquaponic. Before you add the fish, make sure that the water in the vase is at the same (room) temperature of the water that the fish are in.

Assembly instructions

- Fill the Ikea Blomster vase with 3/4 water.
- Release the fish into your Aquaponic.
- Cut 2 tubes of 2 meters length each
- Place an Airstone on the end of each tube. These are the ends that will be in the water.
- Cut 30 cm of each of the other ends and inset an air adjustment valve in each tube.
- Connect the ends without Airstone to the Air pump.
- Place one Air stone into the water
- Place the water plant into the water
- (Extra: activate the mini oxydator and place it on the bottom)
- Attach the Biofilter to the Basket
- Push one Air stone not more than 10 cm. in the bottom end of the Biofilter
- Place the Basket with the Biofilter and the (second) Air Stone into the water.
- Now place your hydro culture plant into the Basket. If you want to use a plant that was grown on soil or dirt, remove the dirt and carefully rinse the root system. Now place the plant with the hydro clay pebbles into the Basket.
- Make sure there are no obstacles in the Biofilter.
- Switch on the air pump. Air must come out of the Air stone in the water. You can see bubbles coming out of the Air stone. Also, water will come out of the Biofilter, allowing the water to wet the hydro clay pebbles and return to the water where the fish is. If the water doesn't come out of the Biofilter, increase the air pressure in the Biofilter.

Beware: Make sure that the air pump is placed above the water level. This prevents the aquarium from running empty in case of a malfunction in one of the tubes. This phenomenon can be explained with: Pascal's principle of communicating vessels and Gravity.

Our shopping list

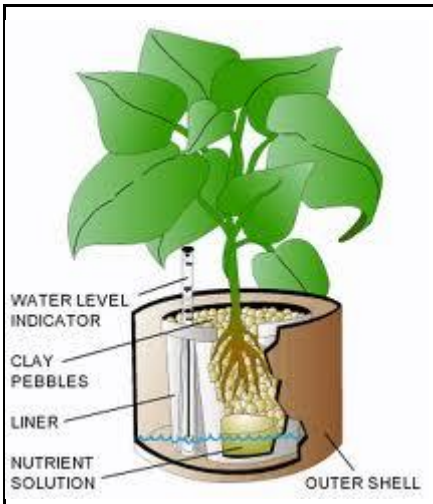
(see pictures 14 to 20)

picture 14, Ikea Blomster

picture 15, TetraTec APS 400 Air pump

picture 16, Air stones

picture 17, Fish food



picture 18, Hydro culture plant

picture 19, Clay pebbles

picture 20, Extra: Mini oxydator to improve water quality for the fish

End of the teacher instructions for this aquaponic system