

# Developing 21<sup>st</sup> Century Skills Building a Low-cost 3D Printer

Kristina Granlund-Moyer, Crystal Perez, Emma Lejeune, Christian Linder  
Department of Civil and Environmental Engineering, Stanford University, CA



## Abstract

A low-cost printer kit (\$229) was assembled and tested in partnership with a high school summer intern in the RISE program at Stanford. Although the resulting system has limited functionality at this time, the process of building, testing and maintaining the printer provided an engaging series of hands-on learning experiences in 21<sup>st</sup> century skills for the intern.

## Introduction

Additive manufacturing makes creating novel designs with features on the micro- and macro-scale feasible. The Linder Lab at Stanford focuses on computational mechanics, and is currently looking into software tools for modeling the additive manufacturing process and 3D printed structures. The goal of this project was to build a low-cost He3D I3 Prusa-style printer for subsequent study of some small-scale engineered structural components. Additionally, the project introduced the RISE intern to the field of engineering and provided daily lessons that developed increasingly sophisticated levels of knowledge and thinking, and 21<sup>st</sup> century skills.

## Remembering, Understanding & Applying

The printer kit arrived in a box with 150+ components, some grouped in zip-top bags, and a packing list. Checking the packing list against the physical components allowed us to familiarize ourselves with the component names, and initiated discussions of stepper motors, printed circuit boards, and the t-slot geometry used in the frame design.



Figure 2. Printer components as shipped. (Right) A typical zip-top bag and its contents.

Assembly instructions were gleaned in a true team effort from two pages of exploded assembly drawings and several poorly-edited videos with no sound. Assembly introduced the intern to many hand-tools (e.g. calipers, wrenches, screwdrivers, pliers, wire strippers, level, multi-meter) and fabrication techniques (e.g. use of various fasteners, cabling). T-slot nuts fastening the frame and subassemblies were difficult to align; initially the intern found this task unapproachable, but ultimately developed the patience and technique to do the alignment on her own.

