PRODUCTION, NARRATIVES, AND IDENTITY IN SCIENCE COMMUNICATION VIDEOS

By

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Dedicated to the village that got me through to the finish line

my family for their unconditional love and support

myself for never giving up

and God for the strength to push through.

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I wouldn't have made it passed the finish line if it wasn't for the support of my committee and the village I gained throughout this marathon, that is the Ph.D.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

An introduction to Phuture Doctors

Science communication incorporates the use of media, activities, and dialogue to inform, influence, excite, and engage with the general public on science and technology (National Academies of Sciences, Engineering, and Medicine, 2016; Metcalfe, 2019). With the rise of sharing science through social media, science educators, scientists, and science communicators have turned to becoming producers of their own media to communicate science (Holliman, 2011; Smith, 2014; Blonder et al., 2013). As the demand for science communication increases, a need is growing for bridging science communication best practices with theories on the science of science communication to ensure effective communication (Nisbet and Markowitz, 2016).

Science communication research highlights the need for the science communicator to be clear about their goals, move beyond the deficit model of communication, and identifying and working with different audiences (Landrum and Hallman, 2017). The science of science communication is the understanding how the audience perceives, understands, or changes their behavior after interaction with the science or science communicator(Kahan, 2015; Guenther and Joubert, 2017). Engaging with the audience aligns with the dialogue model where the expert meets the audience where they are at by listening before engaging in conversation (Metcalfe, 2019). As the practice and theory of science communication is dependent upon who the target audience is, it is essential to include research on marginalized and minorities communities to make science communication more inclusive. As said by Canfield et al. (2020), "Even with increasing interest in science communication and public engagement with science, historically marginalized individuals and communities are largely overlooked and undervalued in these efforts."

The exclusion of marginalized groups in science can be seen in the lack of diversity in the science and engineering workforce. Looking at the most recent demographic breakdown of the science and engineering workforce, 63% are White, 15% are Asian, 10% are Hispanics, and 8% are Black or African American (National Science Board, 2019). The development of new ideas and solutions to global problems require a varied collection of experiences, opinions, and backgrounds (eGan, 2011). With the push for innovation and world leadership continuing to be a priority, the U.S. has set out to fill 3.5 million jobs in STEM by 2025 (Khan et al., 2020). However, two million of these may go unfilled because companies have trouble finding people with the proper skills. Yet an untapped resource of diverse and qualified individuals exists in marginalized communities that the STEM workforce continues to overlook. Competition for talent is fierce, industries must have plans in place to recruit, develop, and retain a diverse staff in today's global market (eGan, 2011).

Efforts to push and prioritize diversity and inclusion in the science and engineering workforce are also seen in k-12 and higher education (Asai and Bauerle, 2016; Ashley et al., 2017; Katz et al., 2017). Significant attention has been devoted to the recruitment and retention of underrepresented students in STEM fields (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2010). These programs often entail structured academic support in the form of academic advising, mentoring, and tutoring (Lane, 2016; Wilton et al., 2019; Estrada et al., 2018; Kitchen et al., 2018; Kricorian et al., 2020; Carmichael et al., 2016). Yet underrepresented minorities graduation rates are consistently lower than majority graduates (Lane, 2016). For example, of the 13 million Hispanic students in public schools, 60% enroll in college, but only 4% go on to earn a Ph.D. That is 17 times less than white students with Ph.Ds (Fayer et al., 2017; National Science Board, 2019; US Department of Education, 2016). There are a multitude of factors the contribute to underrepresented students falling out of the STEM pipeline. Of those include the lack of role models in student classrooms and having negative stereotypes projected onto marginalized individuals (Schinske et al., 2015, 2016; Dortch and Patel, 2017; O'Brien et al., 2015; Shin et al., 2016). Research into science identity and stereotype threat suggests a lack of diverse representations of scientists could impede traditionally underserved students from persisting and succeeding in science (Schinske et al., 2016; Rincón and George-Jackson, 2016; Patall et al., 2018; Jordt et al., 2017).

Science identity based frameworks have proven fruitful in predicting persistence in careers in STEM (McDonald et al., 2019; van Aalderen-Smeets and Walma van der Molen, 2018; Hosbein and Barbera, 2020; Singer et al., 2020). The more important an identity is to a person, the more it should guide behavior such as science identity positively impacting the likelihood of students entering a science occupation (Stets et al., 2017; Robinson et al., 2019a). Multiple factors feed into STEM identity, but in relation to students' motivation to pursue a career in STEM, identity is linked to a student's interest, sense of belonging, self-efficacy, and recognition in STEM (Kim et al., 2018; White et al., 2019; Robinson et al., 2019b; Skinner et al., 2017; Singer et al., 2020). Using survey data from 2,916 students at four large public universities, Rohde et al. (2018) found that an interest in industry-based careers was associated with high engineering identity, belongingness, and motivation scores. Dou et al. (2019) tested the predictive power of STEM identity on career intention on 15,847 college students. Their study found that for every one-point higher on their STEM identity scale, participants' odds of choosing a STEM career in college increased by 85%. Additionally, a web-based survey of undergraduate members of the Society for the Advancement of Chicanos and Native Americans in Science found that self-efficacy and identity as a scientist mediated the effects of science support experiences and strong predictors towards a commitment to science careers (Chemers et al., 2011).

As a first-generation American and college student, representation has been vital to my growth as a scientist. When I attended college at the University of Central Florida, my chemistry professor in community college was a Latina. The chair of the chemistry department at the university was Latino. The director of the McNair Scholars, a program dedicated to getting marginalized students into research, was Latino. Even my undergraduate research professor, who fostered my growth as a scientist, was a Latino. I never once questioned my ability to become a scientist because of my ethnicity or gender; rather, I was only concerned with how I performed in class and my intellectual contributions.

Only after I was admitted into graduate school and moved to Tennessee did I become hyper-aware of how I walk through life as a brown, Latin-American woman. Moving from Orlando, Florida, a city with so much racial and ethnic diversity, to Nashville, Tennessee, was a culture shock. The lack of diversity in the city was reflected within the STEM department into which I was accepted. I was one of only three women in my cohort of about 18 students, and one of only two students of color. When I started in the graduate program, there were only two research professors in the department who were women, and one professor was a Black man.

Looking back at my STEM journey, I have almost slipped through the pipeline myself. I am the first person in my family to pursue college, let alone graduate, and go on to pursue a Ph.D. However, a year into my program, I was told that the way I spoke was more master's material than Ph.D. level, which knocked down my confidence. When seeking advice from faculty within my department, I realized that none of the faculty members understood my experiences or background, or reflected my identity. If I, a person already in pursuit of their Ph.D. can't see myself in this space, how do we expect young students to believe that they belong in STEM?

Frustrated, I wanted to do something about this. So, I founded Phuture Doctors, a platform that is reinventing the way students explore careers in STEM while showing the world that this is what a scientist looks like. My mission is to increase diversity in STEM workforce through representation in science media. I created videos that brought both the diversity of STEM careers and scientists to classrooms, phones, and computers. My goal was to communicate the importance of research by demonstrating how scientists use tools in the lab to tackle problems and to describe complex topics using simple animations. I also used Instagram as an accessible platform to talk about research and reach a broader audience. My videos are engaging and entertaining without "dumbing down" the science. My videos also provide students with real-world examples of science concepts and insight into career paths through scientist's stories.

I was interested in using videos since the lack of representation in science media parallels the lack of representation in the national science and engineering workforce. I used YouTube and Instagram as my platforms because over 70% percent of teens access these platforms daily (Anderson and Jiang, 2018). Many STEM-related channels on YouTube exist, which demonstrates how exciting science can be or serve as online tutors. Further, the hosts of these channels typically reflect one type of demographic. There's nothing like

Phuture Doctors, which means Phuture Doctors fills a unique niche and that its content that will both entertain and serve a community of students who are historically overlooked.

I plan to contribute to the field of inclusive science communication through my initiative, Phuture Doctors. To ensure that I am producing content that serves young, marginalized students, it was important for me to switch my Ph.D. track. This allowed me to research how to produce effective science videos for my target audience. With the help of faculty from the Communication of Science and Technology, Cinema and Media Arts, the Wond'ry, STEM Education, and the Chemistry Department, I designed a study on the effects of narrative and representation in science videos. I also created a resource for science educators and science communicators on how to produce science videos informed by theory and industry practice.

My dissertation begins with Chapter 2, an essay on the production process for creating education science videos which was published in the journal *CBE—Life Science Education* (Castillo et al., 2021). Chapter 3 is a literature review that provides a general overview of the science video landscape, features of science videos, and the scholarly context to my creative approach. Chapter 4 is my creative work in which I have applied the theory mentioned in previous chapters to the videos I produced. Chapter 5 is the design of a survey instrument and a qualitative look at the feedback received from the survey. Finally, in Chapter 6, I conclude this study with a discussion of future directions and how my study fits into the larger landscape of science communication.

CHAPTER 2

Production Processes for Creating Educational Videos

Exact text of published paper (reformatted for dissertation): Castillo, S., et al. (2021), *CBE—Life Sciences Education*

2.1 Introduction

While many biomedical science educators are aware of the benefits of using video, there is a lack of resources that describe and summarize the video production process. Decades of research have demonstrated that video can be used to enhance learning. The combination of verbal instruction with visual images significantly increases recall and retention in students (**Figure 2.1**; (Mayer, 2014a)). The video content's impact can also be enhanced through approaches based on multimedia learning principles. Video has been used in many educational scenarios, including traditional lectures, guided discussions, and self-observation sessions (Pinsky and Wipf, 2000). Furthermore, video has been used increasingly for coaching, mentoring, and professional development in educational settings (Nemirovsky and Galvis, 2004). In contrast to the plentiful amount of research supporting video use, few accessible resources are available to support educators as producers.

Educators have been asked to take on new roles as universities rapidly transitioned education online in response to the COVID-19 global pandemic. While the transition from in-person lectures to videos may be intimidating, it is also an opportunity for instructors to develop new skill sets. Video, defined as electronic recordings that contain both audio and visual elements, has been used for science education and communication for decades (McGarr, 2009; Rajadell and Garriga-Garzón, 2017). The shift towards online learning has challenged faculty to adopt video instruction into their teaching practices in either a live setting (synchronous) or through pre-recorded videos (asynchronous). By learning how to produce video content, educators can build flexibility in teaching practices. Video has already become a valuable tool to support adaptable and self-paced learning. However, students interact with video beyond the classroom and have high expectations for visual and audio quality. Therefore, to make compelling videos, educators should be supported and empowered as producers of video content.

The modern ubiquity of phones with cameras and other portable devices allows most people to easily watch and create videos. Many educators have transitioned to virtual teaching and are becoming comfortable with synchronous web conferencing using Zoom, Skype, Microsoft Teams, and other platforms. Pre-recording online lectures in these programs can be used as asynchronous videos, which supports classroom accessibility by allowing students to re-watch lectures at any time (Clark, 2015). Some educators have even attempted to fulfill both synchronous and asynchronous needs by recording web-based lectures. While recording a web-based session does fill the role of content acquisition, it is not ideal for several reasons. For one, the quality is generally poor and can distract later audiences. In addition, web-based lectures are designed for the synchronous audience, and, most likely, are sub-optimal to the learning experience of the asynchronous viewer. As compared to recorded lectures, produced videos can deploy the multimedia learning theory supported by Mayer (2014a) which may not be a consideration for a standard synchronous videoconferencing lecture. Intentional production of videos for the classroom has been shown to increase learning outcomes with increased motivation, satisfaction, and perception toward the materials (Um et al., 2012). These studies emphasize style, format, and quality, as essential in multimedia educational learning materials. To address this goal within low-budget settings, additional resources are needed to help educators produce quality videos in at-home environments.

