Capitalizing on Curiosity: Putting Chemistry on Display

by
David Kiely

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Thesis Committee:

Dr. Amy Phelps, Thesis Director

Dr. Michael Sanger, Second Reader

Dr. Richard Nagorski, Thesis Committee Chair

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APPROVED:

Dr. Amy Phelps, Thesis Director

Professor, Department of Chemistry

Dr. Richard Nagorski, Thesis Committee Chair

Chair, Department of Chemistry

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Abstract

This thesis explores innovative methods to inspire curiosity and engagement in undergraduate chemistry through visually captivating demonstrations. Recognizing a national challenge in retaining STEM students due to declining interest, the project employs social media platforms like YouTube and Instagram to share dynamic chemistry demonstrations. The initiative showcases experiments beyond typical classroom curricula, aiming to create a low-pressure, curiosity-driven environment. Over 500 hours were invested in filming and editing, resulting in professional-quality videos that have been widely shared across academic and public platforms, including science festivals and airports. The project not only highlights the role of accessible scientific content in fostering student interest but also underscores the transformative potential of open-ended exploration in education.

Introduction

Student recruitment and retention in undergraduate STEM courses have been a concern nationally for years (Gandhi-Lee et al., 2017). Literature suggests numerous reasons for the high DFW rate in STEM classes, one common reason being students' lack or loss of interest in their area of study (Meaders et al., 2019). This project aims to address both the lack and loss of interest in the field by fostering a sense of curiosity in introductory chemistry courses and leveraging that curiosity to keep currently enrolled students engaged in class and garner the interest of aspiring STEM students as they transition from high school to college.

Background

To spark student interest and engagement, I have worked with the MTSU Chemistry Department to start a YouTube channel and Instagram page to display visually impressive chemical demonstrations. Although some information is provided regarding the chemistry in the videos, our goal is to give students a chance to observe reactions outside of the classroom without the pressure of a grade attached. It has been well-studied that traditional grading in the education system can have detrimental effects on the motivation of students, notably, the detrimental effect of grading pressure is compounded as course material becomes increasingly difficult (Hughes, 1985). Although it would be difficult to completely remove grading pressure from the classroom, we can provide course-related content to students in a format that is attention-grabbing on platforms like Instagram and YouTube that are not associated with or related to online platforms students use for school assignments. This project aims to develop and disseminate content that encourages curiosity in students at all levels, with demonstration videos presented in a visually intriguing format with the tagline "Have Questions? Ask a Chemist!". Although chemistry at any level may be a class many students fear, it is not a subject that they don't find interesting. Surveys of popular chemistry YouTube Channels and Instagram accounts provide evidence that chemistry, outside of a classroom setting, is a subject growing in popularity. Several of the most popular chemistry channels on YouTube have subscribers numbering in the millions (fig 1) and views ranging from several hundred thousand to tens of millions on individual videos (fig 2). The popularity of these channels shows that there is interest in chemistry when the chemistry is interesting. What is absent from these platforms are similar channels sponsored by universities and created by undergraduate students. Although many institutions that have a sizable chemistry department have social media platforms, the content published on their platforms looks more like required viewing material for a class than an exploration into the science for no other purpose than exploration (fig 3). This is not to slight other universities; it is just emphasized that there is interest in chemistry, and MTSU has a unique opportunity to fill a void left by the educational community.

The MTSU Chemistry demonstration videos to date feature a mix of content directly related to experiments students will study in their general chemistry courses, as well as demonstrations that students are not typically exposed to in their undergraduate education due to cost or safety concerns. Emphasis has been placed on capturing the attention of our viewers rather than providing a learning outcome to leave them with questions and resources to get those questions answered. Although not as popular as YouTube channels like NileRed or Periodic Videos, organic synthesis channels are growing in popularity (fig 4).

Project Timeline

Filming for this project took place in the Spring 2023 semester and was completed in August of 2024. When this project started, I didn't know anything about videography or editing, and although I had completed general chemistry 1 & 2, I did not have any experience working in a lab without direct guidance. Over the summer of 2023, I spent over 500 hours filming reactions. Much of this time was spent reading technician notes on demonstrations I found interesting and learning how to light and film the reactions, so the final product had a professional appearance. Initial funding and support were provided by the Chemistry Department, and a scholarship was awarded to me through CBAS for 100 hours of total time for filming and editing. One hundred hours came and went before any video editing began, but I continued filming as it is a project I was, and still am, passionate about. In addition to the funding from the department and CBAS, I've personally invested additional time and financial resources into the project.