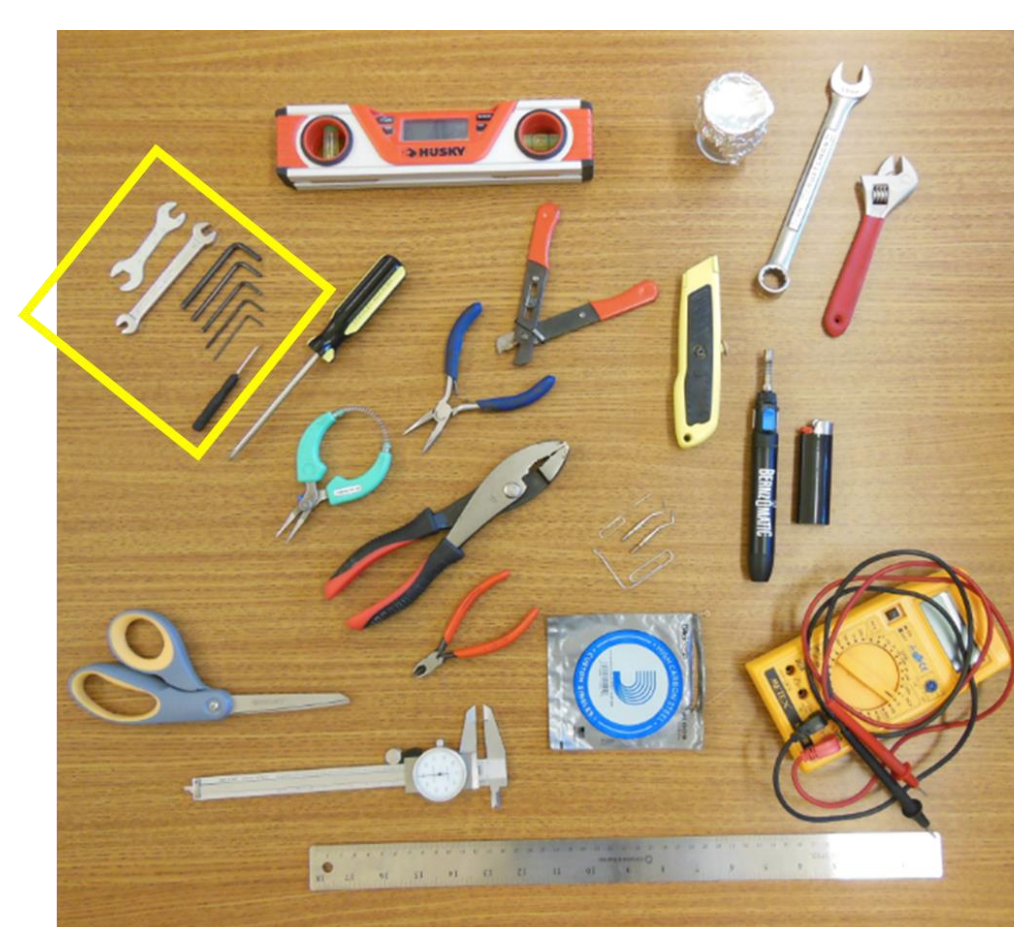


Figure 3. Tools for assembly and maintenance. Kit tools appear in the yellow box.

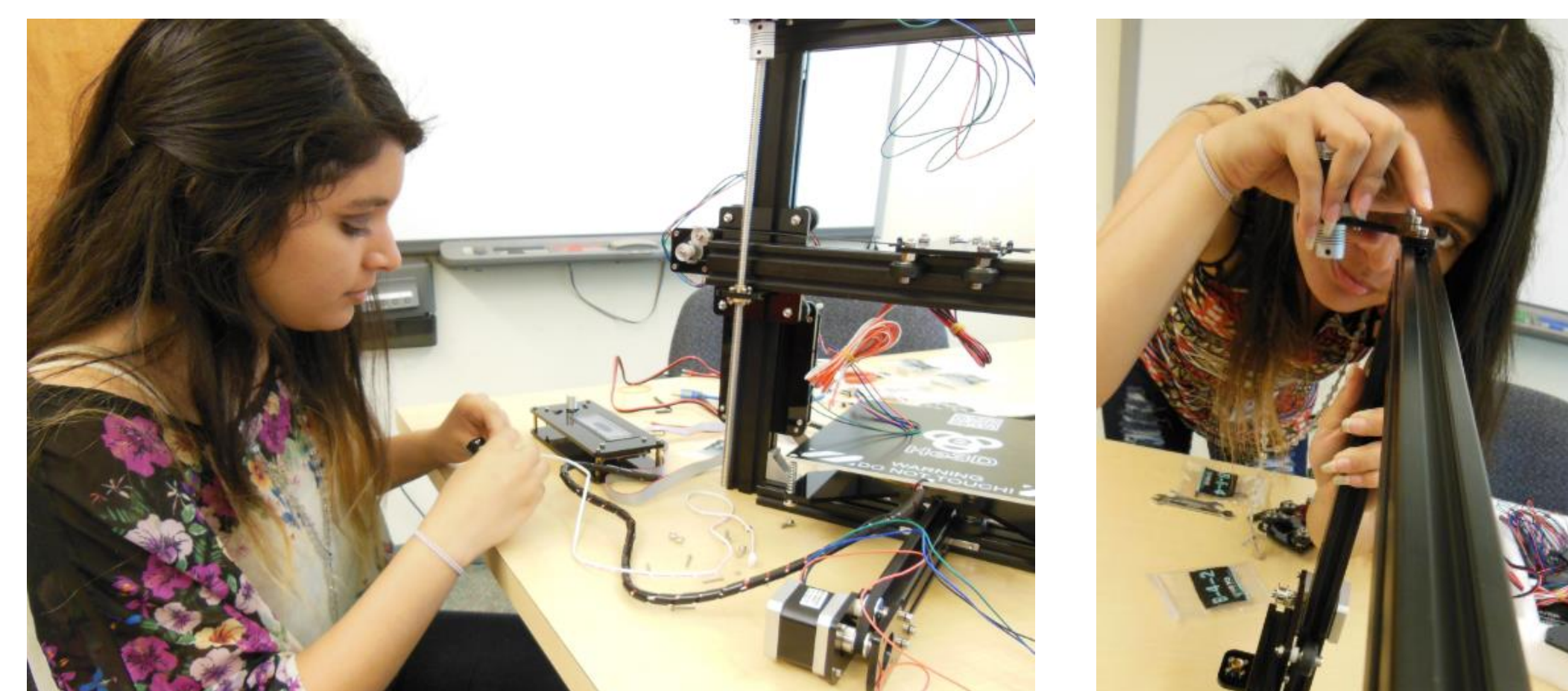


Figure 4. Assembly tasks: (Left) Connecting the y-axis limit switch; (right) Aligning the z-axis motor support t-nuts.

