Designing a Cost-Effective 3D Printed Visible Spectrometer

A. Project Description

Instrumental analysis is an important aspect in understanding chemical properties of various chemical compounds. It is necessary to understand how the instrument operates to truly interpret the data it provides. A visible spectrometer is an instrument which measures and records how a substance absorbs light in the visible spectrum. The spectrometer collects a base reading with a blank sample before comparing the blank absorbance value to that of a sample with analyte.[1] Standard spectrometers cost thousands of dollars to purchase and are difficult to assemble. Thus, there is a need to develop a cheaper, low-cost educational option for students analyzing spectrometers. In this research, I seek to develop a cost-friendly visible spectrometer designed out of 3D printed parts. 3D printing is inexpensive and takes little time to print out a design. With the help of 3D printing, this project will enhance the educational opportunities for undergraduate students and reduce the cost of equipment for the University of Nebraska at Omaha.

B. Methodology

I intend to design and build an inexpensive, visible spectrometer with a high resolution. With prior understanding of how the parts of a spectrometer operate, I will design the individual parts of the spectrometer using 3D printing software. A spectrometer consists of multiple components such as mirrors, lenses, diffraction grating, and detectors[2] as seen in Figure 1. These pieces will be placed into holders created in the 3D design. Therefore, it will be crucial to properly align these holders at the correct angle and allow room for the light to reach the detector once the components are placed inside the spectrometer. Inconsistency in alignment would cause the resolution of the spectrometer to decrease substantially.

<u>3D Printing</u>

The first step to completing the project is to gain experience using a program in which the spectrometer can be designed. Therefore, it is necessary to understand how to operate 3D design software. I will use TinkerCAD, a free 3D printing software, to create a virtual model of the spectrometer. TinkerCAD provides clear tutorials on how to operate 3D printing. Additionally, the software stores previously created models in secure files and allows easy access to basic blueprints.[3] Different pieces can be manipulated and assembled together while being analyzed from all angles. Initially, I will create simple designs and work on developing skills in the software before advancing to the final product.

<u>Physical Design</u>

After gaining an understanding of how 3D printing software works, I will begin printing and piecing together a physical model of a spectrometer. The design of the spectrometer will be based off a spectrometer at UNO. Since I will have a visual representation of the spectrometer, I will be able to determine which designs fit together in an effective manner. The sizes and dimensions of the pieces will be generated from a proportional scale to the spectrometer. Additionally, the printed parts will be designed as easy to assemble and disassemble to promote the enhancement of educational benefits. To achieve high resolution on collected data, trials will be conducted with initial designs of the spectrometer. Absorbance values will be compared to values produced by the provided spectrometer. Once an absorbance value is recorded that is not statistically different from the value of the provided spectrometer, the design will be in its final stages. Minor adjustments will be made to improve resolution and efficiency.

<u>Potential Issues</u>

There are issues which may arise during the development of the 3D printed spectrometer. Problems may stem from the 3D printing software. If the TinkerCAD software cannot support a design, a new software would need to be implemented. Likewise, the final product may experience unforeseen issues. The parts must fit together snugly to prevent the spectrometer from falling apart. However, the spectrometer needs to be easy to disassemble. Thus, a balance needs to be reached between easy disassembly and strong connectivity of the parts. Adaptation and modification to the design will be needed to fix this issue if it arises.

C. Project Timeline

	Mar	Apr-May	Jun-Aug	Sept-Dec
Learn Software	•	•		
Generate Design	•	•	•	
Test Resolution of Designs			•	•
Modify Design			•	•

Learn Software: This time will be spent understanding how to use 3D printing software. I will learn how to use 3D printing services at UNO and begin making simple designs to print.

Generate Design: Using knowledge on how the parts of a spectrometer work together, I will generate a 3D design on the TinkerCAD software. I will need to 3D print multiple parts that will fit together to form the spectrometer. Optimizing each of these parts so they fit together tightly will take time.

Test Resolution of Designs: I will spend time testing different optics within the 3D printed spectrometer. The different optics used will change the resolution of the spectrometer. These trials will reveal if the spectrometer resolution is comparable to the expected theoretical resolution. The knowledge gained from these tests will be used to generate improved spectrometer designs.

Modify Design: It will be necessary to modify spectrometer designs after performing resolution tests. to create the most cost-efficient and useful model. Design modifications will improve the resolution of the spectrometer as well as ensure the educational opportunity of teaching the mechanics of the machine in classrooms. These modifications will be made based on resolutions obtained from testing different optics.

The project will produce a simple, cost-effective spectrometer out of 3D printed parts. This project will allow for the advancement of education in Instrumental Analysis classes. Additionally, an inexpensive model of a spectrometer will be available for students to use in experimentations. Developing this model will save money and provide a crucial piece in the education of undergraduate students.

