BREATHE-IN

TOUCH AND LISTEN

iGEM Tec Monterrey 2019

Touch and listen: Inclusive educational tool and its applications on SynBio education

A guide developed by iGEM team Tec-Monterrey

Introduction

The aim of this guide

Touch and listen are a new tool being currently developed in order to involve children with visual disabilities within classroom activities and other educational environments. The device created by Dr. Cristina Reynaga, based on Universal Design for Learning (UDL), an educational methodology whose purpose is to involve both people with disabilities and without them in the process of learning new concepts. Thus, the purpose of this guide is to comprise the information needed to help tutors, teachers and parents implement this useful device to teach not only Synthetic Biology, but also other areas of interest.

Our experience

During our experience we noticed that, although the use of 3D printed models is a trend to facilitate the production of educational models for Blind and Visually Impaired students (BVIS), the lack of depth and thought of the texture were not engaging to BVIS. However, since the reproduction of 3D printed models is so easy, it is possible to use the printed models with further augmentation that can enhance their didactic potential while also keeping low on cost and technical skills. Our idea began from using common everyday materials such as string or cotton to condition these models into adding an interactive element that both sighed students and BVIS are attracted to. Plain 3D printed models usually are attractive to sighted students but not to BVIS

Current knowledge

By working together with Dr. Reynaga's research group, we learnt a lot about the different assumption that we have on BVIS and what to take into consideration when designing good and engaging materials.

We learned that just like there is literacy among sighted students, which is a skill that is acquired through the constant exposition to words through our sight as well as being exposed to books and words written on blackboards, for BVIS there is also a learning curve in distinguishing different textures and making sense of shapes and patterns present on

educational material. This consideration is crucial since the information must be transformed in a way that it can be both representative as well as easy and engaging, like how sighted student commonly learn in the classroom. For example, in maps designed for BVIS, the use of symbols and simplification of roads and areas in different levels of complexity allow for students to distinguish and recognize places or areas they may have been exposed to. If a map was left untreated, the lack of significant differentiators, such as the use of different colors and fonts that we see in typical map app such as Google Maps, will confuse students to the degree that they describe these representation as “Making sense out of spaghetti”.

To further expand on this, being able to differentiate different components of a model in a clear way is one of the aspects to take into consideration when designing a model from scratch. In models already designed from open source resources, the idea is that in the selection process of materials to “texturize” the models you select, contrasting texture work the best to be able to make clear distinction from each component. A bit harder idea, is relating the textures to the actual sense that is related to that specific part, for example, the use of rigid materials to describe a plant’s cell wall will get the idea of being rigid, while for animal cell the material has to be softer to conduct the idea of a flowing and non-rigid membrane.

Regarding the actual reproduction of 3D printed materials, we also learned about how to balance between the quality of the print, size and being time efficient, since bigger and higher quality prints tend to take exponentially longer than their counterparts. However, certain parts can be of lower quality since their main purpose is to serve a base on which you can add different textures, so that the finish of the actual prints is irrelevant for this use.

For the technical aspects on how to use slicing software to generate the actual g-code for the 3D printer, we learnt to modify the relevant variables that directly impact on the quality and speed of this print. This is shown further on in the document that explains step by step what we learnt through experience using some SeeMeeCNC Rockstock Max V3 with PLA material.

Where can this tool be applied?

Today there are many methods of teaching Blind and Visually Impaired Students (BVIS). Even some of the schools have their own programs designed to meet their needs. However, there are still barriers to the education of people who cannot adapt to learning within a traditional system. For this reason, tools or educational models have been constructed that seek to be inclusive for this sector of the population that is sometimes segregated.

On the other hand, there are situations, specially around public schools and educational centers without proper funding that lack these kinds of programs and adaptations needed to teach people with any kind of impairment. In these cases, teachers may find themselves in situations in which they lack proper tools to integrate the BVIS students into the traditional curricula.

Touch and listen may be applied both situations. The tool is easy and affordable enough to enable teachers apply it inside their own classrooms, for either sighted or BVIS. Age is also not a restrictive factor as the way to apply it does not change, only the topic being covered

during that lesson, so the possibilities of application are pretty much endless as long as the necessary materials are available.

Tec-Guadalajara

We were able to make contact with iGEM team Tec-Guadalajara where their shared with us their experience during the rally they organized for teaching concepts about health and wellbeing. One of the most important aspects that helped us in our design was how kids' attention span is important to take into account, so that the information that we curated for generating the audio cues were short enough to be understandable but not overwhelm children with information and concepts. Also that more interactive layers are better than longer audio cues to explain the same amount of information, since it is easier for students to skip through the already hear audio to reach the information they want hear again, rather than waiting for the whole audio cue to end, while also adding to the interactivity of the model.

Universal Design for Learning

Traditional educational programs are already well established and being used in schools all around the world. Issues arise when trying to accomodate a student with disabilities because most educational programs have tried to adapt to each students' necessities, and every student is completely different. As a result, many parents face situations with schools that can not accommodate their children in existing special educational programs because they fail to suit their necessities. [1] This is where UDL fits into the picture. Its purpose is to be a program that enables equity in education. This means that is does not try to adapt the student into the program, but instead, it is flexible enough to suit every, or most students into the same schooling.