At first glance, the process of video production could be daunting to some educators as there are many different styles of videos to consider creating. Additionally, educators must also familiarize themselves with the technology, editing software, and the overall production process (Petrosino, 2006). There is a wide range of equipment that may be confusing to someone unfamiliar with video production. Notably, with many working from home, educators need to establish simple, low-budget at-home studios. Thankfully, the evolution of video technology has made it easier and cheaper to record high-quality videos by implementing minor design decisions.

We have created this resource to support beginner educator-producers, using their phones and at-home setups to minimize the barriers to producing high-quality videos. In this paper, we present workflows to guide educators in making several video types for their course and produce simple, effective, and engaging videos with a budget-friendly, at-home setup. Educators begin this process starting with preproduction (lesson design and storyboarding), move through production (set-up, styles, and lecture recording), and end in post-production (video editing). We also cover production theory extensively before walking through production workflow and the description of the video styles. Covering the theory behind producing videos will help educators understand the mechanics of producing high-quality videos. Herein, we provide a production process for creating asynchronous video content through using an at-home studio setup and a phone with a camera. The main product is a workflow (**Figure 2.2**) for the educator to begin to take on the producer's role in online video content production.

2.2 Preproduction

By far, the most significant amount of time of the video production process is spent in preproduction. Preproduction refers to any of the planning stage activities before filming and has been well canvased in the literature (Jenkinson, 2017). This critical stage is commonly underestimated and underutilized when it comes

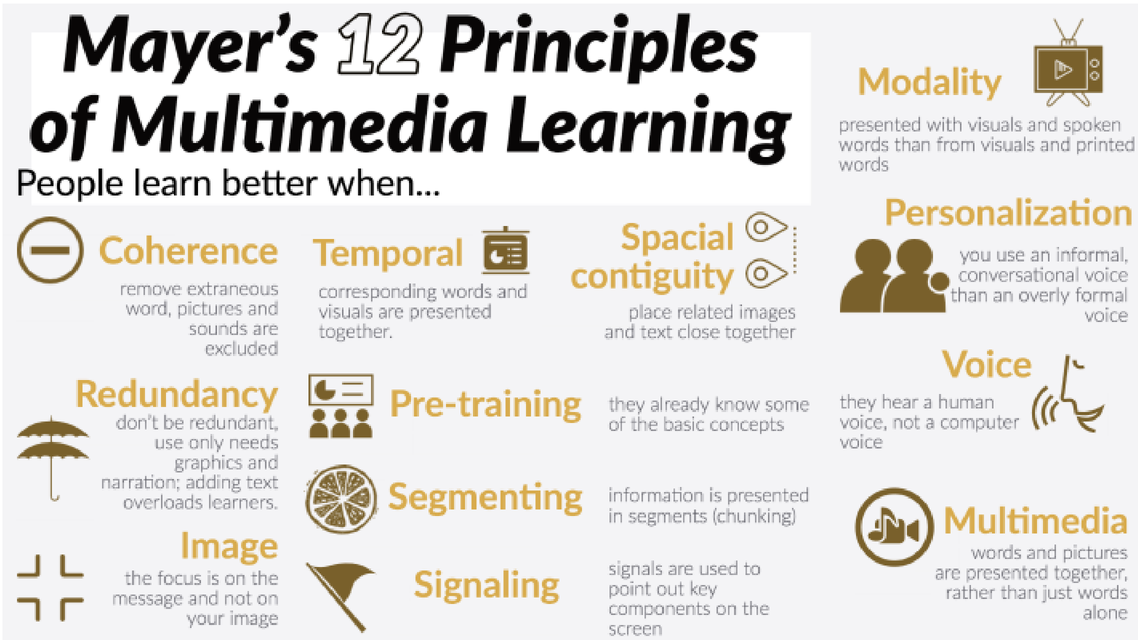


Figure 2.1: Mayer's 12 Principles of Multimedia Learning. The production of video content, including the style and format, can be informed by cognitive multimedia learning psychology to benefit learning outcomes. Visual images, in combination with verbal instruction, significantly increase recall and retention (Mayer, 2014a). Cognitive psychologists, particularly Mayer et al., have identified effective practices in multimedia learning (Brame, 2016; Mayer, 2014a; Mayer and Estrella, 2014a,b; Quitadamo and Brown, 2001). In Mayer 2001, 12 principles for effective multimedia design are established (Figure 1). Multimedia design principles are easy to implement and have demonstrated improved for short-term retention (Issa et al., 2011). When educators begin the production process, they should acknowledge Mayer's principles and evaluate total cognitive load and examine the viewer's overall cognitive architecture. Cognitive load theory states that working memory (as opposed to long-term memory) can hold and process a certain amount of information at any given time (Mayer and Estrella, 2014b). The overload of this cognitive capacity is referred to as "essential overload," and should be highly considered in educational video production. Before starting to create video content in pre-production, creators should observe Mayer's principles and think about eliminating extraneous information based on the desired learning objective. This is known as the coherence principle. The addition of extraneous or unnecessary information can exceed cognitive function and decrease learning outcomes. To prevent essential overload, some guidelines to follow during pre-production and production include: using familiar names and terms (pre-training principle), speaking instead of using on-screen text (modality principle), and combining narration with animation simultaneously (redundancy principle). Before deciding on video style, educators should be open to various formats and think creatively about their content delivery. Additional cognitive psychology principles to keep in mind before pre-production would be how to engage the audience, particularly with voice (voice principle) and by using a more conversational speaking style (personalization principle). During the post-production phase, many elements can be considered to improve learning outcomes from lecture videos using other types of social cues. For example, video can have learner-paced segments (segmenting principle), use cues to highlight essential information (signaling principle), and organize words and pictures to be proximal both in space (spatial contiguity principle) and in time (temporal contiguity principle). By minimizing essential overload, the creator is eliminating extraneous processing to help the viewer grasp the main intention of the video (Mayer, 2014a; Mayer and Estrella, 2014b; Paas and Sweller, 2014).

Figure 2.2: Production checklist. To provide a streamlined guide for science educators and scientists to embark on their production process, we have created a production checklist that outlines the preproduction, production and postproduction processes.

to crafting a video for online learning (Chang and Hirsch, 1994; Corbally, 2005; Currie, 2003). Preproduction involves creating a design that utilizes the strengths of video production and optimizes them for the audience's learning capabilities (Jenkinson, 2017). Lesson design and storyboarding are key components of preproduction. A storyboard is a visual representation of a video's timeline (Orr et al., 1994). It breaks down the video timeline into individual panels containing all instructions necessary for the audio script and the corresponding visual elements such as on-screen text, animations, or the recorded video (McGill, 2017). Storyboarding is specific to video production, and should not be confused with lesson planning.

In storyboarding, the specific objectives for the video, as well as the script, determine the optimal video structure and style. Assuming lessons have already been designed, storyboarding should be a distinct process crafted for video medium. The storyboard eventually becomes the guiding design document that outlines the production process. This document serves as a guide that can be reviewed and approved by any co-instructors, content experts, and instructional designers, administrators, or other stakeholders before commencing production. Furthermore, a storyboard allows for increased style and format consistency across videos. Consistent formatting and repeated graphics help reduce cognitive load for the student (Brame, 2016). The goal of preproduction is for educators to walk away with a detailed storyboard that will guide their production workflow. Here, we break down the storyboard into three sections: contextualizing videos within a course, clarifying learning objectives, and video mechanics. Production efforts that are intentionally designed will help guide the educator-producer during production and post-production.

2.2.1 Video Contextualization

From a broad perspective, the educator-producer should consider diversified instructional approaches such as the implementation of video within the course plan (Dunn and Rundle, 2000; Dunn and Griggs, 2007; Pritchard, 2018). To decide when and where to include videos, how many videos to produce, or what topics the videos will cover, educators can examine and depend on their syllabus. The syllabus should be a user-friendly and meaningful document that logically directs the faculty member and student through the course content (Huang et al., 2019). While reviewing or revising the syllabus, educators should make sure the addition of a video and each video's assigned fit addresses the course learning objective. Consider content mapping, which refers to delivering the right content, to the right people, at the right time. In particular, it is critical to think about how, when, and where the student is engaging with the video content. After reflecting on the syllabus and mapping where a video will be included, producers should next consider the video as a relationship-building opportunity with the virtual student.

Within a virtual education space, educators and students may never have an in-person meeting or conversation. Strategically designing online instructional videos to have emotional connectivity, through the video's style, develops a better relationship with the students (Mayer, 2014b). To build this relationship, context, learning-modes, and connectivity should all be examined during the preproduction process. The context is what the video will discuss, which is determined by your lesson plan and syllabus. Learning modes are ways in which students acquire, process, and maintain knowledge though visual, auditory, and reading/writing. Connectivity is the relationship between student and material, and the relationship between student and educator. One way to hit all three aims in online classrooms is including asynchronous videos in addition to synchronous videos (Clark, 2015). Meaningful interactivity promotes student learning (Anderson et al., 2008; Antonietti et al., 2015; Cairncross and Mannion, 2001). For example, holding discussion during synchronous lectures and then use asynchronous videos to further explain or demonstrate the context of the lesson, or vice versa. To Establishing the best connectivity is dependent on which video style is chosen which we go over in depth in Production Guidelines section.

2.2.2 Learning Objectives

Before deciding which video style to pursue, it is essential to clarify the learning objective. Learning objectives are brief statements that describe what a student is expected to know by the end of a lesson, or in this case, after watching a video (Black and Wiliam, 1998). Prior knowledge of the video topic may vary between different audiences, so content and learning objectives are essential ((Johnson and Hertig, 2014). In many cases, learning objectives build upon each other toward reaching an overall learning goal. Compared to a learning goal, the learning objective is measurable. The objectives must be written in ways that allow the educator to measure whether or not students have achieved them accurately. *As an educator begins to think about the learning objective for their educational video, they must define the learning objective in a measurable format so that the video's impact can be assessed through their course*.

2.2.3 Video Mechanics

The third step that occurs in preproduction is evaluating the mechanisms of how the video will be produced. This portion consists of three aspects for intentional video design: script, style, and length. While rarely used for traditional teaching, scripts for online asynchronous content allow the educator to review material, minimize extraneous information, and clarify learning objectives. Scripts should be developed by looking at the slide order, content included on those slides, and other information relevant to each slide that is not visually depicted. If the educator is more comfortable speaking their lecture material, it is possible to use voice-to-text software to facilitate this process. While a script can contain each and every word that will be spoken, a script can also be a general guideline to help stay on track when filming—essentially creating an outline with talking points and what needs to be addressed for each slide or topic covered. However, if a verbatim script is created, the document can be used to produce closed captioning to promote video accessibility.

Next, the educator should consider various video styles and how each style complements each section of the script. Choe et al. (2019) evaluated eight different video styles designed to deliver standardized content in the life sciences. Here, because of the audience and resource limitations, we have simplified these styles into categories of Speaker, Screen, and Room (**Figure 2.3**. These styles will be covered in-depth in **Section 2.5**. Choosing the optimal video style depends on the lecture content, learning objectives, and how educators like to teach their course. When deciding on a style, educators should consider interactivity and engagement with the learner (refer back to section 2.2.1, video contextualization). No one style works for all educators, and educators should consider their individual strengths when choosing a video style. Additionally, it might be worthwhile to employ a combination of style. Be aware that if multiple styles are used in one video, more post-production is required to connect the distinct video styles.