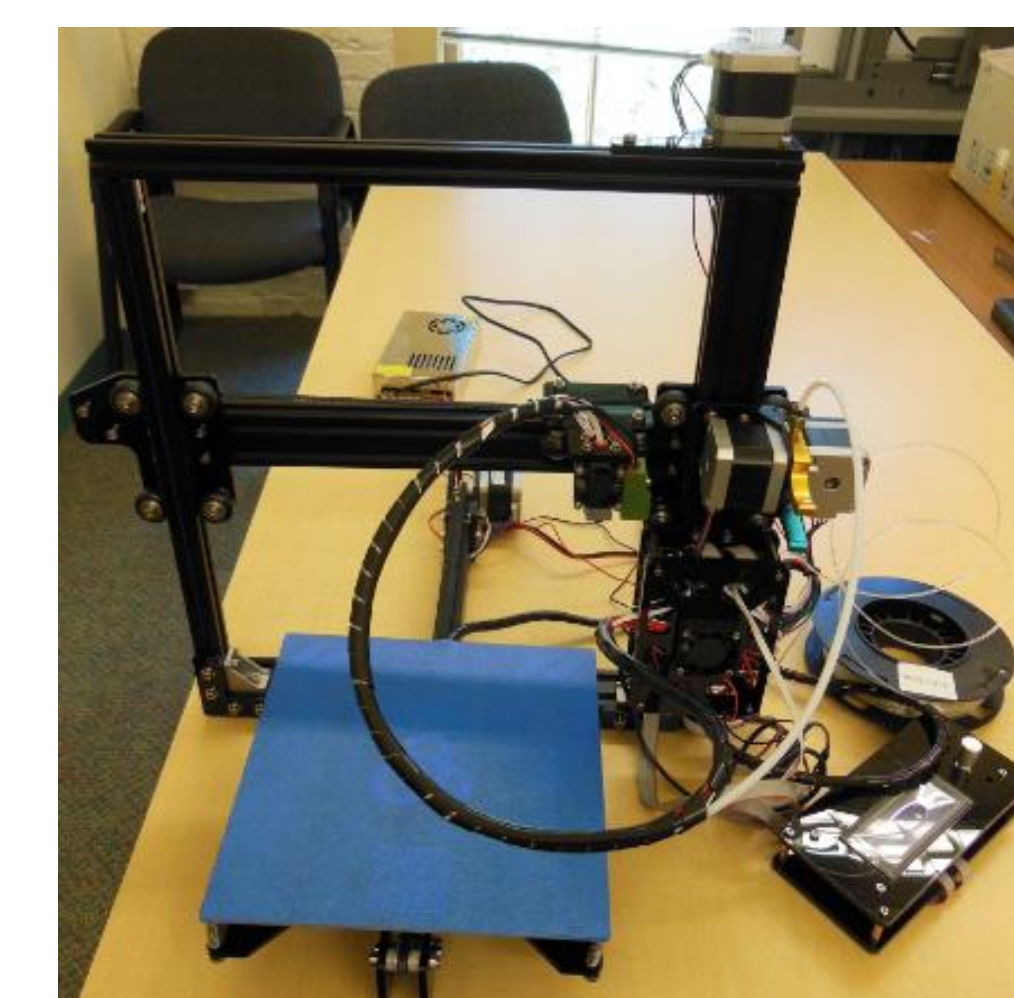


Figure 5. Printer assembled.

With an assembled printer, our discussions turned to the process of designing printable objects, preparing design files for the printer, and the 3D printing process itself. The intern was introduced to CAD modeling, the Cura application for defining 3D print layers from a CAD model, and the programming language (g code) actually processed by the printer as it runs.