BVIS education

Right now, most of the materials that are available in public schools are limited to just adapting into braille the already existent resources, or the use of technologies to amplify images and diagrams.[2] However, these are not as efficient as other material that involve the use of more senses since this make the learning process more efficient. [3] This limits the education that this population receives since the use of special materials for BVIS is a form of exclusion form the material the rest of the students use. This has a negative effect on their education since their conditions or circumstances differ from most of the classroom [4].

Fabrication of models

Preparation of 3D files

Setting up your printer for Ultimaker's Cura

1. When you first start up Cura, the pop up allows you to configure your 3D printer

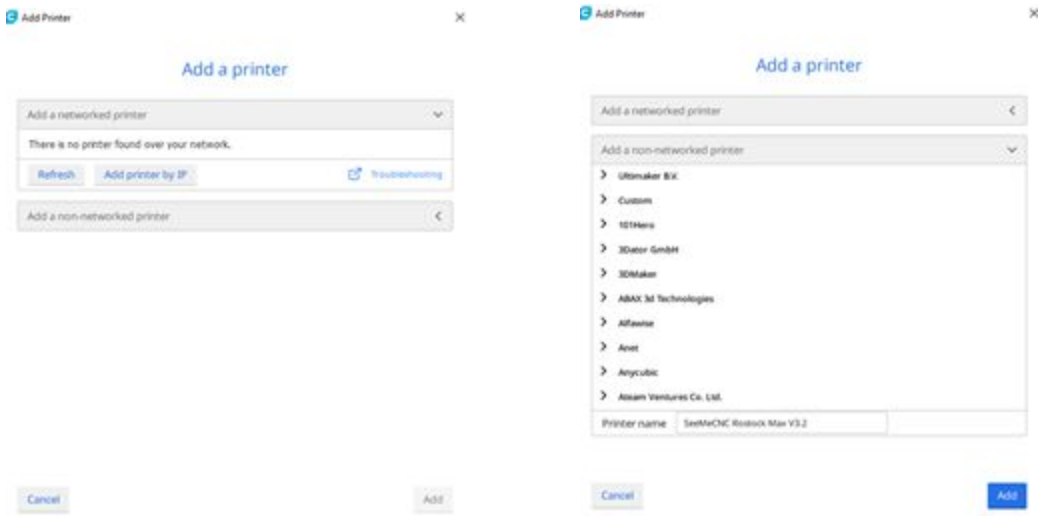


Fig 1. Image showing both option for choosing a networked or non-networked 3D printer.

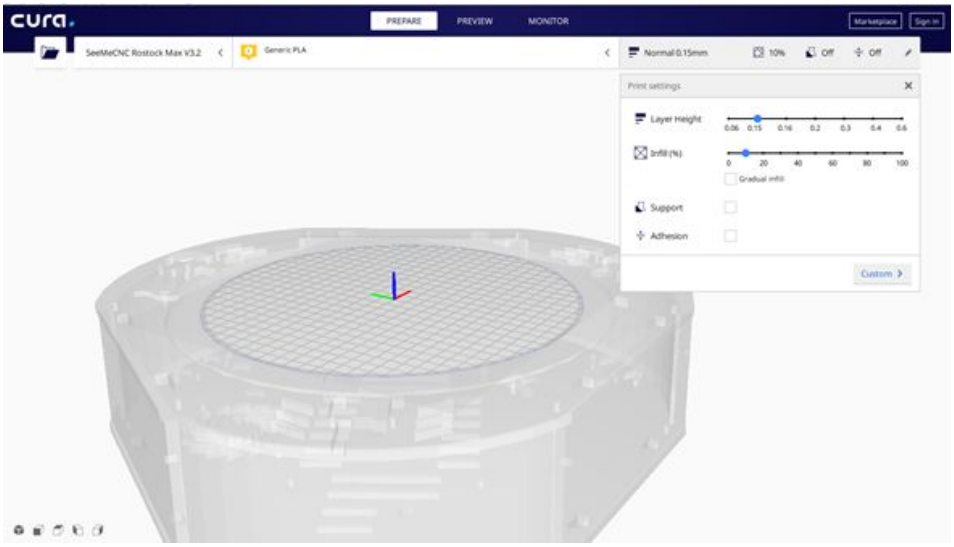
Note: Keep in mind that certain 3D printers might have their own software for slicing models.

2. Once you printer is selected, you can start importing 3D files to slice them in cura.

Fig 2. Image showing the SeeMeCNC Rockstock Max V3.2 printer selected as the 3D printer in which the models will be printed.

Note: If the 3D printer does note appear under these categories, the custom option allows to configure the specific dimensions of the 3D printer as well as the specification of the printer's nozzle.

How to prepare your file using Ultimaker's Cura



1. First you need to import your file using the import button. The supported file formats are 3MF, OBJ and STL.

Fig 1. Image showing the build plate of your selected printer and the icon for importing 3D files.

2. After your file is imported you would see the 3D model appear on the build plate of the printer, you can move it around depending on where you want it printed as well as change the size and rotate it.