The last mechanics consideration is the length of the video. Research supports short videos organized into sections or segments compared to one 40-minute video of a traditional lecture, for example (Brame, 2016). As video length increases, students lose focus and become less engaged with the material (Farley et al., 2013). If it is easier for the educator, entire lectures may be recorded in one sitting and split later during post-production, but this should be planned beforehand. One way to punctuate a single long recording is by incorporating questions or moments of reflection within the lecture. Breaking up the video with questions can guide student learning and help transition into the next video or assignment. In addition, incorporating moments of reflection through rhetorical questions or recap statements can prompt students to pause and consider whether they have internalized the video's learnings or should re-watch the video. While creating an intricate video may be more exciting to watch, unnecessary elements can also add an extraneous load that may limit the video's ultimate effectiveness (Brame, 2016; Corbally, 2005). To prevent this, educators should continuously revisit their script and remember the learning objectives and determine if the style chosen best represents the material.

2.3 Production Theory

Production refers to all activities that involve the recording of audiovisual material. When starting production, it is essential to recognize equipment and resource limitations. For high-production video styles, a full recording studio may be required; this could include soundproofing to eliminate echo and outside noise, a raised floor to minimize vibrations that may cause audio interference and have overhead ceiling-mounted lights to provide additional lighting options. A fully equipped studio may include teleprompters and monitors for the presenter as well. With the assumption that most educators do not have access to full studio setup,

Figure 2.3: Video formats. Choe et al. (2019) evaluated eight different video styles designed to deliver standardized content in the life sciences. The following formats are listed in order of production effort. The Interview format would either capture the educator or subject sitting to the left or right frame with the interviewer sitting off-screen asking questions. The Slides On/Off format strictly captures the lecture slides. The video of the educator can be added in post-production to be switched between the slides or educator being in full-frame as an option. The Pen Tablet format uses an online whiteboard to write lecture material, or it is the direct annotation of the lecture slides on a tablet. The video of the educator can also be overlaid in post-production in the lower third of the frame. The Talking Head format capture the lecture slides with the video of the educator overlaid as a lower-third in post-production. The Classroom format captures the educator on location in front of a board with a monitor or screen displaying the lecture slides off to the side. This allows the educator to work out problems on the board and reference to the lecture slides. The Demo format captures educator working through an experiment or demonstrating a scientific phenomenon. The Weatherman format captures the educator in front of a green screen with the lecture slides overlaid in the background in post-production; the educator will interact with the lecture material using their body. Finally, the Learning Glass uses an LED-illuminated low iron glass that functions as a whiteboard. Instead of lecture slides, the educator reproduces lecture material onto the learning glass on-screen. For our article, we have organized these formats into three main types: speaker, room, and screen. The icons for these three categories are shown in the upper left-hand corner of the figure. The formats to which this category applies is included next to the format name on the right side. In this article, we do not discuss the weatherman or the learning class format because additional advanced equipment is required as indicated (+Adv. Equipment).

we will be considering production for an at-home studio setup using a phone camera.

As the educator takes on the role of the producer, it is important to assess the audio and visual goals of their videos and their feasibility before starting production. Thinking about the limitations of production can help create realistic expectations for the final products created. High-quality videos can still be achieved through budget-friendly setups if educators apply production theory to their videos. Four key elements must be considered for optimal video production: light, sound, video, and set. For the sake of simplicity, we will refer to the phone camera as ‘the camera’ and will specifically note when we are referring to a stand-alone camera (including single-lens reflex camera (SLR), digital-SLR, or camcorder). Please note that many of these theories can apply to both a phone camera and professional camera.

2.3.1 Lighting

Lighting is key to making high-quality videos. With the right lighting, it is difficult for viewers to discern between a phone camera and a professional camera. Lighting should generally be placed at a 45-degree angle down at the subject from above (**Figure 2.4, A**). It should also be placed off-center, about 45 degrees left or right of the subject, and out of frame. The inverse square law applies to light, meaning that the closer the subject is to the light source, the more drastic the change in light level or intensity appears on the subject. As the light source is moved further away from the subject, the drop in light level based on the distance from the light source is dramatically reduced, allowing softer diffused light to hit the subject. Additionally, the larger the light source, the softer and more flattering the light will be on the subject. If no lighting budget is available, a window can be used. Have the camera placed such that the window is about 45 degrees off-axis. If the light seems harsh, put some translucent drapes across the window or sit further away. While a window might be a low budget option, keep in mind that it will be difficult to build consistency with natural lighting across multiple filming days.

When additional speakers or objects are added to the frame, it is particularly important to be mindful of the lighting. For a recording that includes multiple speakers or objects, larger light sources can help ensure the lighting is bright, soft, and even. If a light source is not available, perform the demonstration or the interview straight on axis with the window. This will give even light across both subjects and objects. In this case, the light should enter directly behind the camera, leading to even lighting across the scene. For those that are interested in purchasing equipment, two equally large and bright light sources on either side of the camera at a 45-degree angle above and to the side of both subjects would be suggested, similar to the structure of an individual subject recording.

Another consideration with light is the temperature. White balance, is the process of having objects that appear white in reality are rendered white in your video. The light is measured by temperature on the Kelvin

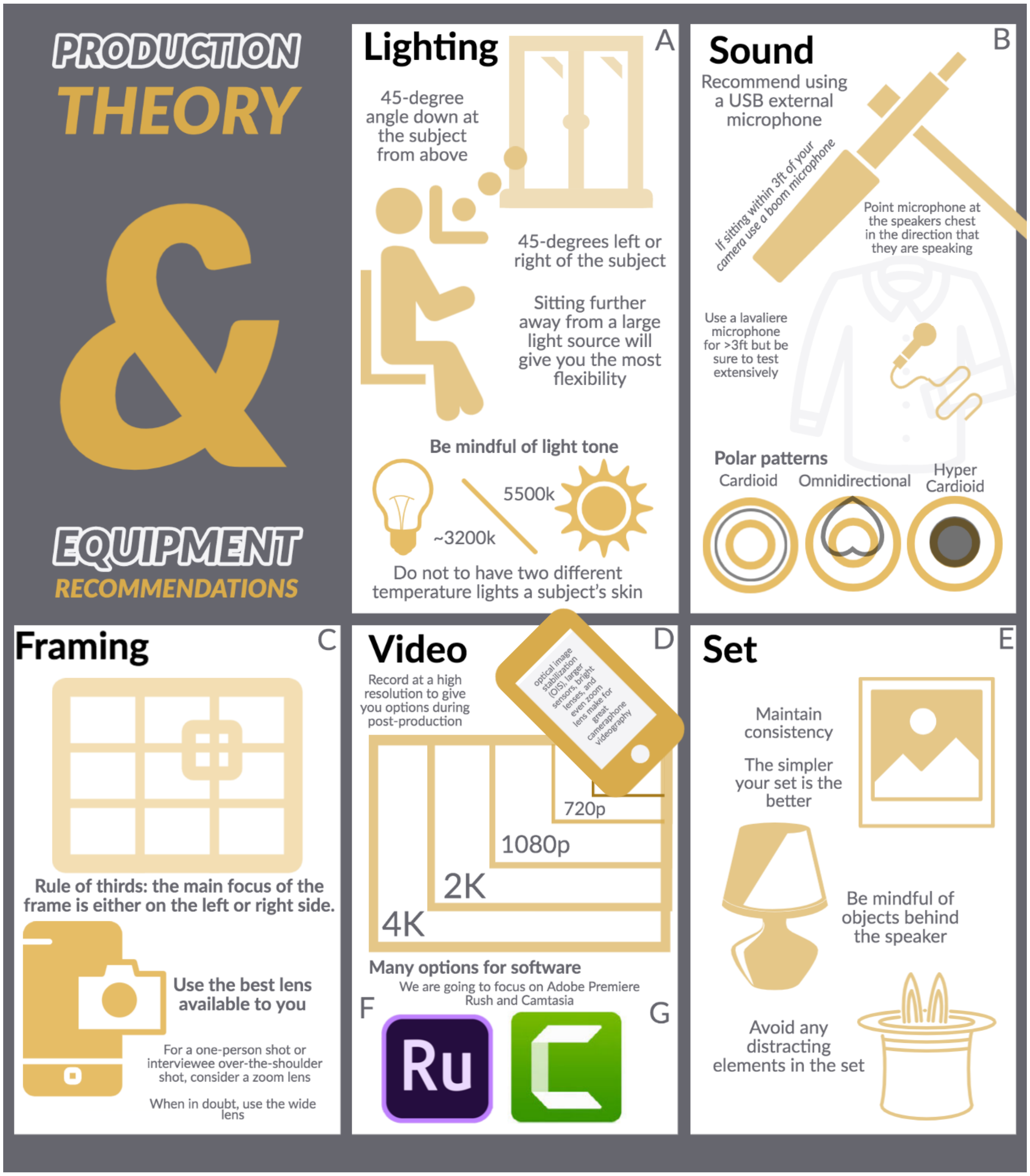


Figure 2.4: Production theory and equipment recommendations. Here, we provide an infographic that discusses the five major areas of video-production theory, including (A) lighting, (B) sound, (C) framing, (D) video, (including two video editing and recording options; (F) Adobe Rush and (G) Camtasia) and (F) set. More detailed discussion of these areas can be found in the text and on the SciVid (https://www.scivid.online/).

scale. Typically, Kelvin temperatures for commercial and residential lighting applications fall somewhere on a scale from 2000K to 6500K. 3200k is the temperature at which tungsten burns, and often the temperature of soft interior incandescent lighting, while 5500k is the temperature of sunlight. It is important to have a single temperature illuminating a subject's skin. For example, room lights and sunlight should not enter the frame at the same time, and any light fixtures intended to remain in the frame should be as dim as possible. It is often advised to turn off all interior lighting (room lights) to avoid mixed light.

2.3.2 Sound

Poor-quality videos with clear sound are more likely to be accepted by an audience than a high-quality video with poor audio. To record crisp and clear audio, it helps to record in a quiet room to achieve as large a signal-to-noise ratio as possible. The signal-to-noise ratio is based on the difference in the volume of the subject and the background noise that cannot be controlled or removed. The larger the difference between the audio of the speaker versus background noise, the larger the signal-to-noise ratio is, resulting in better audio quality. To achieve low background sound, turn off air conditioners, fans, and buzzing cell phones. Set up away from noisy windows or appliances like refrigerators. If loud background noise cannot be avoided, position the camera to avoid collecting the sound or consider using an external microphone, as discussed below.

A microphone diaphragm is the thin membrane that vibrates with sound pressure levels and produces the electrical signal that becomes the analog audio wave. The size of the diaphragm regulates some of the basic characteristics of the resulting wave. Large-diaphragm microphones tend to have better low-frequency reproduction. These types of microphones are often used in radio, voice-overs, vocal recordings, and podcasts where sound is key and having a large microphone in front of the person speaking is not an issue. The positioning of the microphone to reject background noise is based on its polar pattern. The polar pattern of a microphone is a graph of the microphone's sensitivity to picking up sound arriving around the central axis of the microphone capsule. Polar pattern plots show the sensitivity of the microphone across various angles tested at different frequencies, depicted with separate lines for each frequency tested (**Figure 2.4, B**).