At the time of this writing, there were 23 videos and 33 photos published on the Instagram account and 17 videos published on the YouTube channel. The home pages for both accounts have been formatted to be visually appealing and represent the MTSU Chemistry Department (fig 5). All videos have been watermarked with the department logo and links to the department website for those wanting to know more. I post chemistry-related memes daily to the Instagram account and have begun building out playlists on YouTube containing helpful study resources for chemistry students. In addition to the time spent filming, I've spent over 200 hours editing.

This project's social media pages can be found on Instagram and YouTube, @MTSUChemistry (QR code fig 6a & 6b respectively). Additionally, a compilation video of what was filmed during the summer of 2023 is on display in the science building on the TVs located on the 3rd floor and in the atrium. Off-campus videos are currently displayed at the Nashville International Airport, and several images have been published online by Chemical & Engineering News. During the fall of 2023 and 2024, our videos were displayed at the Murfreesboro STEAM festival. Additionally, a poster presentation, with videos displayed, was given at the 2024 Biennial Conference on Chemical Education at the University of Kentucky.

A Simple Reaction

What I learned can best be explained in the story of *A Simple Reaction*. A Simple Reaction was the name given to the nitrogen gas oscillator. Oscillating reactions have fascinated me since the first time I saw a video of a Belousov–Zhabotinsky (B-Z) reaction. After researching lab procedures for a B-Z oscillator and realizing I didn't have the materials to set up a demonstration, I went in search of other oscillating reactions. I found a video published by the Royal Society of Chemistry titled *Let's get Fizzical* (*Let's Get Fizzical*, n.d.). In this video, they described a nitrogen gas oscillator as a "simple reaction."

In this video and the associated procedure notes, several chemicals and relative amounts of each were described. Sulfuric acid, ammonium sulfate, and sodium nitrate (III). I gathered the required materials and mixed them as described in the procedure, and to my surprise, my simple reaction was not working. Not only did it not work, but there was no indication a reaction was taking place at all. I double-checked my notes, watched the video again, and repeated the experiment 10 more times. Each time, nothing happened. I asked Dr. Phelps and several other professors what sodium nitrate (III) was and if it was the same thing as sodium nitrate. I was repeatedly met with confused looks as no one had ever heard of sodium nitrate described as sodium nitrate (III), and ultimately left with more questions than answers.

After repeating this experiment several more times and failing several more times, I began to think maybe I just wasn't meant to be a chemist. What kind of chemist can't set up a 'simple reaction' such as this? After watching the demonstration video several more times and reading the procedure notes again, I noticed that the equations they used to describe the reaction did not contain nitrate ions, rather, they were written with nitrite ions. This was a little confusing, but I thought I would check the stock room sodium nitrite.

I couldn't find sodium nitrite, but I did find potassium nitrite. With sodium and potassium being in the same periodic family and both being spectator ions in the reaction, I thought it should work the same. This time, there was a reaction, but it was not oscillating. I ran the experiment several more times and couldn't understand why what I expected to be a reaction that evolved gas looked more like snow falling out of a solution. Frustrated and discouraged, I turned to Dr. Phelps and asked if she could look at my procedure and the reaction to help determine what was happening.

We ran the experiment again, and when it had finished reacting, we looked at the test tube and noticed what looked like salt crystals. Dr. Phelps asked what chemicals I used and gave a confused look as nothing in the test tube should have been able to form a solid. We dried the crystals and ran experiments to determine their chemical composition. From a solubility test and a flame test, we determined the salt we had in solution was potassium sulfate. This was met with much confusion among professors in the department, including the Dean, as potassium sulfate is generally considered soluble in most situations. As it turned out, the high concentrations of ammonium ions and protons in the solution caused the potassium and sulfate ions to have a higher affinity than normal to form ion pairs, leading to the crystals falling out of the solution and giving the appearance of snowfall rather than the evolution of a gas. After running the experiment several dozen times unsuccessfully, I finally found some sodium nitrite and prepared to test again. To my excitement, the reaction worked as described on the first try.

While trying to troubleshoot this reaction, I learned persistence, patience, and attention to detail are necessary when working in a lab. I learned that what is written in a procedure does not always translate directly to what is observed in the lab. Although I had read research articles related to my classes, I did not know that failures are not typically reported in the literature. This left me with a misconception that when competent chemists experiment, they get it right on the first try. With this misconception and an experiment referred to as a 'simple reaction,' I felt like I must not have what it takes to be a professional chemist. It turned out the issue with my experiment was that someone I considered a professional was simply using incorrect nomenclature.