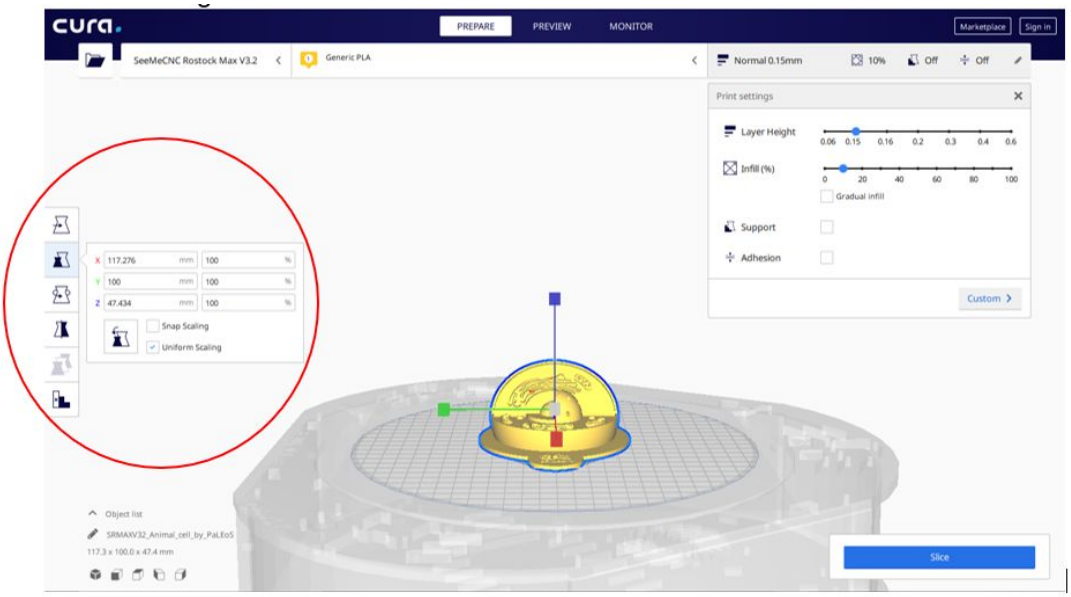


Fig 2. Image showing model on the build plate with the options to modify size or rotation.

3. After you have selected your desired size and orientations, you need to configure the parameters for your print, such as layer height, infill percentage, if supports are needed and if a raft is desired (See Appendix for a glossary of each parameter).

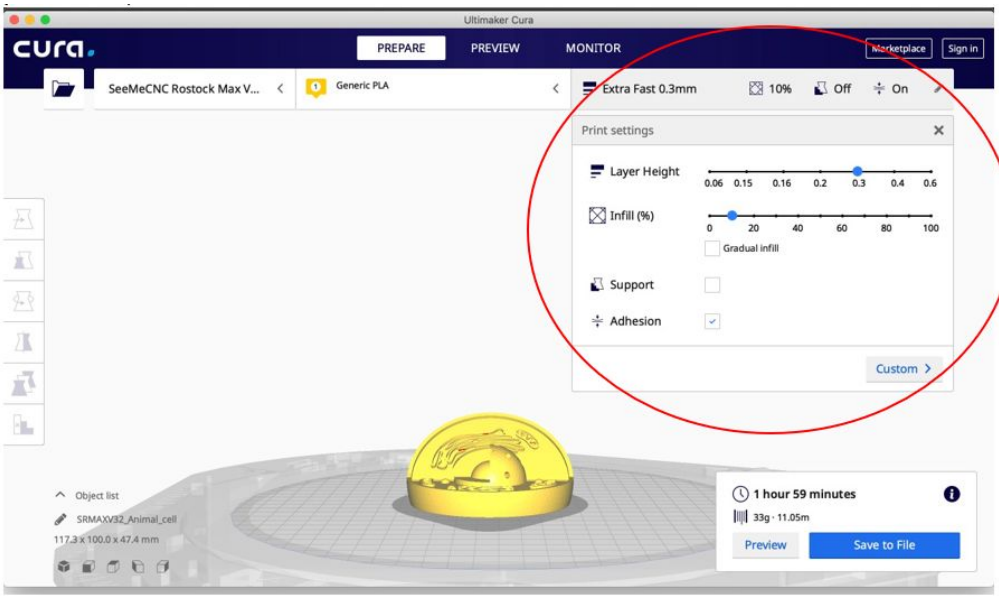


Fig 3. Image showing the settings window where the parameters for the print are selected.

Note: Not all 3D models require support or draft, usually refer to the designer's specifications when using a model from Thingiverse, or if it's an original design, adjust the angles at which

support are generated by trial and error. The default value is of 45° but some models may only require support for greater angles depending on the printer. Rafts facilitate adhesion when model have thin parts touching the, however certain models may not need it.

4. Adjusting the layer height determines the quality and has a significant impact on printing time, because lower layer height require more layers to complete the size of the model. For example, a print with a layer height of .3 mm would require less layer than a print with a layer height of .1 mm, thus decreasing the printing time.
Note: Since the printed will be used as a base for creating the inclusive models, the quality of the print would not significantly impact the experience of the student if it would be coated or covered with another material of the desired texture.