There are three types of polar patterns for capturing audio for video: cardioid, omnidirectional, and hyper-cardioid. Cardioid polar pattern microphones are ideal for picking up one or more subjects from a close to mid-range distance. Microphones with this pattern are a good option for recording interviews. The microphone can be placed between the two subjects pointed down at the center of the conversation with the back facing the nosiest part of the space. This will capture even sound while rejecting unwanted noise. An omnidirectional pattern is often found in lavalier microphones; this pattern makes them able to pick up audio from all directions, which makes placement on the subject much easier. Hyper-cardioid patterns are often found in boom microphones and work well for single close-subject audio or picking up multiple subjects from a distance.

While phone cameras can be used to collect high-quality visual recordings, external devices are generally needed to improve the audio quality. There are multiple approaches to collecting high-quality sound. A lavalier microphone, sometimes referred to as a lapel microphone, might be useful but can present its own challenges. A lavalier microphone could have unintentional periods in which unwanted sounds, like clothing ruffle, are collected or when audio is not collected at all. Lavalier microphones are also susceptible to poor placement which can lead to poor audio quality. The lavalier microphone capsule should be omnidirectional, meaning that receiving signals from or transmitting in all directions. The lavalier microphone should be placed mid-sternum center on the chest. If the subject is within three feet of the camera, a boom or hyper-cardioid microphone may be best. A boom microphone will sound natural and requires less troubleshooting to assure quality. The boom microphone should be out of the video frame and be no more than one-to-three feet from the subject. If conducting an interview with a soft-spoken guest, each person in the video can be provided a lavalier microphone. There are several options compatible with a cell phone, but the distance from the camera should be considered. An extension might be necessary. The boom should be pointing at the subject's chest in the direction they are most often speaking. Additionally, it is important to note that all microphone types can be connected to a cell phone. Finally, if your audio collection and your video collection mechanisms are not synchronized, use a "clap" to help synchronize the audio and video in post-production. This can either be a hand clap, a film slate, or some other event that can coordinate visual and audio cues.

2.3.3 Framing

Framing, or composing the visual content of a series of frames as seen from a single point of view, is essential to direct the viewers' attention. When positioning speakers or objects in the frame, use the rule of thirds. This grid breaks up the frame into three equal parts, both vertically and horizontally. The main subject of the frame should be placed on either the left or right vertical line with their eyes where the top horizontal line intersects the vertical line, or in the center of the frame. If the subject is facing the interviewer or otherwise obstructing the key light to the left of the camera, the subject should be placed on the right vertical line. This will provide leading space or space in the subject's gazing direction that fosters a pleasing and clear image for the viewer. Even if other elements are in the frame, organizing frame composition using the rule of thirds will direct the viewer's attention (**Figure 2.4, C**).

Another key consideration for proper framing is focal length, which is the distance between the lens and the point where the in-focus image is formed inside of the camera. Changes in the focal length impacts the angle of view for the camera. Also, the same lens on different cameras can also result in different angles of views because the light sensors may not be identical. To make comparisons across cameras, the 50 mm lens is considered the standard full frame format for a stand-alone camera. Lenses above 50mm are in the 'tele' zone that compress perspective, whereas lenses less than 50mm are within the 'wide' zone that exaggerate features. With a phone camera, these measurements do not directly correspond to those on stand-alone cameras (SLR, DSLR, or camcorder) and must be adjusted to carry similar meaning. For example, the wide-angle lens on the iPhoneX has a focal length of 4.25mm, which is a 26mm equivalent. The telephoto lens on the iPhoneX is 6mm, equivalent to a 52mm full-frame camera. The rear-facing camera on the iPhone, now called the TrueDepth camera, has a 2.87mm focal length.

For a one-person shot, or for an interviewee framed over the interviewer's shoulder, consider a telephoto effect to separate the subject from the background. Make sure not use the digital zoom because this will reduce the resolution of the video captured. Instead, use the 2X lens or other options that may be available based on the phone camera. Many phones have 2–3 lens options and more details can be found in each phone model's user manual. When in doubt, use the wide-angle option. Wide-angle filming options, or a lens that allows more of the scene to be included in the video frame, generally have a larger aperture size, letting in more light and producing a sharper image with a natural focal length. If the decision is made to use a wide frame filling approach, it is also possible to crop the frame during post-production to make the video more interesting and dynamic.

2.3.4 Video

Video quality impacts the utility and quality of your video. In terms of equipment, the cameras in phones have become quite advanced, with several features that have improved the quality of images, including optical image stabilization (OIS), larger sensors, bright lenses, and optical zoom. Since the advent of widescreen TV (aspect ratio of 16:9), the term "HD" video resolution, which refers to a video of higher resolution and is typically greater than 720x480 pixels, has been used to refer to the measurement of pixels. A pixel (also referred to as pel or picture element) is the smallest addressable element on a display element of a screen. The "standard" HD resolution is 1080 which refers to a resolution of 1920x1080. However, 4k is quickly becoming the new standard for video distribution as data speed, and video compression improves. 4k resolution, when referencing a 16:9 aspect ratio, is 4096x2304. This resolution is often referred to as Ultra High Definition (UHD). Most modern phones are capable of 4k video or higher. Also keep in mind that front-facing cameras for phones and laptops typically have relatively low resolution as they are designed for functionality rather than image quality (**Figure 2.4, D**).

A few camera functions that affect video quality retain their historical names but are now performed through digital processing. For example, digital cameras no longer contain mechanical shutters, but shutter speed values can be adjusted to mimic film cameras allow light to expose the film. Shutter speed is measured in fractions of one second (e.g., a shutter speed of 1/50 would expose the film for 1/50th of one second). Additionally, the aperture is not an adjustment that occurs physically for built-in phone cameras. Instead, the exposure setting automatically adjusts based on internal algorithms of the device designed to optimize video quality. However, it is likely that the videographer will need to adjust these settings to avoid underexposure or overexposure based on a number of setting factors. Ultimately, it is best to error on the side of underexposure versus overexposure.

2.3.5 Set

Considering the set is essential to minimize distracting background items. It is key to consider consistency and intentionality for all video elements, including the background. One key aspect of building a set is to ensure minimal distractions behind the subject that would pull the viewers' attention away from the purpose of the video. Often, this means that simpler is better. A plain, neutral-colored wall with a simple plant or background object to break up the wall might be sufficient. Be mindful of objects like lamps and plants. A poorly placed plant behind the subject could make it look like the plant is growing from the top of the speaker's head. If curating the set is not possible, hanging a fabric backdrop can also work well. Blurring the background can also minimize details and add focus on the subject. A blurry background is achieved by wider apertures with longer focal lengths combined with increasing the distance between the subject and the background. To attempt this effect on a phone camera, click on the subject of the frame so that it is in focus and separated from the background. This is a great option when busy backgrounds are unavoidable (**Figure 2.4, E**).

2.3.6 Editing Software

There are several apps available for making high-quality recordings using a phone. We will be focusing on the Adobe Premiere Rush app because it is free and available on both iOS, Android, and Windows **Table 2.1-2**. It is fairly approachable for users compared to the more complicated Adobe Premiere Pro video editing software. Ideally, as the educator-producer's skill increases, they can transition these files to Adobe Premiere for more sophisticated post-production editing. Using Adobe Rush, it is possible to record content directly into a project within the application. Properly setting the exposure is an essential aspect of creating a high-quality video. The exposure circle must be placed over the brightest part of the skin. ISO is like a volume knob for light, whereby higher ISO values digitally increase the sensitivity of the light sensor. If the light input becomes too overwhelming, video footage appears overexposed and is unusable (**Figure 2.4, F**). If editing on a computer is preferred, we recommend Camtasia as a screen-capturing and video editing program

(**Figure 2.4, G; Table 2.1-1**), but there are also free alternatives including iMovie and OpenShot. We feel that Camtasia, although over $200, is a great middle ground resembling the simplicity of the Adobe Rush App with the editing capabilities of Adobe Premiere Pro. The built-in graphics, animation, and transition features facilitate editing for educators to have more control in tailoring and enhancing their videos. Whichever editing software you select, it is important to spend time familiarizing yourself with the options available to optimize your editing process.

2.4 Production Workflow

These guides mainly employ Adobe Premiere Rush, a free, simple, and accessible software that can prepare educator-producers for more advanced software such as Adobe Premiere Pro. We also discuss Camtasia, which is a proprietary screen recorder and video editor with a free trial currently available. There are many additional recording software options to choose from. A more extensive and updated lists are provided on the website resource that we have created (http://www.scivid.online/).

Adobe Premiere Rush. For the scope of this essay, we limit this workflow discussion to a recording using Adobe Premiere Rush and the built-in phone camera (**Figure 2.5**). When opening the Adobe Rush app, a plus [+] sign can be seen at the bottom; this will create a new project. There is the option to start with pre-captured media (camera roll) or start taking a photo or recording a video right from the app. Selecting "take video or photo" will open the camera, oftentimes on auto mode. Move the circle icon around the screen to the brightest part of the subject's face. In "Pro" mode of Adobe Premiere Rush, the default setting is still set automatically govern the camera. This is where the camera analyzes the image and selects the appropriate settings for the scene. However, from this interface, it is possible to select the exposure compensation. While the exposure might be ideally set using the auto selection, sometimes it may not be properly selecting the subject's skin and may need adjustments. Use +/- exposure control to increase or, more often, decrease the exposure compensation until the subjects are bright but not overexposed, or allowing in too much light that reduces the quality of the video. Then select the exposure adjustment (lens aperture icon to the left of the exposure) and make sure the automatic setting is turned off. This will lock in the exposure settings, and the phone will be ready to begin recording.

2.5 Production Guides

Choe et al. (2019) outlined eight different types of video formats or styles used in an educational setting. These video formats include classroom, weatherman, demo, learning glass, pen tablet, talking head, and slides on/off. These classifications help set the terminology by which educators can refer to various video formats **Figure 2.3**.