Capitalizing on Curiosity

When I was taking General Chemistry II, I asked a lot of questions. Dr. Phelps' door was always open, and I stopped by office hours two or three times a week. I usually had a question about class material but rarely left without asking about an interesting chemical reaction I had recently seen or read about online. During one of these meetings, Dr. Phelps suggested I read *The Disappearing Spoon*. This book gets its name from Gallium, element number 31. The book gets its name from a lab prank chemists used to play on each other. Gallium is unique in that it has a melting point of 29.78°C, which means it's a solid at room temperature but will melt in your hand (*PubChem*, n.d.). Chemists took advantage of this unique melting point by casting a spoon and passing it off to their friends to use with their morning cup of tea. After a few minutes, the spoon would disappear.

Fascinated by this story, I began reading about gallium online and found a demonstration called The Gallium Beating Heart. I asked Dr. Phelps if there was any course offered where this demonstration might be used in the lab. To my disappointment, there was not. Dr. Phelps mentioned a similar demonstration that was used in labs many years ago, but it used mercury and, due to health concerns, was no longer used in undergraduate classes. I asked if the department might have any gallium so we could try out the experiment. Again, to my disappointment, the MTSU Chemistry Department did not have a stockpile of gallium sitting on a shelf. Thankfully, Jeff Bezos is also a fan of gallium, and I was able to have 50 grams shipped to my house with free two-day shipping.

When the gallium arrived, I immediately made a spoon. I brought my new spoon to school, showed it to Dr. Phelps, and asked if we could try the beating heart demonstration in lab. She agreed and after we finished our next lab, helped me set up the demonstration to show the class. Seeing this demonstration in lab was like pouring acetylene on the candle flame that was my curiosity, and the video captured in lab that day was what eventually led to this project.

What made this project successful was the willingness of faculty and staff in the Chemistry Department to answer endless questions about both class content and chemistry questions I found interesting but were not covered in class. In addition to Dr. Phelps always having an open door, Dr. Bicker, Dr. Ding, Dr. Handy, Mr. Ben King, and Mr. Jessie Weatherly all contributed to this project by answering questions, helping find supplies, or running analysis on product samples. I had a misconception that if I had a question not related to course content or if I had a question for a professor that I hadn't taken a class with, I would be brushed off and sent on my way. The willingness of the faculty and staff in the department to take my questions seriously and have a conversation with me was a major contributing factor in not only following through with this project but also in my decision to change my major and shift my career goals of becoming a physician's assistant to becoming a college chemistry teacher.

The other major contributing factor in my growing passion for chemistry was Dr. Phelps' giving me creative freedom to run the chemical reactions I was most interested in and edit the videos into a format I felt best-displayed chemistry in the most interesting way possible. Had I been given a list of reactions to run and a template for how the videos should look, I don't think I'd be on the path I'm on today. I've learned a lot in my chemistry classes at MTSU, but being able to explore what I was interested in without the pressure of deadlines or grades attached taught me more than I could have ever hoped to learn in a classroom. In class, I learned the theory and math behind chemistry. In labs, I learned the techniques needed to apply that theory. However, the freedom to explore in an open lab setting allowed me to apply what I learned to things I found interesting that didn't appear in a syllabus.

Putting Chemistry on Display

The first videos began being shared in the fall of 2023. I had not planned to share the videos or my experiences with students other than sharing the content on social media. The feedback from faculty and students was better than I had expected, and Dr. Phelps encouraged me to step out of my social comfort zone and share the experience with others. I began performing demonstrations with prospective students, taking tours of the science building and students attending the MTSU STEM camp. During the semester, I perform demonstrations for MTSU students in Dr. Phelps' General Chemistry I & II classes and Dr. Frick's General Chemistry I lecture. I also had the opportunity to display the videos at the Murfreesboro STEAM Fest in the fall of 2023 and fall of 2024. Being able to share these videos and see the excitement in future scientists has been one of the most rewarding experiences of my undergraduate career.

When this project started, I didn't consider myself an artist or a chemist. I didn't know how to adjust camera settings, set up lighting, or edit video. I was familiar with chemical calculations on paper, but I didn't feel comfortable working in a lab setting where the procedure was relatively simple, had a known outcome, and the necessary materials were provided. Today, I feel comfortable calling myself both an artist and a chemist.

What I hope the reader takes from this is that curiosity should be encouraged, even if that curiosity is not directly related to the next exam. I would encourage the teachers of future chemists not only to have an open-door policy but also to make sure the door is open. Dr. Phelps' office door was always open, and if I had a question, she made time to answer the question and have a conversation about what I was curious about. I think that encouraging students to not only do well in class but to ask questions about the world we live in and what we observe can have a bigger impact on student success than one might think.