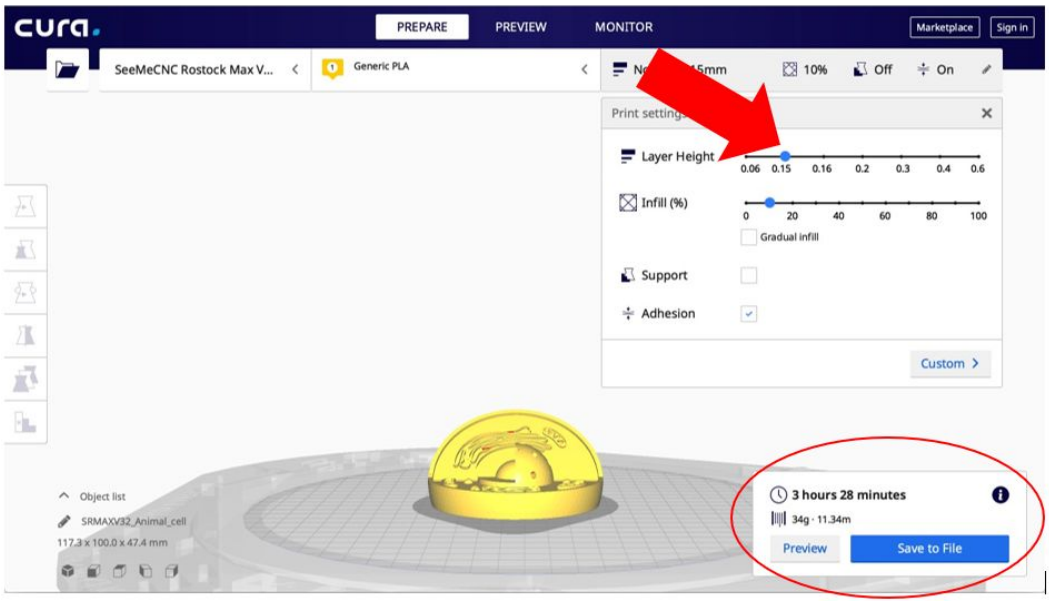


Fig 4. Image showing that a .15 mm layer height would take 3 hours and 28 minutes with a 10% infill.

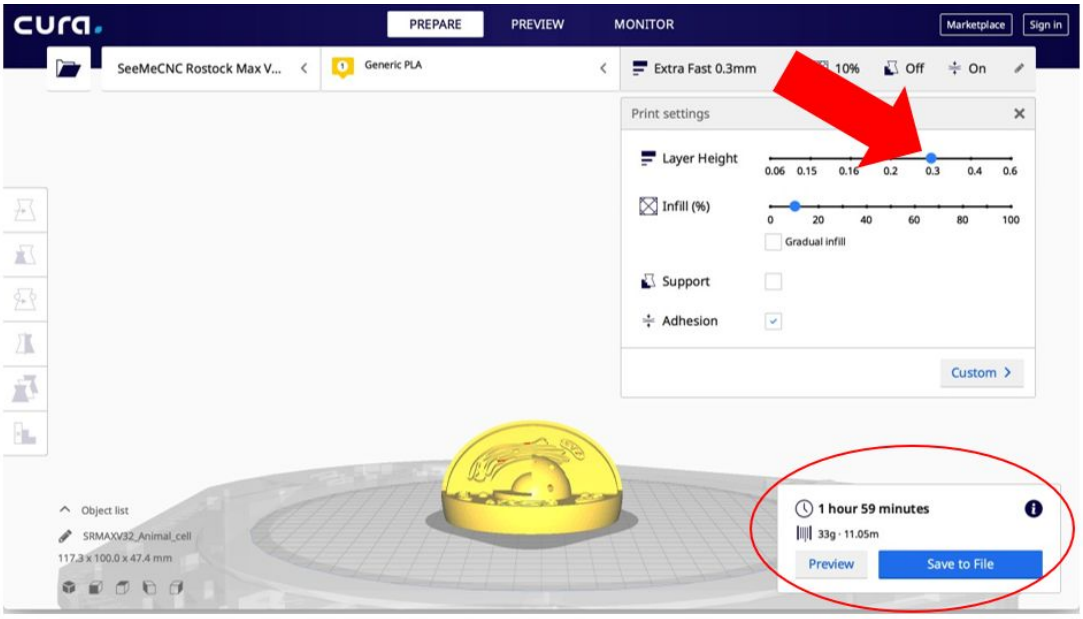


Fig 5. Image showing that a .3 mm layer height would take 1 hours and 59 minutes with a 10% infill.

5. Infill refers to the percentage of material present inside of the model. A 10% Infill means that the model is 90% air on the inside. This percentage can be adjusted to create sturdier prints with more infill depending on the size of the print. Smaller prints Different infill patterns have more properties for resistance to vibration or force but for general purpose the default grid pattern works for most models.