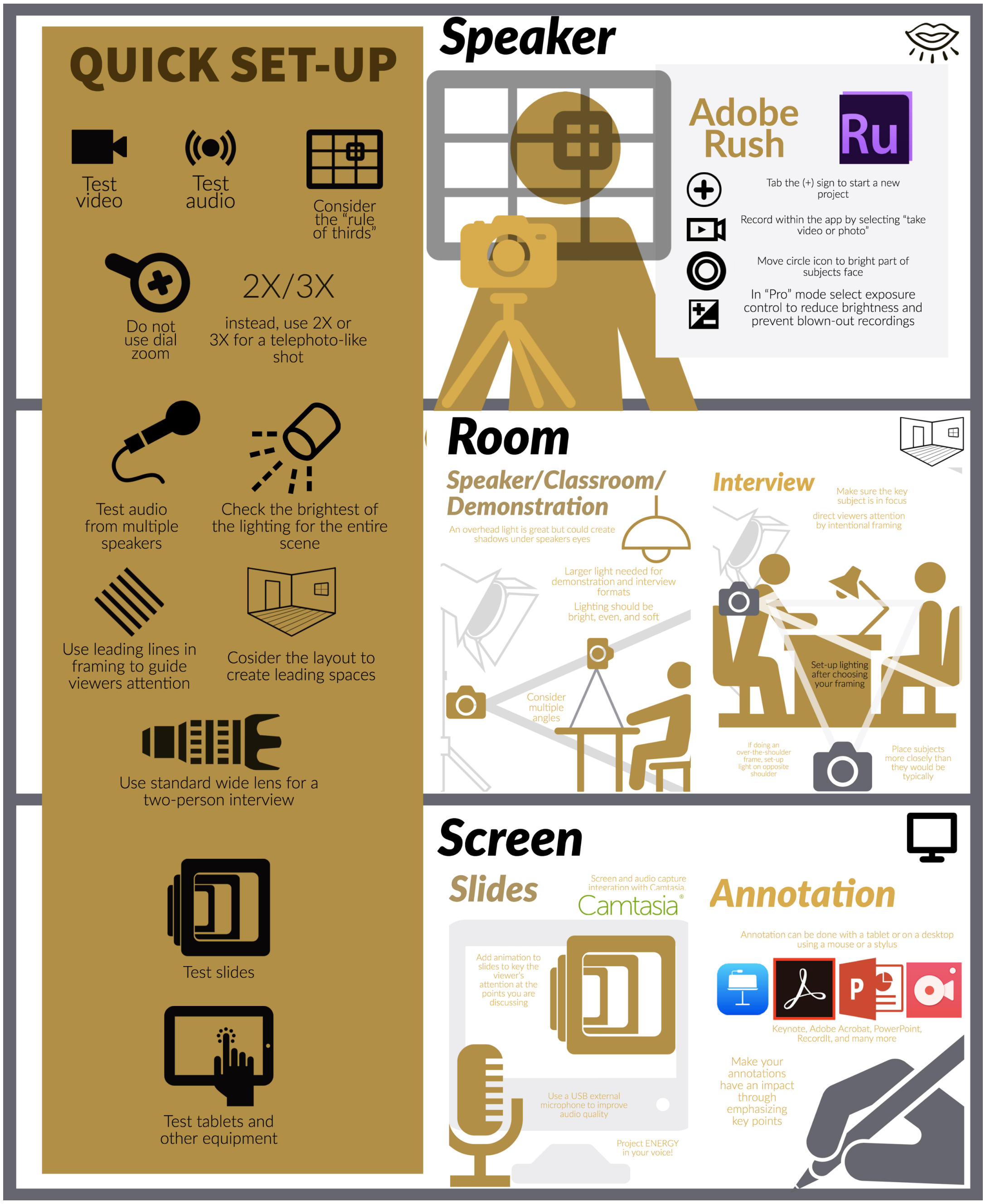


Figure 2.5: Production guides for speaker, room and screen recordings. A quick set-up list can be found of the left side of the graphic. The items listed in the quick guide are arranged vertically based on their relationship to the format type (speaker, room, screen). Within each format, production suggestions are shown within the infographic. Within speaker, the steps to recording using Adobe Rush is shown in addition to demonstrating the rule of thirds for a single speaker using a graphic. In Room, more detailed recommendations for the speaker, classroom, and demonstration formats are provided. Additional recommendation for an in-person interview style format is also provided in this section. Finally, within the screen recording section, slides and annotation suggestions are provided. The icon on the upper right-hand side of each format is correlated to the various formats outlined by Choe et al. in Figure 2.3

Table 2.1: Video Tutorials

Video	Description	Website Link
1. Camtasia introduction.	This video is an introduction to Camtasia, a screen capturing, and video editing program developed by TechSmith. We quickly cover what types of video formats can be achieved with this program, as well as the limitations of the software itself.	https://www.scivid.online/post/introduction-to-camtasia
2. Adobe Rush introduction.	This video is an introduction to Adobe Premiere Rush, a video editing mobile app. We quickly cover the types of video that can be achieved in the app, as well as the apps limitations.	https://www.scivid.online/post/adobe-rush-introduction
3. Example of a speaker format created with Adobe Rush.	This video covers how to set up your phone to record a Speaker format for Adobe Premiere Rush.	https://www.scivid.online/post/camtasia-speaker-format
4. Example of a speaker format created with Camtasia.	This video covers how to record a Speaker format using Camtasia.	https://www.scivid.online/post/speaker-format-adobe-rush
5. Example of a screen recording created with Adobe Rush.	This video covers how to screen capture your phone to record Slide formats with voice over for Adobe Premiere Rush.	https://www.scivid.online/post/slide-format-with-adobe-rush
6. Example of a screen recording created with Camtasia.	This video covers how to screen capture for electronic pen and tablet format recording using Camtasia.	https://www.scivid.online/post/camtasia-slides-format
7. Example of a room recording created with Adobe Rush.	This video covers how to set up your phone to record the Room format, specifically an interview, using Adobe Premiere Rush.	https://www.scivid.online/post/room-format-adobe-rush

2.5.1 Speaker Format

The speaker style (**Table 2.1-3, 4**) has become a popular approach. This style typically captures the educator in full-frame from the mid-shoulders up, with slight space above their head. Video of the speaker can be used alone or in conjunction with Slides and Tablet as a lower-third. For this style, a phone camera, a microphone, and a small tripod or stand are required equipment. Position the phone horizontally on the tripod. Then, place the phone and tripod such that the educator is at eye-level with the camera and in good lighting following the aforementioned theory. If the educator will refer to their notes or lecture slides while recording, position the references out of frame. However, the references should be close enough to the educator so that when the educator reads the material, they still appear to be facing the camera. It is important to test this extensively before recording. For the educator to appear natural and engaging, having consistent "eye contact" with the camera gives the illusion the educator is speaking directly to the student. Ideally, notes should not be read verbatim, and a calm conversational tone should be used. Although the educator may feel restricted, uncomfortable, or reserved speaking in front of a camera, using positive body language and facial expressions helps to convey interest and retain the student's attention.

2.5.2 Screen Format

Video formats that capture screen content, such as slides or pen-and-tablet, are straightforward options for beginners (**Table 2.1-5, 6**). These approaches can be very forgiving in that they are screen-captured and do not require considerations for lighting and camera focus. For this type of video style, a USB microphone and any screen-casting software are required materials. Because the educator is not on camera, it is possible to use notes without considering how their placement affects video cues, but it is important to be mindful of papers that can be noisy and picked up by the microphone. To keep the audience engaged, be mindful of voice tone and intonations. The viewer will not see a face, so the speaker can only project energy through their voice and words, placing greater importance on the audio quality in general. Therefore, microphone choice is key, and it is essential to consider the acoustics of the space. To increase the recording quality and prevent reverberations off walls, blankets or cardboard boxes can be used as low-cost options to dampen sound. Alternatively, recording in a closet or interior space might be beneficial due to the fabric "absorbing" sound reverberations. Since slides are the only visual, special attention and effort should be placed on the detail and timing of the slide points. Utilize the animation features in slide software to build the slide components over time, which will keep and direct the audience's attention.

2.5.3 Room Format

Classroom, demonstration, and interview video styles introduce increased complexity of filming and may not be appropriate for beginners (**Table 2.1-7**). When beginning production with these styles, it is first important to reflect on the purpose of the video. Knowing the purpose of the video will help determine what should be included within the frame. The challenge with filming in a classroom or doing a demonstration video is deciding to focus on the board, demonstration, or the speaker. Obtaining a clear shot containing two items of focus (i.e., an object and a speaker, or a speaker and an interviewer) can be difficult with only one camera, therefore it is important to decide which object should be the primary focus and then use the 'rule of thirds' to direct the viewers' attention. For example, if the guest answers are the focus of the video, including an over-the-shoulder shot would work well. On the other hand, if both sides of the conversation are equally important, a wide shot framing both people might be best. Another consideration for this video style is the placement of the subjects and objects. In an interview-style, for instance, oftentimes, the interviewer will be positioned closer to the interviewee than normally comfortable. This is because the camera frame does not take into context the large room. Nonetheless, being mindful of the space around the subject(s) is important to make the shot feel comfortable and not crowded.

The lighting setup also depends on the video's main purpose. The light position should be based on the view of the camera. For example, if using a wide two-person shot, placing the light in the center and slightly behind the subjects can facilitate ideal lighting. If recording an over-the-shoulder one-person shot, a light above the opposite shoulder of the interviewer would generally work best. If only one camera is available, a decision will need to be made about what is most important. For all video styles in this category, the setting should be as brightly lit as possible. Overhead light adds to the overall intensity but also creates shadows on the eyes because the light is directed downward. For an at-home studio, a make-shift pop-up white bounce (white screen or board; larger is better) that is leaned against the tripod facing the speaker can reduce these shadows. Large bounces, placed as close to the subjects as possible, are ideal for these purposes.

With interviews, never underestimate how nervous a guest might be during the recording. Having everything ready when they arrive is important to allow for time to make the subject comfortable within the recording environment. Although over promising editing capabilities should be generally avoided, let your interviewee know that editing is possible and they can restart or re-frame an answer if needed. The interviewer should also make sure to avoid responding audibly to the subject's answers and to use head nods instead. The reason for this is not only to collect clean audio but also to avoid rushing the guest's answers.

An extra consideration for both the classroom and demonstration style is to be mindful of light exposure. Whiteboards are often reflective, and some are made of glass. Make sure the camera can capture the writing or demonstration legibly without losing text clarity to over-exposure. Additionally, when testing the setup, it is important to ensure that strict framing bounds are added to prevent accidentally writing beyond the filling frame. This can be accomplished by marking the board just outside of the frame, so it is clear what part of the board is captured.

2.6 Post Production

Post-production encompasses all efforts occurring after the shooting or recording. Typically, this includes editing the recorded film's content and adding visual elements, music, or other sound effects. Adding these extra video elements can enhance the aesthetics of the video and cue the viewer into key concepts or major points. Before elements can be added, the captured footage's organization and a rough cut of the video should be prepared before evaluation and revision. Organizing the footage allows the educator to catalog the recordings by the day it was filmed, by video style, or by the lecture material covered. This is often referred to as 'content logging' (Jordan and Henderson, 1995) where a table is made listing the name of the file, date, and location of the footage, a brief description of the content of the video, and any other helpful notes (e.g., what might need editing). Videos may be organized directly into a designated folder on the computer or within the editing software. Editing software is required for post-production, and a variety of options are available for beginners or advanced editors. Examples of editing software include Adobe Premiere, iMovie, OpenShot, Final Cut Pro X, and Camtasia. Ideally, find an editing software such as Adobe or Camtasia that is user friendly with extensive tutorials. Once footage has been organized, import videos into the editing software of choice and begins piecing together the footage to create a rough cut (draft) of the video lecture. Refer back to the storyboard or script during this step as a guideline on how the videos should be ordered. Once the videos are compiled, additional revision processes can begin.

During this phase, the educator should revisit Mayer's (2014) multimedia principles (**Figure 2.1**) and revisit the video and course objectives established in preproduction. Consider adding visual effects such as arrows, circles, highlights, or sound effects to direct the focus of emphasizing the slide. Questions can also be inserted between scenes to lead students throughout the lesson to reach the final objective. It is essential that educator-producers avoid adding superfluous effects that do not benefit the video content's clarity. By revisiting Mayer's (2014) multimedia learning principles, post-production efforts can enhance the videos' impact on learning outcomes. After going through this evaluation process, the final edited file can be exported.