Appendix A

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Appendix B

Referenced Figures:

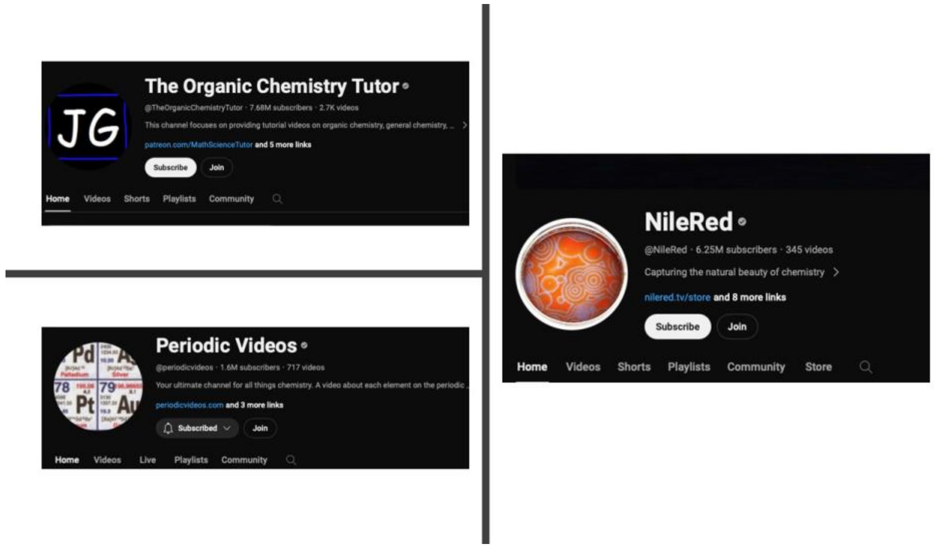

Figure 1: YouTube subscribers for popular chemistry channels

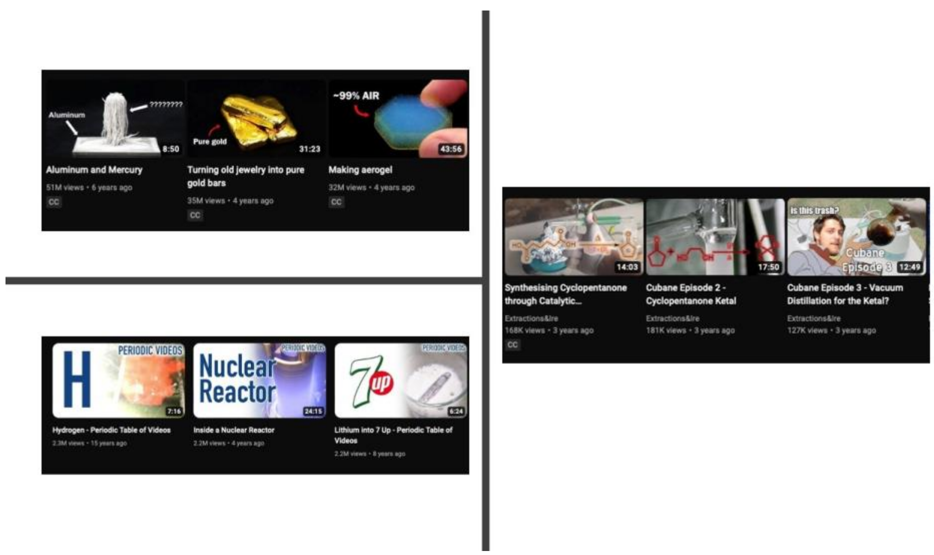

Figure 2: Examples of view totals for individual videos on various YouTube channels