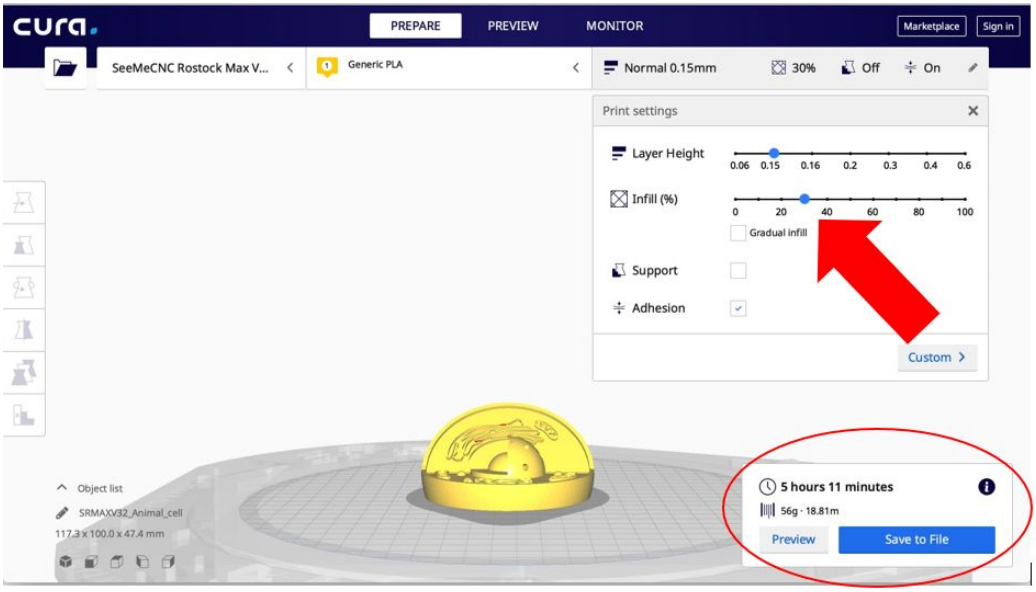


Fig 6. Image showing that a .15mm layer height with 30% infill would take 5 hours and 11 minutes.

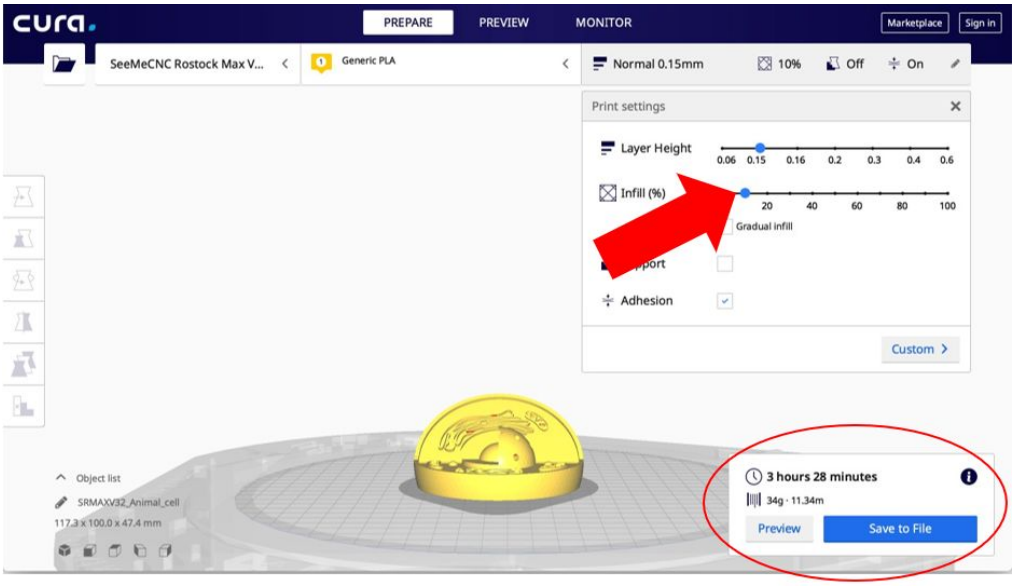


Fig 7. Image showing that a .15 mm layer height would take 3 hours and 28 minutes with a 10% infill.

6. After determining the parameters for your print, make sure the material selected for the print correspond to the type of material spool set on the printer, since that configures the temperatures for the nozzle and bed during the printing. Too low or too high temperatures can lead to bad prints or can cause your 3D printer to malfunction.