2.6.1 Using Camtasia or Adobe Rush for editing

The Adobe ecosystem has a rich array of tools to make videos and many other types of media. We chose Adobe Rush as an introduction to video editing as it is a functional and approachable editing software. In Adobe Rush, it is possible to add basic titles, trim clip length, and move clips around with ease. It allows three layers of video and three layers of audio. If photos or videos are not being directly collected within a project, media can be added from the phone's photos, files, or cloud-based accounts. The order item selection is the order by which they appear on the Adobe Rush timeline. To export from Adobe Rush, use the "sharing" feature. For more advanced editing, it is advisable to download Adobe Premiere Rush onto a desktop computer. Again, there are free video editing software options out there, but we recommend to use Camtasia as it is an editing software specifically made for educators. When it comes to editing on Camtasia, please refer to our website (http://www.scivid.online/) for online tutorials on using this editing software.

2.6.2 Blending styles

If choosing to blend two different styles in a video, it is best to record everything in one setup before moving on to the next. Completely recording each style will help build consistency and save time on setup. When organizing various styles, file organization schemes should be considered. Include a label in the first frame to visually display key pieces of information, including the project name, the video number in the series, segment number, and/or last the take number in the file name. This information can be written on a piece of paper and shown at the beginning of a recording session to help during post-production organization.

2.6.3 File organization and collaboration

During the post-production, file organization, cloud storage, and collaboration, and review are critical. File organization is instrumental in streamlining post-production and avoiding overwhelming a phone memory capacity. Furthermore, if blending multiple video files, it is important to know where each file is to be able to find it later. While collecting graphical and video assets, it is important to periodically back-up all files. Although Adobe Premier Rush does organize the project files, be mindful of device space on the phone without an external solution. Therefore, we recommend using a large external hard drive to store recordings. Cloud storage systems are a great approach that is particularly beneficial for long-term storage files.

After creating the video, determining the best way to collect and implant feedback is key. Frame.io, a software that allows frame-by-frame commenting, is an option for uploading the final video and having any number of people review and add comments in an organized format. Frame-by-frame commenting makes it very easy to know what needs to be done and where it needs to be done. Dropbox and Vimeo have also added this functionality for some of their proprietary options. If it is not possible to use this type of software, make sure that all reviewers are given clear instructions on how to interpret the time in their video player, so everyone is using the same system to provide feedback.

2.6.4 Exporting and file format

The file type used to collect the video footage and the file export type are important factors that play into the video's lifespan. It is essential to identify the type of file formats that are produced by your recording device and the optimal exporting video file type for your intended use (e.g., MOV, RAW, MXF, MP4, etc.). While the quality of video recording continues to improve, 4K (3840 x 2160) is a useful acquisition setting that is possible when using a phone camera. Filming in 4K and exporting in 1080p can be useful in some circumstances. For example, using 4K and exporting in 1080p can allow for a digital zooming on speaker that does not impact overall resolution. Zooming-in or slightly reframing by moving the video file up or down within the frame is a great way to add dimension within the constraints of a video captured in a single recording.

2.7 Copyrights Consideration

There are a few things to consider when creating videos beyond production. One major consideration is the use of external resources or images. Intellectual property rights protect ownership and control over creative works or inventions is governed through copyright, trademarks, and patents. Copyright covers a wide range of artistic works. Fair use of artistic work includes things like criticism, comment, news reporting, teaching, scholarship, and research (Section 107). Furthermore, Section 110 (1) of Copyright Law allows for classroom performance and display. Unfortunately, the guidelines are quite broad, and it can be unclear what may be considered fair use. Overall, there is a balance between the public's interest in open access and the interests of the copyright holder. Before using copyrighted materials in videos, conduct a fair-use analysis to determine if it is necessary to request permission. The video hosting platforms should also be considered so that secondhand download and distribution are not permitted. Next, it is also important to consider the educator's intellectual property rights. Teaching in higher education, and particularly teaching in blended or online programs, is a time-intensive process. Colleges and universities are making significant investments in people (instructional designers, media educators, librarians, etc.) and digital platforms and tools in support of the teaching and learning enterprise. At the same time, every college and university would be wise to affirm principles of faculty control of material created for teaching.

2.8 Conclusion

The COVID-19 pandemic has challenged educators to adjust educational approaches to accommodate online teaching practices, while providing opportunities to innovate and design video content that enhance accessibility and engagement. The necessity now compels educators to explore digital media for remote teaching and learning. Although producing a video may seem like a daunting task, it can also be a creative one. Educators can be positioned as designers and producers in a way they may not have been during their previous teaching experiences. This is likely to be especially true for more experienced faculty members who may not have had any previous experience making and using videos for teaching. Rather than feeling that new approaches are being imposed, seeing video creation as a form of creative expression shifts the narrative for educators to an opportunity to learn a new skill and explore their creativity as a form of continuing professional development.

This article outlines the production process to create high-quality, effective education videos in an at-home setting using a low-budget setup. If educators are making to produce a large volume of complex videos, this workflow may not be appropriate as the advanced software, file organization, file storage, a more advanced camera, equipment options, and workflow would be required. We have provided a simple checklist for the education video creation process across preproduction, production, and post-production, that can be customized depending of the type of video being developed (**Figure 2.2**). We have tried to address one consistent hurdle across production case-studies: that the effort required during preproduction is typically underestimated ((Chang and Hirsch, 1994; Corbally, 2005; Currie, 2003). The preproduction process is needed to determine the type of video style based on the video's objective. Even if one style was chosen for a particular lecture, it is essential that the educator reflect if parts of the lecture can be better communicated through an alternative approach. Ultimately, preproduction informs the entire video production process.

Ultimately, this article presents a process for creating digital educational resources to help guide the creation process for educators. Video is an accessible and prevalent medium for communication that can support asynchronous teaching that combats students' and educators' technical and logistical bandwidth requirements. The rising importance of video technology in biomedical science education calls for a thorough understanding of its production process by the educators who create them, to enhance video content effectiveness through design principles. The process that we describe here is one that is shared with cinema and media art. While educators explore this process, we also highly encourage educators to either work with producers or their institutions' media team. However, if that is not possible, the educator should adopt a producer's perspective. Creative exploring of at-home instructional video production that takes these recommendations into consideration will lead to aesthetically pleasing and effective educational videos.

CHAPTER 3

Race and Ethnicity in Science Videos: A Notable Absence

3.1 Online Videos for Science Communication

The relationship among the actors involved in the process of science communication has radically changed because of the Internet(Khan et al., 2020). Scientists can now communicate directly with the general public without the mediation or constraints of the mass media, multiplying the number of outlets used to communicate science (Khan et al., 2020). Traditionally restricted to magazines, newspapers, public lectures, radio, and television, the Internet has helped popularize science through the wide dissemination of scientific information to a non-specialized public. According to the National Science Board (Besley and Hil, 2020), in 2018, 57% of Americans cited the Internet as their primary source of science and technology (S&T) news, increasing 28% from 2008. Whereas reliance on television and traditional newspapers as primary sources of S&T news has declined from 39% in 2008 to 22% in 2018. Within the same study, 70% of people reported using the Internet as their main source of information for learning about specific scientific issues.

The Internet allows science to be conveyed in new ways, with new formats and new contingencies, such as hypertextuality (online connectedness via links), interactivity, and multimediality (videos, text, images, images, etc.) (Brossard, 2013). The interactivity of the internet can be attributed to the use of social media networks such as Facebook and Twitter, in addition to video platforms such as YouTube and TikTok. Social media "employ mobile and web-based technologies to create highly interactive platforms via which individuals and communities share, co-create, discuss, and modify user-generated content (Kietzmann et al., 2011; Holliman, 2011; Obar and Wildman, 2015)." Social media networks and online video platforms have become a fundamental medium for audience traffic allowing large entities (businesses, news outlets, academic institutions, government sectors, etc) to interact with large audiences down to the individual user. In the second decade of the twenty-first century, much of the growth of video consumption is related to social media, making social networks a fundamental contributor to the rise of online video production.

Proponents of online videos provide a more accessible format for disseminating information about science to the lay public (Sugimoto and Thelwall, 2013). Online video consists of any form of audiovisual content that can be viewed through the Internet. Internet video is produced in several formats, the most notable being AVCHD, FLV and MP4. It includes videos hosted on YouTube and other aggregators, such as Youku, Hulu or Vimeo; films and series on demand; video produced for mobile and tablet consumption; video conferences, video blogs and other formats. The consumption of video on the Internet has grown exponentially, ending the monopoly that broadcast television had on the production of audiovisual content.

According to industry data, 62% of world Internet users view online video every day (eMarketer, 2017). Google sites, including YouTube, are currently attracting over three billion unique users with 774 million active users per month (YouTube, 2021). A number of features define the online video environment, in which not only is exponential growth is observed but also a diversity of authorship. Nevertheless, as of 2011 television companies were still the primary producers of professional quality news content and generate the majority of online news videos, although they face increasing competition from YouTube (Peer and Ksiazek, 2011).

We are immersed in a new cultural paradigm in which individuals take active roles in the production, dissemination and interpretation of cultural goods, roles that are related to the 'Do It Yourself' ideology (Jenkins, 2006) and also to the blurring of lines between producers and audiences (Bruns, 2008). As science communication teachers, trainers and researchers we need to facilitate strategies through which scientists and citizens can engage with the development of digital stories about the sciences, how they are represented in the digitally-mediated public sphere, and how audiences consume and respond to them (Holliman, 2011).

3.2 Effective Features of Science Videos on YouTube

The videos scientists and educators produce are often intended for use in formal learning environments and are designed to improve student learning. However, videos produced for use outside the classroom, for less formal learning environments, can be designed differently. In fact, online videos are considered to be an accessible tool for spreading accurate scientific information to the general public (Sugimoto and Thelwall, 2013; Thelwall et al., 2012; León and Bourk, 2018; National Research Council, 2009; Dahlstrom, 2014). One of the uses of YouTube is as an informal learning platform. Informal learning refers to an engagement with a subject outside of a formal learning environment Rosenthal (2018); Ratner and Ucko (2016). YouTube was founded on the user-generated content model, whereby content was to be derived from YouTube users and consumers (Welbourne and Grant, 2016). In León and Bourk's book on *Communicating Science and Technology Through Online Video* (2018), they explains how users have created innovative forms and styles of videos that may be designed either to serve a small group of potential users or to reach a large audiences.

Many of the features of effective online educational content overlap with the features that make educational content popular and entertaining for informal environments. A number of studies have dissected the different artifacts that go into the creation of science communication videos (Munoz Morcillo et al., 2016; Welbourne and Grant, 2016; Muller and Sharma, 2005). By examining the different features of science videos, these authors were able to identify factors that may contribute to their popularity. Munoz Morcillo et al. (2016) found the main characteristics of popular science videos have the following features:

- a variety of genres and subgenres,
- moderate production quality,
- high complexity of how the video is edited,
- storytelling as the driver of the narratives,
- recognizable and memorable intro and outro sequences,
- and the ability to build an emotional and personable network

In addition to the features of science videos, Munoz Morcillo et al. (2016) broke down the production qualities that go into making popular science videos. Most YouTube science videos are made up of multiple shots, formats, and storylines with the use of music, animations, and graphics to direct viewers attentions to elements the video creators deem most important in the videos. The production qualities are similar to the production qualities found in producing effective online videos for formal learning. However, key differences exist that distinguish videos produced for the classroom from those produced for popular consumption. One difference is that informal learning science videos lean more towards informing, educating, or inspiring, whereas formal learning science videos are intended to improve student learning. Another difference is that science YouTube videos are driven by storytelling to help the viewer understand scientific concepts and to retain their attention, whereas formal learning science videos are centered around classroom lecture materials (Angelone et al., 2019; Torres and Pruim, 2019; Engel et al., 2018; Pitrelli, 2011). However, these differences are not strict, and science educators are beginning to see the importance of storytelling to improve engagement with lecture material in science classrooms (Morais, 2015; Peleg et al., 2017; Blonder et al., 2013; Francis, 2018; Mayhew and Hall, 2012).