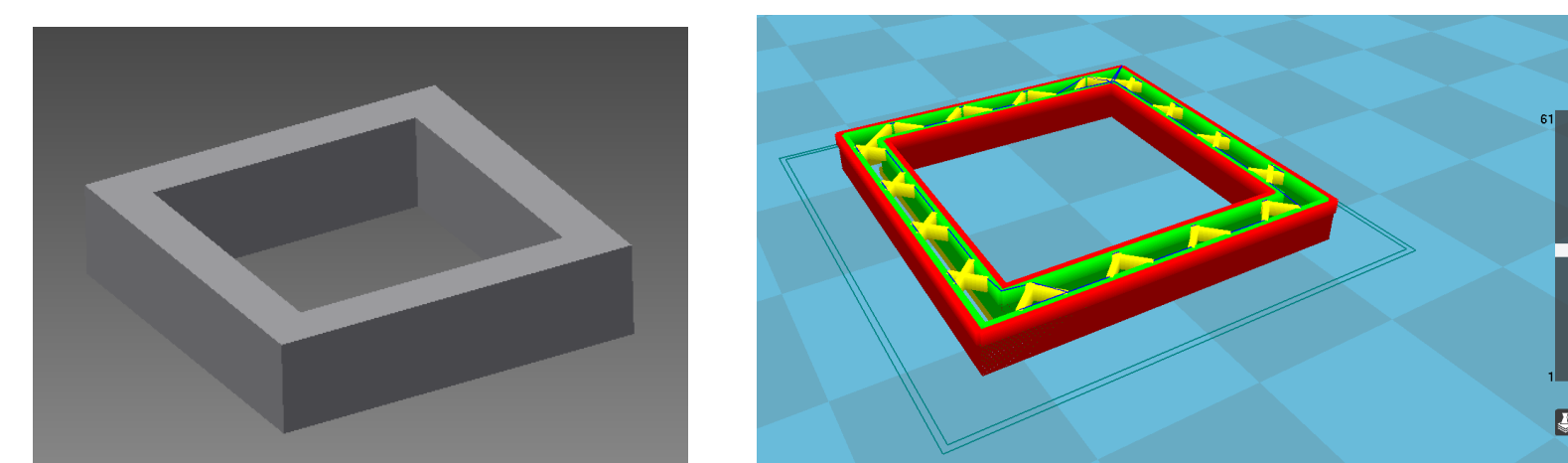


Figure 6. CAD model in Autodesk Inventor and "sliced" test print model in Cura.

## Analyzing, Evaluating & Creating

With the printer assembled and powered on, troubleshooting began. No operational documentation had been provided, and customer support from the supplier was hampered by time-zone lag and language issues. Linder Lab colleagues with troubleshooting skills collaborated on improving orthogonality between the print bed and extruder axes, clearing clogged extruder nozzles, and print parameters. Dozens of postings from the global 3D printing community were scoured for best practices.