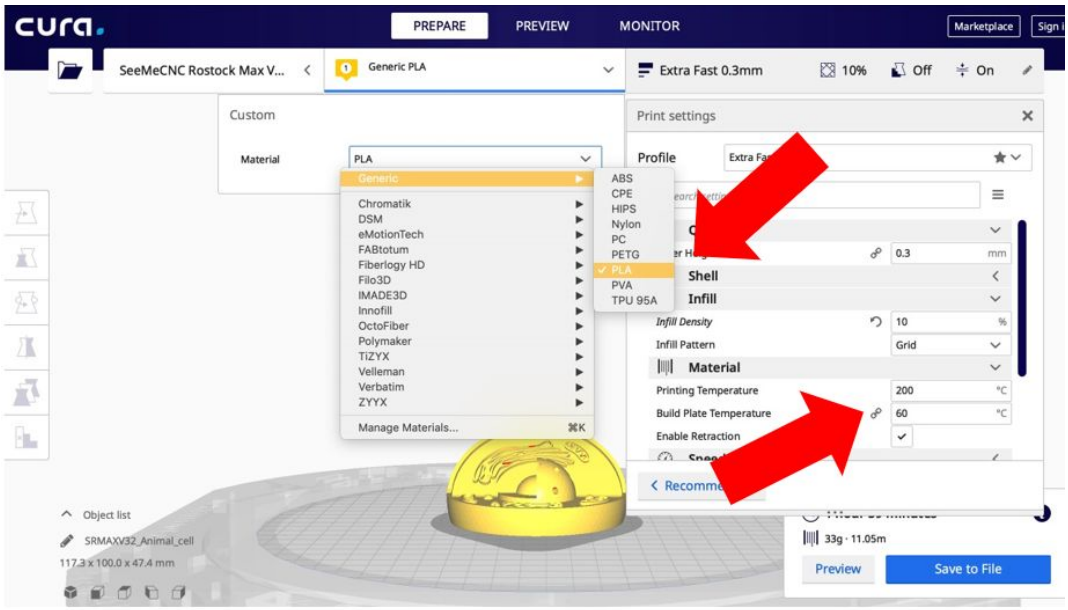


Fig 8. Image showing the material drop down menu for selecting appropriate material and the custom tab that shows the actual nozzle and build plate temperatures.

Note: Cura sets by default the temperatures for when the material is selected, but they can be modified depending on the specification by the spool's fabricator or troubleshooting seen from defects on prints such as stringing.

7. Finally, export your gcode and plug it into the 3D printer and you're ready to go!

Modeling in CAD

Considerations when designing in CAD
Make sure the material has a clear indication of the orientation of the model. Make use of small marking or indicator that help BVIS get the idea if they are holding the material in the correct direction. You can put letters referring to the cardinal point on the corners or markings such as a pronounced edge that has the same functions.

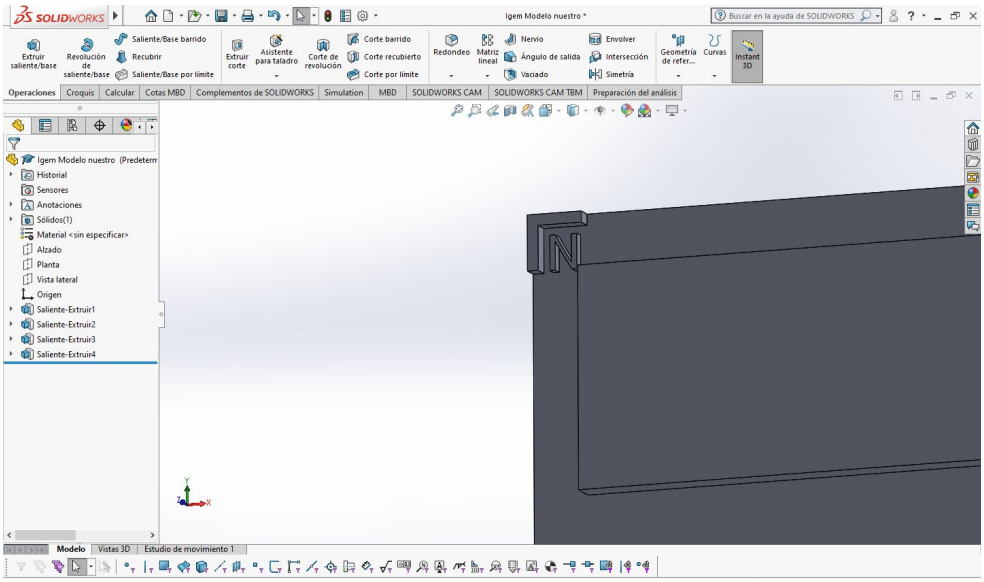


Fig. 1 Image of a model that has marking on its corner to indicate the orientation of the base.

There should be a difference between the area in which the models are located form the rest of the area of the model. Underneath the section where the models are located, braille or symbols that refer to each model. Models can be done in a 2.5 D or 3D way depending on the approach that is being taken.

Consider the accuracy and tolerance of your design so that it is easier to print. Poor design or expecting that every measurement matches the design using CAD software can generate some problems when printing the files. For example, if your 3D printer does not have the accuracy or is not well calibrated, fine details will not be able to be printed or may result in failed prints.

In order to properly troubleshoot problems and make appropriate changes in the design there are several pages that offer guides on determining the source of failed prints or printing problems. Some pages that we recommend based on our experience are:

1. https://www.simplify3d.com/support/print-quality-troubleshooting/
2. https://www.prusa3d.com/print-quality-troubleshooting/
3. https://www.matterhackers.com/articles/3d-printer-troubleshooting-guide

Note: See how to prepare your file using Ultimaker's Cura for a better explanation on parameters that can be changed without altering the CAD design.