3.3 Narratives in Science Video

Although the style and quality of a video is important in producing popular science videos, science communication research indicates that storytelling is the most important element to include if the video is to effectively engage with the viewing audience. Science can be difficult to communicate since the topic matter is often complex and requires specific technical knowledge. When it comes to preparing films about research, scientists have the tendency to communicate scientific findings using linearly structured narratives (i.e., introduction, methods, results, and discussion) that reproduce the traditional narrative structure of scientific papers (Angelone et al., 2020). They have been trained and reintegrated throughout their careers, but scientists run the risk of alienating the general population, potentially reducing the impact of informing the public about scientific breakthroughs (Torres and Pruim, 2019). As a result, science communication research emphasizes the importance of storytelling, training scientists and educators to tell stories, and looking into how narratives play in the mass communication of popularizing and understanding science.

Narrative is an umbrella term for personal stories, exemplars, testimonials, and entertainment–education content (Shen et al., 2015). Narratives are necessary not only for learning but also for speculating, for posing questions, and then for finding answers. Studies done in the past decade have looked into the effectiveness of using stories for science learning (Robin, 2008; Dreon et al., 2011; Smeda et al., 2013). In the paper *The Power of Storytelling and Video* (Dahlstrom, 2014), the author mentions that "logical-scientific communication is context-free in the sense that it deals with the comprehension of facts that keep their significance regardless of their context." Narrative communication, on the other hand, presents scenarios from which an individual can generalize or infer what the general truths must be in order for event to occur (Dahlstrom, 2014).

The use of narratives is relevant in formal learning environments. When it comes to telling stories in the classroom, an engaging story takes use of how children's brains naturally develop in order to assimilate information, and it gives rich context to bring otherwise abstract concepts to life in a human way (Engel et al., 2018). Students' recall and sustain attention when instructors incorporate narrative into teaching (Kromka and Goodboy, 2019). Students were also more engaged and motivated when they were in control of reflecting, visualizing, and creating digital stories to share with a large audience (Foelske, 2014). In the framework of formal science learning, presenting new material in the form of stories about scientists and scientific achievements further encourages a natural approach of information processing for many learners (Dahlstrom, 2014).

The use of narratives is also relevant for a public audience. A communication gap exists between those who have an academic backgrounds in scientific subjects and can understand the scientific terms used in scientific journals and those who do not have a science backgrounds and cannot comprehend the technical jargon of scientific terms used in professional books and journal articles (Deobhanj, 2017). To reduce this gap, science communicators must take seriously the task of bridging the gap between scientists and the general public. To better connect with audiences and maintain trust, communication researchers recommend that scientists and science communicators not only recognize themselves as storytellers but understand that one of their roles is to help people connect with and understand problems and issues on a more human level, in terms of what matters to them, without distorting the truth (Deobhanj, 2017; D. Jones and Anderson Crow, 2017).

D. Jones and Anderson Crow (2017) argued that if the structure of a narrative is understood, scientists can present their work in ways that are compelling and thus productive in solving problems. The narrative can be broken down into four parts, the: setting, characters, plot, and moral (Cohen, 2011; D. Jones and Anderson Crow, 2017; Torres and Pruim, 2019). The setting is the time and place in which the story is taking place; it is also the ideas, facts, and perhaps the policy that provides context to the story's topic. The characters are individuals or figure who perform actions or speak dialogue, which drives the narrative forward. They are also considered the emotional engine of the story. The plot is a sequence of actions and events, as well as establishes the relationship between the character and the setting. Finally, the moral is the lesson that viewer is supposed to walk away with, often the solution to the topic's problem.

Using narratives in science communication allow the audience to be transported into the story or identify with the characters. The phenomenon in which readers' real-world views and attitudes can be influenced by narratives has been termed "narrative persuasion" (de Graaf et al., 2012). The extent that individuals are absorbed into a story or transported into a narrative may show effects of the story on their real-world beliefs (Green and Brock, 2000). When readers adopt the perspective of a character, "identification" is proposed to be one of the mechanisms through which narratives can change attitudes (de Graaf et al., 2012; Green and Brock, 2000; Isberner et al., 2019; Hoeken and Sinkeldam, 2014). Narrative transportation and identification with characters has been shown to be impactful in reducing three forms of resistance (Moyer-Guse and Nabi, 2010; Shen et al., 2015) and can lead to behavioral change Shen et al. (2015).

3.4 Representation in Science Media

A key feature that makes online videos effective for online learning and engagement is the consistent presence of the educator or scientist/communicator (Welbourne and Grant, 2016; Choe et al., 2019). However, there is a sever lack of diversity amongst the science communicators presented in science videos. A study done by Amarasekara & Grant Amarasekara and Grant (2019) looked into the gender breakdown of the host in 391 of the most popular YouTube science channels. Of the 391 channels, only 32 were hosted by female communicators. Additionally, female hosts have shown to negatively affect the popularity of the science videos, resulting in fewer views and an abundance of negative comments pertaining to the appearance of the female presenter (Amarasekara and Grant, 2019; Welbourne and Grant, 2016). According to a panel of science YouTubers presenting on an EduTainment panel at YouTube's VidCon2017 convention, the science channel's audience is predominantly made up of educated males from either the UK or the US (Sally LePage YouTube Channel, accessed May 25, 2020). This lack of representation in science media plays into and reinforces the stereotypical narrative that science is a domain reserved for boys/men. Yet, this stereotypical narrative can be challenged by changing who we choose to present on camera as the scientist and science communicator.

Stereotypical representations of scientists in either the classroom or media have the potential to reduce interest in science, technology, engineering, and math (STEM) fields among women and people of color (Schinske et al., 2016; Amarasekara and Grant, 2019; Pietri et al., 2017). "*If students hold stereotypes that portray scientists as a different 'kind of person' than themselves, those students might conclude they are* *not'science people' (Schinske et al., 2015, 2016).*" Studies have shown that the lack of role models and the projection of negative stereotypes are some of the factors that cause marginalized students to leave STEM (Dortch and Patel, 2017; O'Brien et al., 2015; Schinske et al., 2015; Smith et al., 2015; Rainey et al., 2018; Johnson, 2012).

Several interventions have been done at the university level to recruit and retain marginalized students in STEM such as summer research programs, mentoring, and career coaching (Byars-Winston et al., 2016; Williams et al., 2017; Ong et al., 2018; Carpi et al., 2017; Zumbrunn et al., 2014). In addition to these interventions, science education researchers have also looked into media as an intervention tool. For example, Schinske et al. (2016) explored if undergraduate students' perceptions towards scientist stereotypes would change after exposure to a diverse group of scientists. Students watched videos, listened to podcasts, and read biographies of diverse scientists and their research as homework. At the end of their course, following the intervention, students shifted toward counter stereotypical descriptions of scientists and conveyed enhanced abilities to personally relate to scientists (Schinske et al., 2016). Shin et al. (2016) led a similar study in which they tested the effects of role-model biographies that challenged common STEM stereotype; in this study they saw an increased sense of belonging, STEM interest, and self-efficacy amongst college students in and out of STEM. These studies support the need for increased production of underrepresented minorities is science videos.

3.4.1 The effect of stereotypes on gender

Role models are often seen as providing a way to motivate individuals to perform novel behaviors and inspire them to set ambitious goals. This is especially true for members of marginalized groups within educational and occupational settings (Morgenroth et al., 2015). However, when stereotypes of scientists are enforced, stereotype threat can occur. Stereotype threat is "the self-perceived concept and the apprehension caused by the idea that engaging in certain behaviors may confirm negative attributes commonly associated with minority group membership" (Meador, 2018). Several studies have looked into how stereotype threat concerns influence women's identification with science and motivation to pursue a career in STEM (Smith et al., 2015; Schuster and Martiny, 2017; Ahlqvist et al., 2013; Sunny et al., 2017; Meador, 2018; Young et al., 2013; Simon et al., 2017). Positive stereotypes, such as women seeing feminine role models, can shrink the gap between the career role and the family role for women and reduce attrition between the STEM education and the career levels (Luong et al., 2020), as well as reduce the implicit stereotype that science is masculine in the culture-at-large (Young et al., 2013). However, when women encounter negative stereotypes, women report weaker science identification and, in turn, weaker science career aspirations in contrast to men (Cundiff et al., 2013; Olmedo-Torre et al., 2018). In the study by Murphy et al. (2007), women who watched a video with unbalanced gender representation had more cognitive and physiological vigilance, a poorer sense of belonging, and a lower desire to engage than women who watched a gender-balanced video; this situational cue had little effect on men.

3.4.2 The effect of stereotypes on race and ethnicity

There have yet to be studies that examine the impact of the race, ethnicity, or cultural identities of the science communicator and how this factor might affect video popularity. In addition to the absence of knowledge regarding racial representation of the presenter in science videos, there is also a lack of research on how marginalized students are impacted by science videos featuring racial representation. However, Schinske et al. (2015) found that students at an Asian American and Native American Pacific Islander–Serving Institution identifying non-stereotypical images of scientists at the start of class had higher rates of success in a biology course than their counterparts. Schinske et al. (2015) also found evidence suggesting many students had few real-world reference points to inform their stereotypes of scientists.

Based on the typology of what makes an effective YouTube science video and the lack of representation in science media, what is missing in the literature is exploring or examining the question: *How students identify with different narratives and racial representation in science videos*? My dissertation work is one of the first attempts to assess the impact of racial representation in science videos. Racial representation is explored through video storytelling. I assess how my target audience interacts with the character through two different story narratives and video styles. With the majority of science communicators producing and viewers watching science videos on YouTube being college educated-adult men, I am interested in targeting teens and young adults. Specifically, students of color in high school and college by featuring a young, person of color as the scientist in the videos. As well as constructing narratives within the range of their level of understanding and opportunities to identify with the characters.

CHAPTER 4

Narratives and Identity in Science Videos

4.1 Producing Science Videos for College Students

Utilizing science communication theory and practice established in **Chapters 2 and 3** I address the question *How do students identify with narrative and racial representation in science videos?* I crafted two different science video narratives and present a counter-stereotypes of scientists by featuring a Black, female scientist. The videos were self-produced following the production workflow in **Chapter 2** published in Castillo et al. (2021). The first video narrative is centered around the scientist's personal STEM journey. The second video narrative is centered around explaining the scientist's research. I collected qualitative feedback on the videos from diverse students enrolled in university across the U.S. to understand the elements that attract this audience and how students perceive the scientist in the videos.

Here, I detail the workflow of my production process in producing the videos for my study (Castillo et al., 2021). The development of the videos went through three stages: pre-production, production, and post-production. *Pre-production* involves creating designs that utilize the strengths of video and optimize them for the learning capabilities of the audience (Jenkinson, 2017). This includes but is not limited to content mapping, lesson design, storyboarding, and scriptwriting. During this stage, the goal of the filmmaker is to identify the main objective that then informs the script and storyboard. *Production* refers to all activities involved in the recording of audiovisual material. This includes lighting, sound, set, framing, and video. In this stage, I present the course of actions that went into recording the video. *Post-production* includes editing the content of the recorded film, adding visual elements, adding music or other sound effects, and publishing the final video. I then share the video editing tools used and the reasoning behind the graphic and music elements chosen.

