Where Does 3D Printing Fit Into Your Pedagogical Thinking?

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I’m a biologist so why did I want a 3D printer?

I realized that I could design 3D prints from 2D photographs or jpg files and make tactile learning objects for blind and visually impaired students.

But, the majority of learning objects produced today exist in the digital world and many have a structural component at their core which if 3D printed would permit a digital learning object to exist in the real world and now available as a way to learn by tactile means, i.e., touching and feeling.

So, I wanted a 3D printer to design a proof of concept that I could make a tactile learning object.
3D Printing has been listed as one of the disruptive technologies ready to mature over the next 4 - 5 years but affordable 3D printers such as those listed below are now available for the home or office. (There are many other models as well.)

**Replicator 2**
- fully assembled
- 0.1 mm nozzle
- large build platform
- approx. $2100.00

**Prusa-Mendel**
- self-assembled
- 0.3 mm
- large build platform
- approx. $440.0

**Cube**
- fully assembled
- 0.2 mm nozzle
- smaller build platform
- approx. $1300.00

I chose Replicator 2 for build platform and smaller nozzle opening.
My Replicator 2 arrived in late January, 2013 after an 8 week wait due to the damage caused by Sandy. The MakerBot store is located in Brooklyn.

My Replicator 2 is below and has been modified to fit into my work area in my home office.
What do you need to make an object with a 3D printer?

1. 3D Printer requires a stereolithographic file (stl) in which the 3D image is sliced from bottom to top and is used to build a structure layer by layer so 3D printing is sometimes referred to as additive manufacturing.

2. CAD programs can produce stl files but I found software that can make stl files from 2d photos in JPEG format called PhotoToMesh (www.ransen.com).

3. What is produced is an stl file that raises the dark areas of the photo higher on the Z axis than the lighter areas now lower on the Z axis.
3D printing workflow - for CAD-free stl file production

2D photo (jpg file) → PhotoToMesh software

Adjust captured image for best 3D appearance

Save as stl file

Use MakerWare to load stl file into Replicator 2 and adjust software for best print.

Wait for stl upload and 3D printer to begin to print object.

Let's Make Some 3D Prints
PhotoToMesh Software

* Makes 3D STL files from 2D photographs or JPG images
* Black or darker colors given lower Z-axis values
* White or lighter colors given higher Z-axis values

Example 1 - 3D Printed Business Cards in Braille
Example 2 - Histology slide image - neuromuscular junction
Example 3 - Gross Anatomy - posterior left leg muscles
*Used Braille Translator for text to Braille  
(see http://www.brailletranslator.org/ for software)

Space on single card side limited when Braille symbols used so opted for “tent” card - 2 cards hinged together

These are end product - how did they get made?
Used Adobe PhotoShop to produce two 3.5 x 2 inch rectangles with background black and Braille raised bumps white to save as jpg files.

*Remember that black will be saved in the stl file lower on the Z-axis and white will be higher
PhotoToMesh production of stl file

Loading stl file into 3D printer with MakerWare software
Use MakerWare Software to load stl file into 3D Printer

MakerWare prior to stl file load
Note that two Braille cards loaded onto build platform
MakerWare software as it loads stl file into 3D printer
3D Printing Begun
Use knife to pry 3D Print off of build platform
Assembled Braille Tent Business Card

Image shown for printing Braille with smooth bumps in vertical direction.
Braille bumps come out smoother if 3D printed in vertical rather than horizontal position

back view of 3D printer to show filament on spool being fed to extruder
General rule of thumb with PhotoToMesh software is that some color adjustment or grayscale or inverted coloration “tricks” need to be done to ensure proper Z-axis location for areas of jpg files or photo images.

Let's look at 3D Prints using Replicator 2 follow.
Example 2 - Histology slide image - neuromuscular junction

Original Image from Primal Pictures Anatomy & Physiology Online etext

Adobe Photoshop Inverted, Grayscale
(note touch up to balance light and dark coloration)

PhotoToMesh
Higher Z-axis with lighter color

Completed 3D Print with labels

Completed 3D Print
Skeletal Muscle Fiber Striations (Histology)

3D Print

3D Print Labeled

Original image from Anatomy & Physiology Online etext by Primal Pictures
Simple Cuboidal Epithelium
(Histology)

3D Print

3D Print with labels

Simple cuboidal epithelium
Basement membrane
Lumen

Original image from HAPS data bank
Ulnar Nerve - Gross Anatomy
Transverse Section at Elbow

3D Print

3D Print with labels

Original Image - National Library of Medicine
Virtual Human Project
More 3D Print Examples in Histology, Cell Biology, Astronomy and Geology

These stl files were sent to i.Materialize in Belgium to be made into 3D prints. Turn-around time for 3D print production was around three weeks and each 3D print cost just under $17.00 to make. If the order was more than $100.00, shipping was free.

These 3D prints were made with polyamide on EOS 3D printers using Laser Sintering technology. See http://vimeo.com/14737152 for more information.
Astronomy 3D Prints (original photos from Hubble website)

Saturn

Jupiter

Butterfly or Bug Nebula
Geology 3D Print (original image from LandSat web site)

Mississippi Delta USGS

Mississippi Delta USGS with labels

Mississippi Delta USGS Original image from LandSat site
So, when does a learning object become usable?

For instructional design - when it stands alone, is reusable like “Lego” blocks and delivers learning.

For the learner - when they can access it!

What has been shown thus far is that 2D images and computer generated graphics can be made into 3D prints - we have our “proof of concept”.

So, what must be added to our 3D prints to make them usable as a tactile learning tool?
What is needed to make the telophase 3D print into a tactile learning object (a TLO)?

Need some way to have labeling such as plastic or metal arrows or lines to each muscle and tendon

Text to Braille directions with explanation of what structures should be identified

Need to have a way to test for knowledge gained from using real learning object (a TLO)

Not all blind or visually impaired students know Braille - should also have LiveScribe audio option

Let’s look at a first attempt at a telophase tactile learning object.
Progress toward making first Tactile Learning Object or TLO

Original 3D Print  "Line" Graphic  Structure list in Braille

Let's look at individual components
Steps to make a line graphic 3D print from original 3D print

Original 3D Print → Line Graphic 3D Print

Make Black & White in Photoshop

JPEG file → JPEG file

Adjust color to desired future Z-level
Braille identification of structural elements of TLO

- cell membrane
- chromosomes
- cytokinesis
- spindle fiber
- chromosomes
- cytoplasm
Addendum links:
a. 3D prints made using MakerBot Replicator 2
   www.nextgenemedia.com/3DPrint/3DprintExamples.html
b. 3D prints made using i.Materialize
   www.nextgenemedia.com/3DPrint2/3DprintExamples1.html
c. 3D scanners - www.makerbot.com/
d. 3D pen - www.the3doodler.com/

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Discussion Questions
Should digital learning objects all be made real and accessible?

What other methods exist for 3D printing of 3D objects?

Where else does 3D printing fit into the curriculum?

How does copyright fit with ability to 3D print?

Where should faculty go who need help 3D printing?

Should the library be viewed as a site for 3D printing?

How can students help make what faculty need in 3D printing?

Is 3D printing really a disruptive technology?