Once your design is finished, consider sharing it with others! Making easily available these types of material can help people without CAD skills to be able to contribute and make their own adaptations of your model. Remember that sharing is caring, which brings up the next subject.

Tips for people not familiar with CAD modelling

If you are not an expert in cad modelling but still plan on using and developing your models for use in teaching fear not. There are several open source repositories where people form all parts of the world contribute their design about different subjects or models of their interest. These type of websites are useful to look for a model of your liking and adapt for didactic purposes. One of the most useful and widely used repositories is thingiverse.com, which has a large library of really cool designs and models that can be useful for this purpose. Each author put the printer setting as well as parameters used for slicing their models to make easier for you to be able to replicate it in your 3D printer.

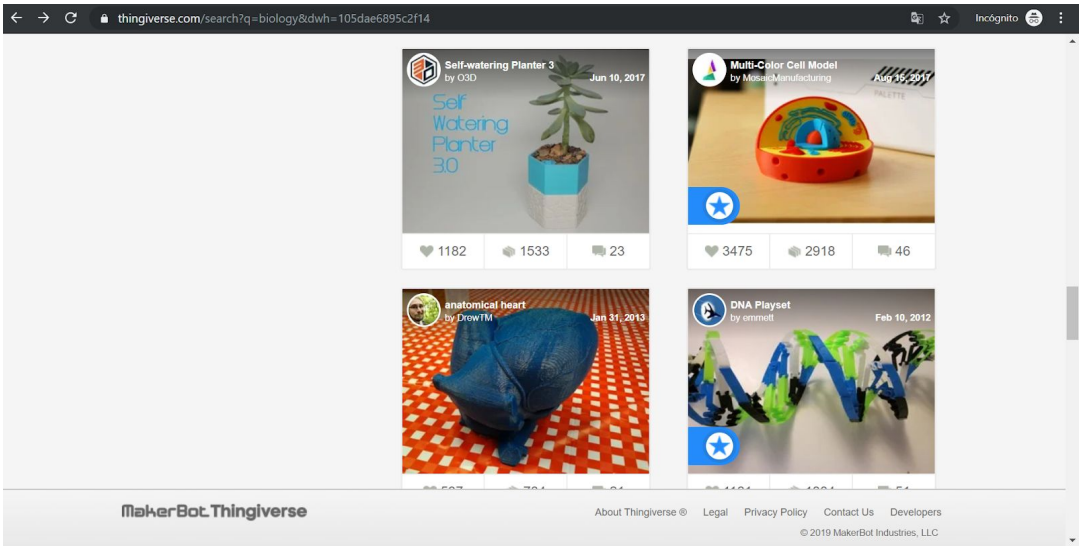


Fig. 9 Screenshot of examples of search result when looking the term "Biology"

Ideas to Texturize and Decorate the Models

There are several ways in which the models can be decorated. This would depend to some extent on the students being taught, however the possibilities are endless. Teachers should look for ways to make them attractive to both sighted and BVIS, always focusing on textures that can be differentiated from one another. and verbally describing each texture with adjectives that can accurately be translated by the students when running their hands around the model.

To simplify the learning process, decorations can mimic the way that objects feel in real life. (In the case it can be actually touched) This may be the case when the students are learning a topic such as farm animals, where the textures can simulate an animal's fur. In the case of Synthetic Biology though, there is no way of applying this strategy, therefore any material can be used. Some of the preferred materials to be used are the following:

- cotton
- glitter
- cardboard
- tissue paper
- wood
- plastic bottles
- thick paint
- dried-up glue
- among many others

The reasoning behind using these and not others is the ease at which you can find them. Recycled materials are ideal because there is no extra charge coming from producing a model. However, any material can be used as long as it is not harmful to touch, smell or taste. The most important factor when choosing which material to use is the description that is going to be given when talked about on the audio cues. It is important to take this into consideration as the teacher will need to accurately describe it if it ends up on the final model.

Selecting information for the audio cues

When curating information to add as audible cues for the model, it is important to have a logical order that corresponds to the model for teaching certain concepts. For example, when teaching about an animal cell, an approach that can be logical for teaching the information is starting from the outside components such as the cell and afterward generate other layers of information explaining the organelles cell up to the nucleus of the cell. That way, students are able to follow along with the model in a way that is able to make sense to them. Also it is more common for student to start touching the outside part before working their way into the inside of the model.

Another important aspect so that the representation and explanation can be accurate, is explaining accurate concepts without going into the complex inner mechanisms that trigger it, since they are better depending on the level intended for the model that matches the level of the students. An introductory model to animal cells might explain the basic function of each component of the cell without going to deep into the chemical complexity and interactions of each part but keeping the accurate role of each part.

Something important to consider for the audio files is to include description and orientations of the model to help student make sense of what they are touching. For example, a possible description that explains model of the central dogma could start something like this "On the left most part of the model you can feel a shape that has long thin lines that are intertwined

in the middle, this represents a double helix DNA ….next to that you can feel the same shape but only one strand that represents RNA … etc”

In order to engage with students better, starting with familiar concepts or general explanations work as an introduction to the subject the model is teaching, so that students are able familiarize and connect the new information the preexistent notions they have on the subject.