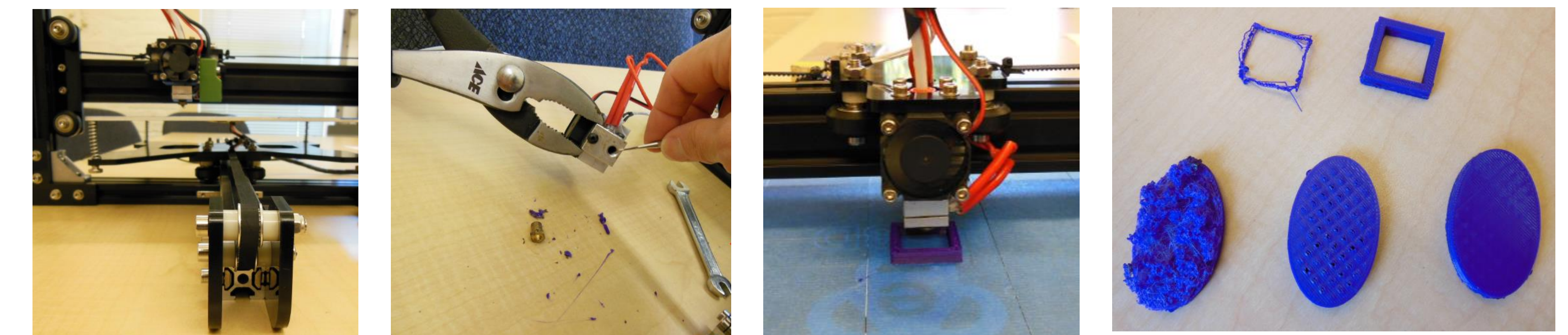


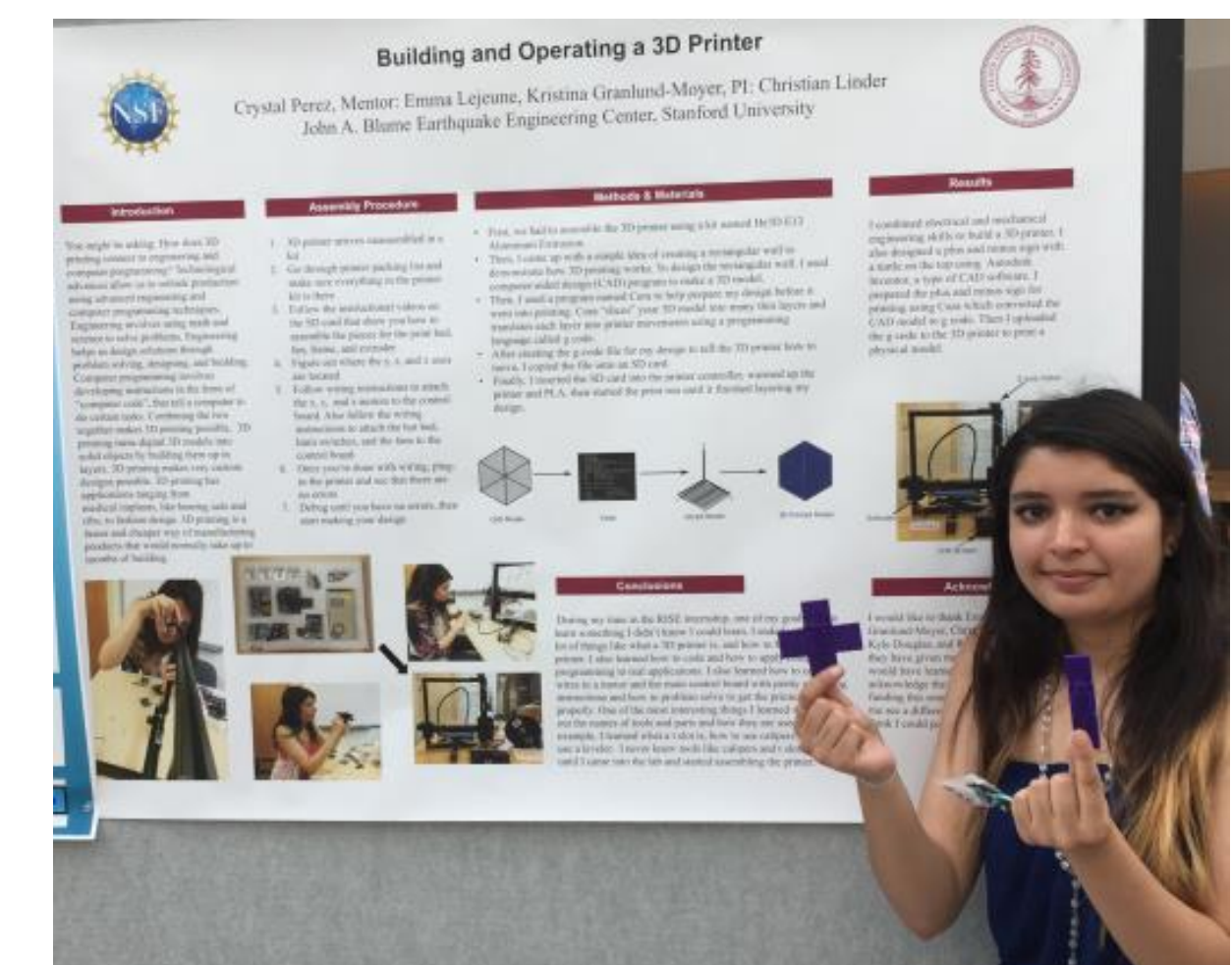
Figure 6. Recurring issues. (Left to right) Variations in extruder height above the print bed cause uneven printing; extruder design and mis-assembly lead to leaking plastic blobs and clogging; successful simple test print; improved printer results (top left to bottom right) over changes in hardware, set-up and parameters.

## 21<sup>st</sup> Century Skills

Our assembly and troubleshooting of the 3D printer has been an excellent example of **collaboration and teamwork**, demonstrating the usefulness of bringing the complementary skills of many people to a task. **Critical thinking** was essential in deciphering incomplete assembly and operational information, **creativity and imagination** in devising techniques for making adjustments using the tools at hand and designing models to test printer performance. **Problem solving** allowed us to unclog the extruder and draw conclusions from print run observations.