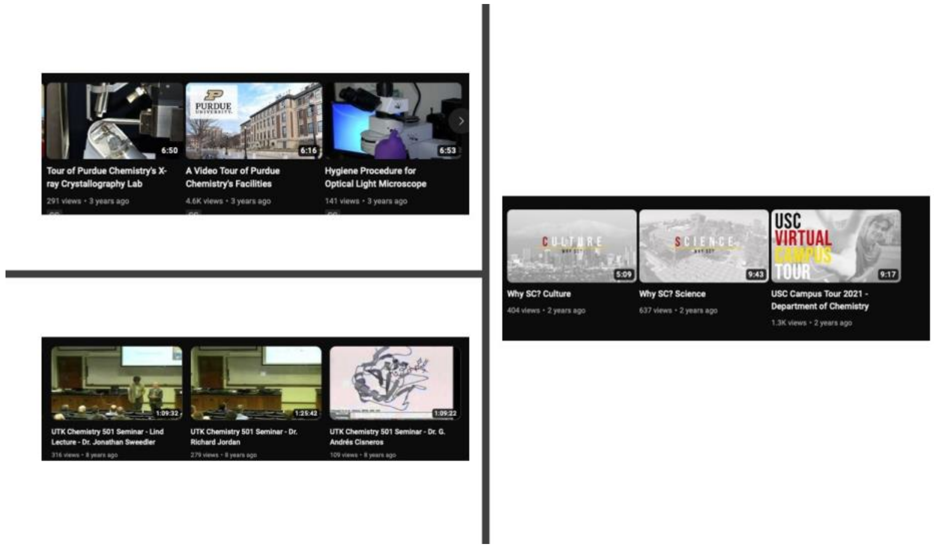

Figure 3: Samples of content from universities with notable chemistry programs

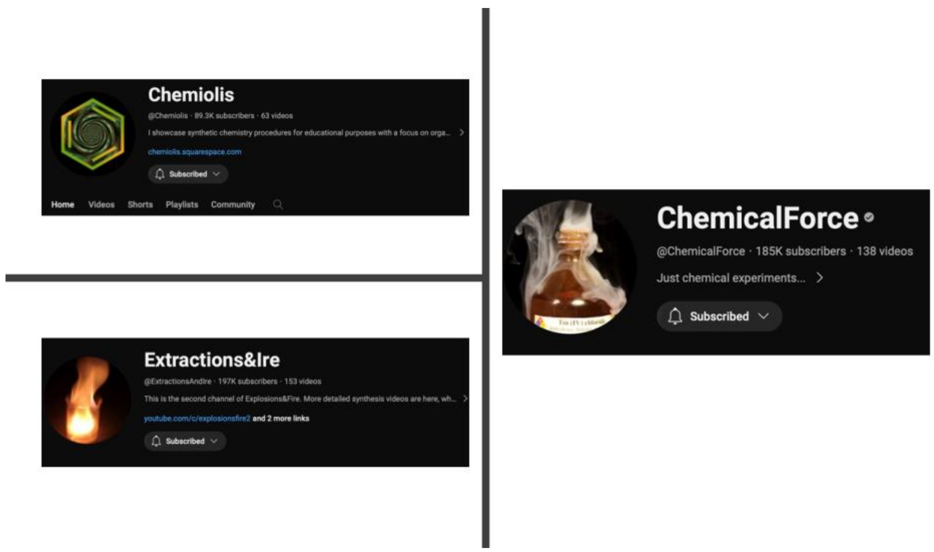

Figure 4: Interest in organic synthesis

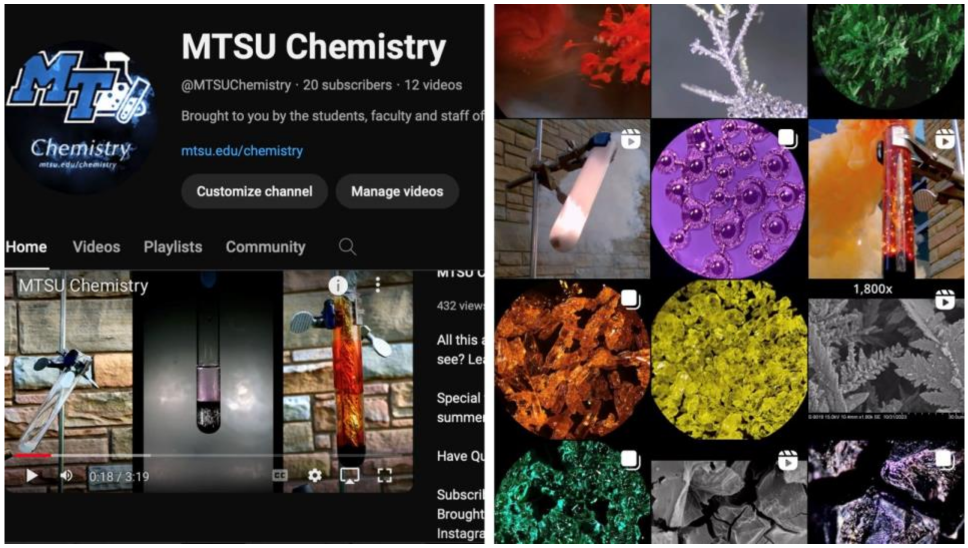

Figure 5: MTSU Chemistry social media home pages

MTSUCHEMISTRY

Figure 6a: Instagram QR code

Figure 6b: YouTube QR code