Application in SynBio

Currently, lessons about SynBio are not included in the actual curricula for students from Elementary, Middle School and High School. However, we believe they are important to get a better understanding of the world around us and how this technology can be applied in the future. For this reason, the use of inclusive material of this nature is important in teaching a subject related to Biology and SynBio. Since most of the concepts used in these areas are of microscopic nature, adaptations scaled into bigger proportions are useful to explain what was usually taught through the use of images. The idea with this is that the materials can be both useful to sighted students and BVIS in understanding these topics, that way it is used equally by both groups of students to achieve inclusion in the classroom.

Due to the abstract nature of some of the concepts related to SynBio, simplifications or representations should be taken into consideration when looking for models or designing one. For example, in order to explain the central dogma, one way of explaining the topic would be by making a representation of a double helix DNA, a single stranded RNA and a simple model of a protein to give the idea of a process that involve these important steps. The explanation of the relation of these models as well as the relevant processes are described by the audio so that with both strategies combined, the learning process can be more efficient.

Some topics that can be taught using these models are the following:

- Parts of a cell
- What is a Virus?
- How do bacteria look like?
- CRISPR, its application on health, food and agriculture
- How can a genome be modified?

This are just a few examples but in reality teachers may choose any topic. The concepts portrayed do not need to be very complex as models are supposed to be accompanied by a teachers’ lesson, so whatever is learned by feeling and seeing the model should be then complemented with extra information that will help to complete the lesson being taught.

Figure 1. Several models of SynBio that we replicated.

General considerations when teaching to BVIS

1. There are some limitations when using this tool, but mostly it will depend on your imagination! Abstract concepts may be more challenging to model using a 3D printer, however, there are many ways in which they could be simplified or adapted to fit you students' necessities.
2. Anyone can learn from this prototypes, from the youngest to the oldest. The versatility of printing in 3D is that anyone can make a model according to the topic they want to cover.

3. Models can also be adapted to teach students with hearing impairments! In these particular cases, the teacher, instead of relying on audio cues, may want to either transcribe the information into paper or create a video using their sign language of preference.
4. This manual contains the basic information on how to develop your own models, nevertheless, teachers can complement the information with as much knowledge as they already possess. The idea of making this manual is to share what has already been created and build upon with new ideas and ways to implement it, creatively.
5. It is ideal to accompany the models with a teacher's lesson, as not everything can be learnt from an object, it must be used mostly as a tool to catch the student's attention and integrate students with disabilities into the traditional curriculum.
6. Remember to give orientation when placing something so that students are able to easily find the material or model for use.
7. Remember to have fixed placements for materials the distribution in the classroom, this is so students feel more comfortable as they are aware of the spatial position of the room. Remember to also keep the classroom door either completely opened or completely closed to avoid having BVIS bumping into them.

References

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[2] C.G. Reynaga Peña, I. Hernández Valencia, J.N. Rico Moreno y D. Treviño Escobedo, "Educación científica de niños con o sin discapacidad visual por medio de representaciones táctiles auditivas y actividades multi-sensoriales," IX Congreso Internacional sobre Investigación en Didáctica de las Ciencias, Girona, España, 2013, pp.2997-3001.
[3] M. Chan y J. Black, "Direct-manipulation animation: incorporating the haptic channel in the learning process to support middle school students in science learning and mental model acquisition," Proceedings of the 7th International Congress in Learning Sciences ICLS, International Society of the Learning Sciences, 2006, pp. 64-70.
[4] D.H. Rose, W.S. Harbour, C.S. Johnston, S.G. Daley y L. Abarbanell, "Universal design for learning in postsecondary education: reflections on principles and their application," Journal of postsecondary education and disability, vol. 19, no.2, pp.135-51, 2016.

3D Printing Appendix

In the print settings, there are several different factors that can be changed to achieve a better 3D print. For basic use, only the quality, infill, material, speed, support, and build plate adhesion will be covered with its basic settings.

Quality

Layer height: defines que height of each layer, a higher amount is a coarser print.

Initial layer height: first layer to be deposited, since it is important to have a good adhesion with this layer, a higher amount can be a good idea.

Infill
Infill density: density of the total 3D print, a higher density uses more material, takes more time to be done, but is more durable and resistant.

Infill pattern: depending in specific needs, different patterns can be used, if it is not important to change the way in which this pattern will be building up the structure, the standard grid or zigzag can be used.

Material
Printing temperature: temperature at which the filament will flow, for standard ABS temperature is of 235°C and for PLA 200°C.

Build plate temperature: temperature for the heated bed, should be high enough for the first layer to be deposited properly, for ABS use 80°C and for PLA 60°C.

Speed
For ABS change the Print speed to 40 mm/s for optimal printing, for PLA leave it at the original value.

Support
Check the Generate support box if there are parts of the model with pronounced overhangs, otherwise the printing could collapse or not print correctly depending on the model.

Build Plate Adhesion
Build Plate Adhesion type: Brim is usually fine, gives some error margin for the initial layer.

Brim width: Change for the distance of the total brim, a value between 5 and 8 mm is good.