## Conclusion

Although further adjustments to hardware, print parameters and processing will make our 3D printer a more useful device, the 3D printer project has been a rich teaching tool. As a result, the intern understands the 3D printing process, has assembly experience, is adept with a range of hand-tools, is comfortable using her observations to identify and address problems with a mechanical device, and is poised and confident discussing her knowledge of the device with others.



## Acknowledgements

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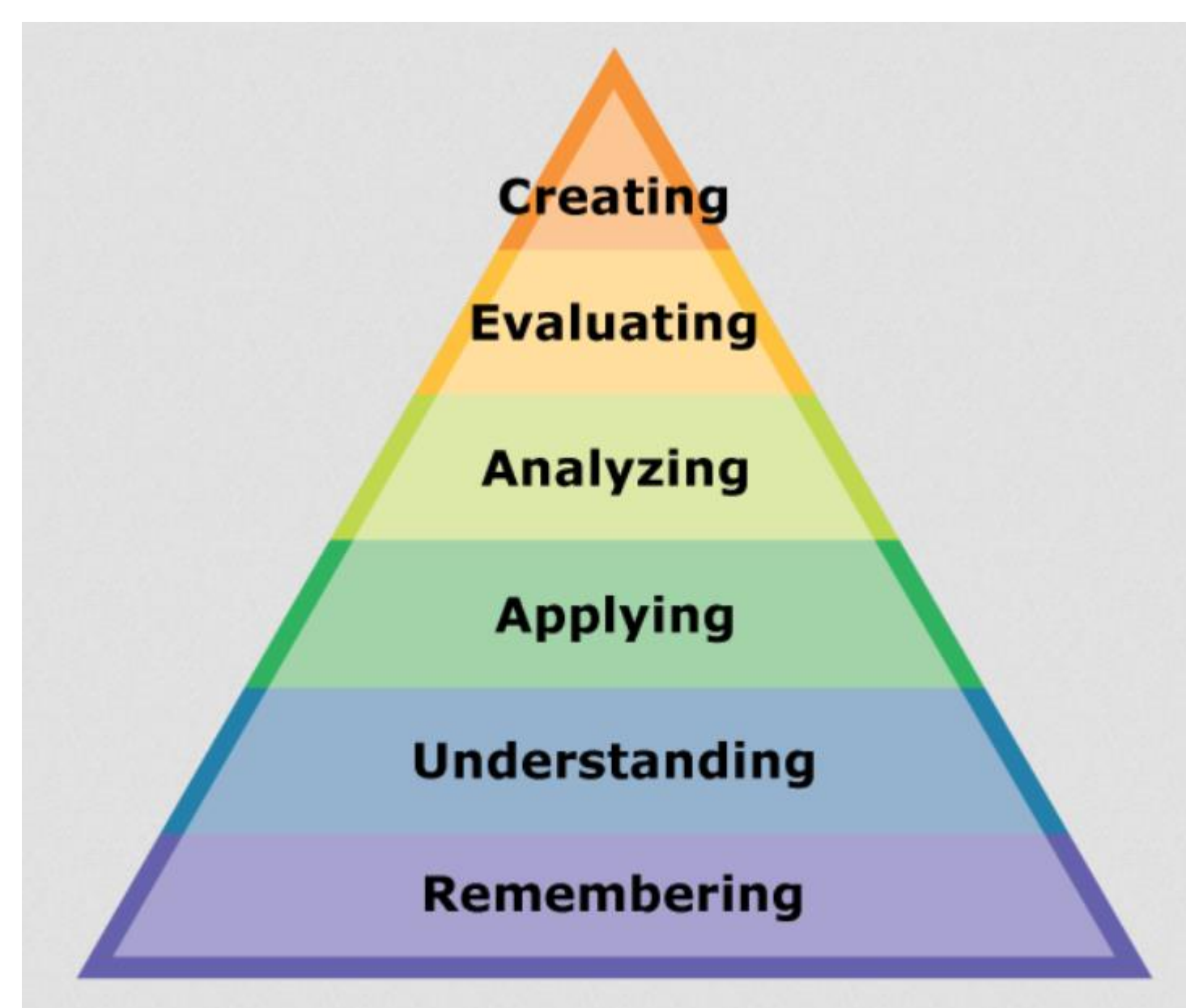


Figure 1. Bloom's Taxonomy links stages + depth of learning in a hierarchy from remembering to creating.