Technology Division
Cullen College of Engineering

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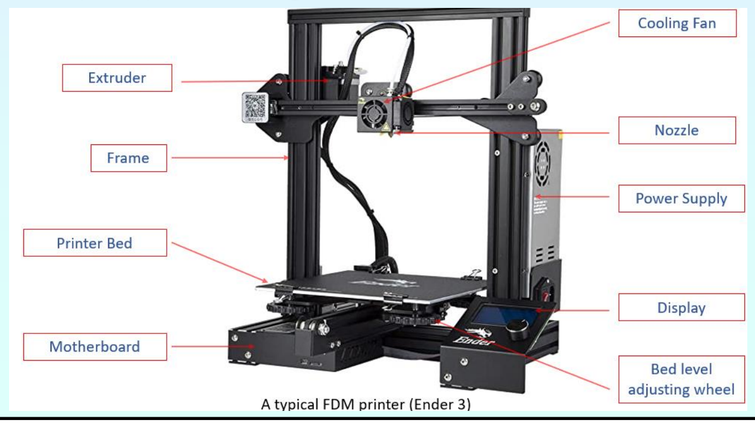
Dissecting 3D Printing for Engineering Design Education with High School Preservice Teachers

Introduction

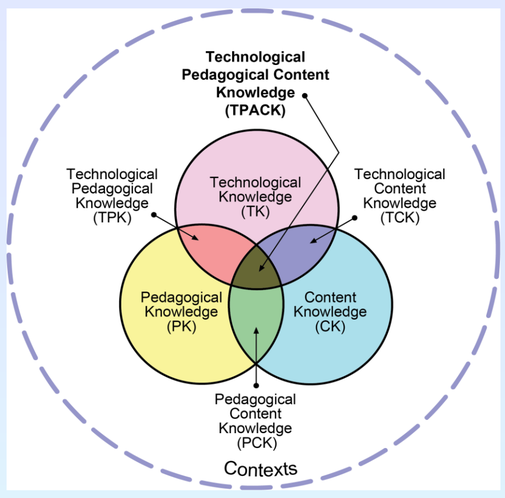
High school is a critical period for students to decide their imminent university major selection which in turn will impact their future career choices. High school students are usually intrigued by hands-on tool such as 3D Printing (3DP) which is also an important contributor to other courses such as robotics. However, mere availability of 3DP is not enough for teachers to fully utilize its potential in their classrooms. While basic 3DP skills can be obtained through a few hours of training, the basic training is insufficient to ensure effective teaching Engineering Design Process (EDP) at the high school level.



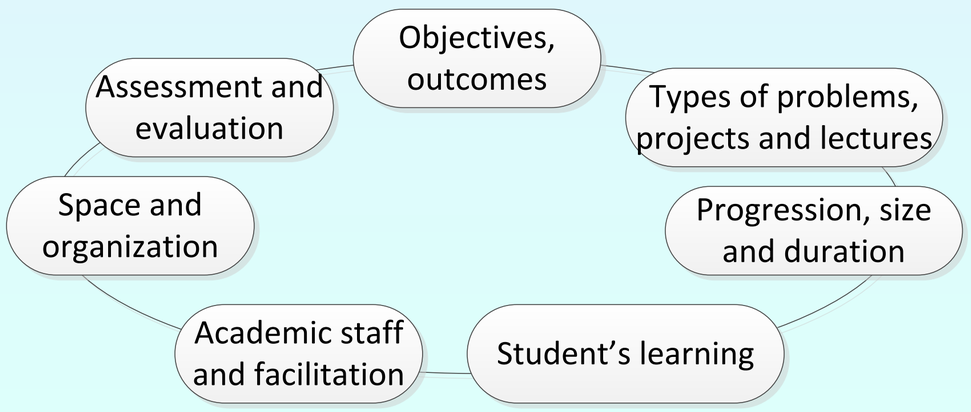
A typical FDM printer (Ender 3)

Literature Review

Technological Pedagogical and Content Knowledge (TPACK): guides our course design.



Problem-based Learning guides our pedagogy.



Methods

This project develops an EDP course tightly integrated with 3DP for preservice teachers (PST) who are going to enter the workforce in high schools. Engineering design process (EDP) has become an essential part for preservice teachers (PST), especially for high school STEM. 3DP brought transformative change to EDP which is an iterative process that needs virtual/physical prototyping. The new PST course on EDP has been purposefully integrated with an in-depth discussion of 3DP.

#	Hrs	Contents	Key Information
I	6	Engineering design process	Reverse Engineering of a product; customer needs matrix; sketch; functional models; activity diagrams
II	9	Part 1: 3DP dissection and reverse engineering	Disassemble a 3D printer and identify components, materials, and their manufacturing methods
	3	Part 2: 3DP operation	3D printing process, G code, STL, slicer
	6	Part 2: 3D modeling	SolidWorks Apps for Kids; open source models
	3	Part 2: 3DP troubleshooting	Print quality, calibration, post-processing, maintenance
III	6	Invention design challenge	Each group prototype an innovation using 3D printed parts and standard components that can be purchased
IV	12	Curricular development	Preservice teachers' own lesson plans

Dissecting a 3D Printer

The approach is to dissect a 3D printer's hardware, explain each component's function, introduce each component's manufacturing methods, describe possible defects, and elucidate what works and what does not.

No	Components	Materials and/or Machine Elements	Manufacturing Processes
1	Plastic filament	Polymer materials	Plastics extrusion
2	Aluminum frame	Aluminum bar	Bulk deformation
3	Heated bed	Aluminum sheet metal	Sheet metal working
4	Belt and pulley	Belt and pulley standard	Rubber, casting / machining
5	Spring	Spring standard	Winding
6	Bearing	Bearing standard	Heat treatment, sheet metal
7	Leadscrew rod	Screw standard	Rolling
8	Bolt and nut	Bolt and nut standard	Cutting, forging, heat treatment
9	Nozzle	Rotational part	Machining

Benefits

1) PSTs will know what is possibly wrong when a printer or printing process fails,
2) PSTs will learn more manufacturing processes besides 3DP that can be used to support engineering design prototyping,
3) PSTs will know how to design something that can meet the manufacturing constraints, i.e., can be actually fabricated, and
4) reduce errors and frustrations caused by failed design and failed prints which happen frequently to novices in 3DP.

Lessons and Conclusion

- The course has been implemented in spring 2024 semester with a focus group of 6 students.
  - Start student recruitment early
- Additional time and opportunities for practice with prototyping and curricular design needs to be allotted than what was originally planned.
- PSTs found creative ways to integrate engineering design into their desired content area (i.e. biology, chemistry).
- Customer needs analysis during reverse engineering leading to more in-depth discussion around data literacy and data analysis.
- PSTs developed prototypes using 3D printers for pieces that could be integrated into their lesson and for things they can be useful to their everyday activities.
- PSTs recognized limitations with 3D printing integration with regards to the time needed for prints.

Broader Impact

1. After graduation, PSTs will bring the knowledge to their future high schools and will be more confident in teaching engineering design, reverse engineering, prototype development, manufacturing, and technology.
2. The course modules have been disseminated through multiple channels including in-service teachers in the Research Experience for Teachers site and pre-service teachers in the Research in a STEM setting at University of Houston.

Reference

1. Chai, C., & Koh, J. (2017). Changing teachers' TPACK and design beliefs through the Scaffolded TPACK Lesson Design Model (STLDM). Learning: Research and Practice. doi:10.1080/23735082.2017.1360506.
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National Science Foundation
WHERE DISCOVERIES BEGIN
IUSE Grant# 2174674

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