D. Student and Mentor Roles

I, Ben Yanovich, will design and print the spectrometer. I will also run analytical tests to determine accuracy and precision. Modifications will be made as necessary to improve the overall design. The mentor will provide guidance on designs as well as knowledge on how the spectrometer functions. Any difficulties and questions will be discussed with the mentor. The mentor will ensure that the quality of work done by the student satisfies the standards of the scientific community.

E. List of previous Internal Funding

I, Ben Yanovich, have not received internal funding. Dr. Gift had a student, Shelby File, who had a FUSE proposal accepted in the spring of 2020. Due to COVID 19, Shelby File was not able to do any work on her project. All funds were returned.

Budget and Budget Justification

The budget for this project comes to $2,500 and is broken-down as follows:

Supplies

A total of $500 will be needed for supplies. This project will require to purchase of resin to use in the 3D printer. Additionally, optical lenses, USB cameras, and diffraction gratings will be purchased as these are other important components in the spectrometer. If a subscription is required for software to analyze the data gathered, it will be purchased using these funds.

Student Stipend

A total of $2000 is budgeted for the student to work during the summer. The student will complete over 200 hours of work on this project during the summer. This accounts to 10 hours a week for a project that lasts 20 weeks. The time will be spent creating 3D designs in TinkerCAD, printing designs on campus, collecting data in the lab, and analyzing the data to determine the resolution of the spectrometer.

References

(1) Liu, H.; Meng, Q.; Zhao, X.; Ye, Y.; Tong, H. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES)-Based Discrimination for the Authentication of Tea. *Food Control* **2021**, *123*, 107735. https://doi.org/10.1016/j.foodcont.2020.107735.

(2) Ravindran, A.; Nirmal, D.; Prajoon, P.; Rani, D. G. N. Optical Grating Techniques for MEMS-Based Spectrometer-A Review. *Ieee Sens. J.* **2021**, *21* (5), 5645–5655. https://doi.org/10.1109/JSEN.2020.3041196.

(3) Engelbrecht, R.; Patey, C.; Dubrowski, A.; Norman, P. Development and Evaluation of a 3D-Printed Adult Proximal Tibia Model for Simulation Training in Intraosseous Access. *Cureus* **2020**, *12* (12), e12180. https://doi.org/10.7759/cureus.12180.

(4) Figure 1: Schematic of Single and double beam spectrophotometer https://www.researchgate.net/figure/Schematic-of-Single-and-double-beam-spectrophotometer_fig1_328353870 (accessed Feb 2, 2022).

University of Nebraska Omaha

COLLEGE OF ARTS AND SCIENCES
Department of Chemistry

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Dear Committee Members:

I am happy to write a letter of support for Ben Yanovich's FUSE grant application. Ben was a student of mine in Quantitative Analysis (CHEM 2400) in the Fall of 2020 so I have known him for 1.5 years. He is intelligent and has a great work ethic. I am very confident he will be productive and successful with this research project.

Ben wants to develop a 3D printed spectrometer. Several years ago, I had a student that developed a spectrometer using PVC pipe. That project work, however, there were problems and issues with the instability of the design. Ben plans on improving the previous PVC spectrometer by using 3D printed parts instead of PVC parts. The Creative Productions Lab in the UNO library has a 3D printer. I am confident that Ben will be able to design parts that will fit together properly. This will involve learning software, designing components, and submitting projects for the printing of components. There will be some trial and error with finding the correct design, but I am sure it can be done. In addition, the Creative Productions lab have employees that can advise if we need help.

I will support Ben Yanovich in this project. I have a lot of experience in building spectrometers, so I can help Ben during the design stage. I do not have any experience with 3D printing, but the Creative Productions Lab does have employees that can help. In addition, I plan on learning with Ben on how to use the software to design parts, so if we encounter a problem we can figure it out together. After the spectrometer is build, I will advise Ben on what needs to be done to characterize the spectrometer.

Ben is well prepared for this project. He earned an A+ in my Quantitative Analysis class and he earned an A in the laboratory. He has a great analytical mind and loves to solve problems. Ben will be able to educate himself on topics that will help him more this project forward.

I would like to verify the budget for this project. $2000 for a student stipend is accurate. I have spoken with Ben and he understands that he will working at least 200 hours on this project. The $500 for supplies is also accurate. The supply money will be used to buy USB cameras, reflective diffraction grating, transmission diffraction grating, lenses, and 3D printing costs at the UNO Creative Productions Lab.

I am excited to work with Ben on this 3D printing research project. I highly recommend his FUSE proposal be funded.

Sincerely,

Alan Gift

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