4.1.1 Pre-Production

Video Contextualization. The purpose of the video treatment is to test two different storytelling narratives and if racial representation matters to undergraduate students. Determining what type of science video students gravitated more towards could inform the production of an entire digital mini-series. To test both story narrative and representation, the goal was to keep the character (the scientist) and topic the same between both videos so that the narrative is the changing variable. The first video narrative is centered around the science with the second centering around the scientist, **Figure 4.1A**. The *science-centered* videos focused on the science and research featured. The scientist serves as the subject matter expert in explaining the science and research highlighted in the video. The *scientist-centered* videos focused on the scientist's motives and personal journey with respect to the science featured and the scientific objectives in the research, **Figure 4.1B**.

In both videos, I feature a scientist of color as the main character. However, in the science-centered video I am featured on-camera as the host and in the science-centered video off-camera to help carry the narrative forward. Narrowing down to one scientist featured as the subject-matter expert allows for continuity and consistency while still meeting my objective to study representation. The goal in presenting the two different videos is to determine if students are motivated by the science itself or the scientist. To determine if the representation matters in the videos for students, for each narrative style, students were asked about their perception of the scientist in the survey.

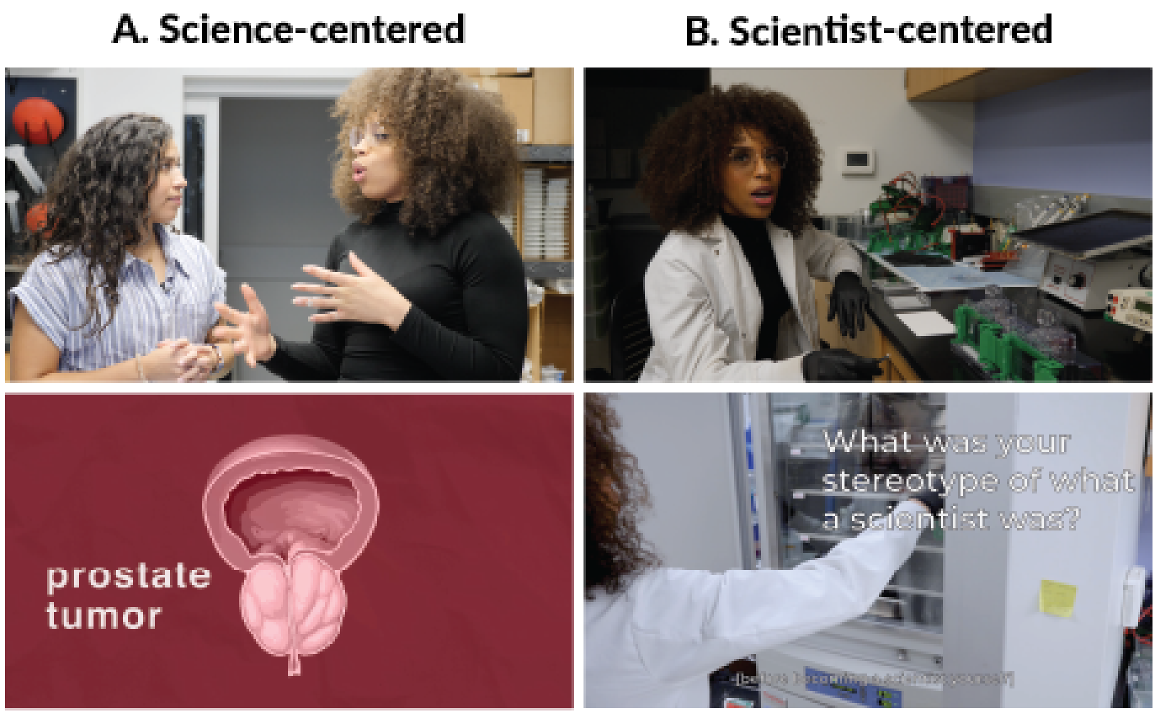


Figure 4.1: Screenshots of Video. A. Screenshots from the science-centered video showing me, the host, interviewing the featured scientist (top), and an animated scene introducing the science topic (bottom). B. Screenshots from the scientist-centered video featuring showing medium-shot of featured scientist (top), and text overlay of questions over scene (bottom).

Learning Objectives. The goal of the two videos is to explore careers in STEM by exposing students to a field of research with which they are perhaps unfamiliar. The scientist featured is Dr. Korie Grayson, a Black woman who was a part of the Biomedical Engineering Ph.D. program at Vanderbilt University, researching therapeutic technologies for late-stage prostate cancer. The two-story narratives being produced each had their own learning objective but had the same goal of introducing students to a field of research and a diverse scientist. The learning objective for the science-centered video is for students to walk away with a general understanding of the research Dr. Grayson conducts. Specifically, students should be able to identify how Dr. Grayson is using small biological particles to treat stage-four prostate cancer. In the scientist-centered video, the learning objective is for students to walk away with having learned the motive behind why Dr. Grayson decided to become a scientist—specifically that Dr. Grayson first pursued med-school and pivoted towards chemistry because she enjoyed research.

Video Mechanics. Before any filming took place, I had to first decide the style of the videos. For the science-centered video, I was inspired by explainer-style videos predominantly seen on YouTube from popular channels such as *Veratasium*, *It's OK to Be Smart*, and *SciShow*. In this style of video, a host or science communicator typically walks the viewer through the science of a topic throughout the video. The host also interviews a subject-matter expert of said topic on-camera too. Additionally, these videos use graphic animations to help explain and visualize how the science works. These features of a typical YouTube science explainer were what I desired to produce in my science-centered videos. I present as the interviewer and Dr. Grayson presents as the subject-matter expert.

For the scientist-centered video, I aimed to produce a documentary-style video. Documentary-style videos typically follow a main character through a journey to some endpoint. The producer/host is not featured in the video, with the primary focus being the scientist. The character is the one narrating the video as well. To achieve this style for the scientist-centered video, I interviewed Dr. Grayson off-screen to prompt her in answering questions about her journey. The final video then shows Dr. Grayson in the lab in which she works, sharing her story as to why and how she become a scientist.

YouTube-explainer videos can range between 5 to 30 minutes depending on the content creator, channel popularity, and science topic. Documentary-style videos have a wider time range, including short films that are at least 5-minutes and up to feature films at 60 plus minutes. When it comes to presenting videos in a classroom, the ideal lengths of educational videos are between 5 to 10 minutes long before students lose interest or no longer retain the material (Brame, 2016). Since my target demographic is young adults enrolled in college and high school, I aimed to produce the science and scientist-centered videos with lengths of 5 to 10 minutes.

Next, I focused on the content that would be covered in each video and potentially writing a script to inform the next stage of production. To gain a better understand of the scientist featured and the work that they do, I interviewed Dr. Grayson on campus in a private conference room and recorded our conversation using an audio recorder loaned out from Vanderbilt University Library's Gear2Go service. The interview was an hour long. The first half of the interview I asked a series of questions related to her research; I asked her to summarize her graduate work and then expanded the conversation to cover the details of her methods and the science of how it works. The second half of the interview then focused on her journey in becoming a scientist. We talked about how she got involved in science in high school, her undergraduate experience, and how she pivoted from pre-med to studying chemistry and pursuing graduate school.

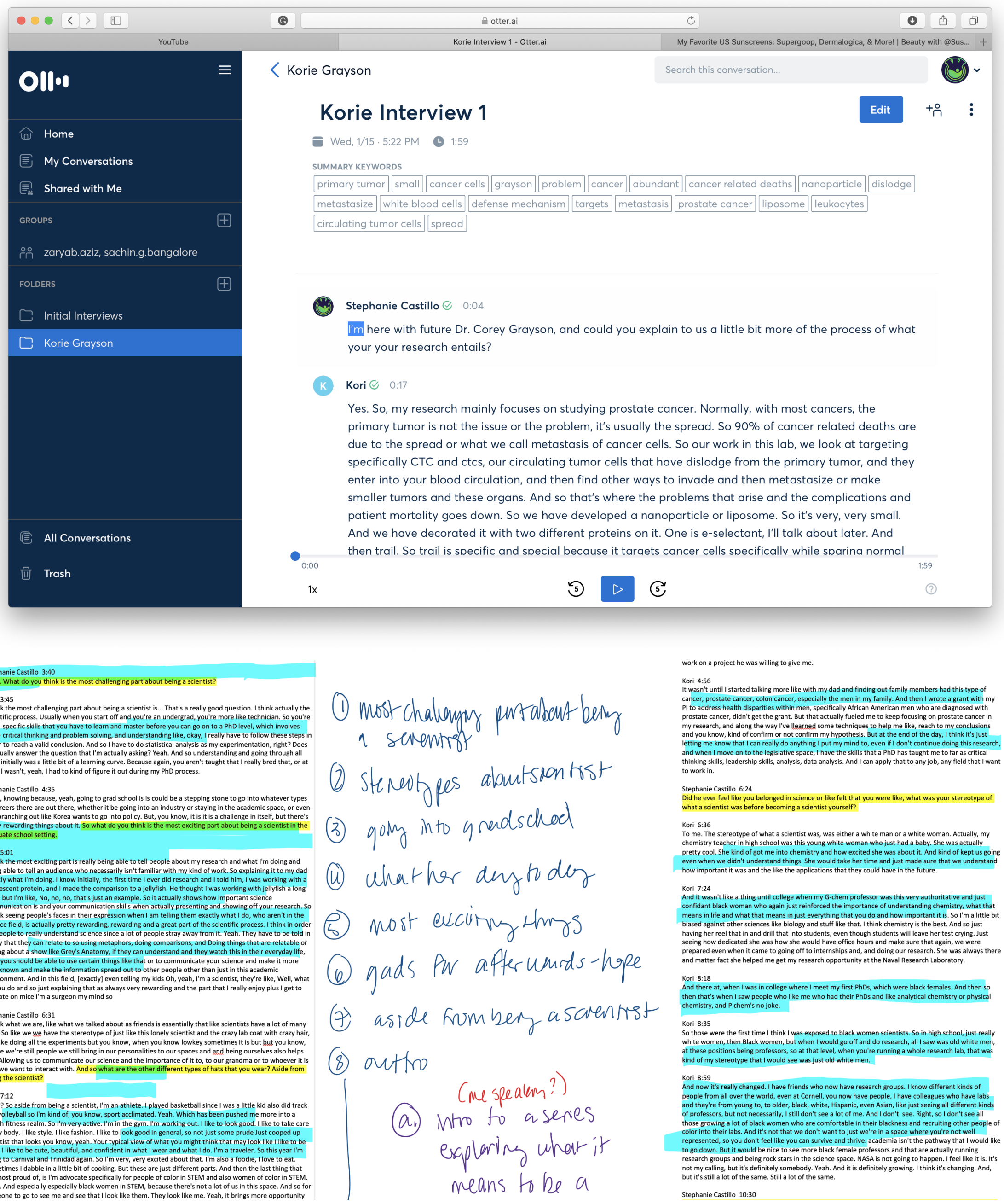


Figure 4.2: Screenshots of Preproduction. Screenshots transcription platform, Otter.ai (top) and screenshot of my notes on planned questions derived from transcription (bottom).

The interview was transcribed using Otter.ai, an online AI transcription service. The transcript was used to inform the questions I planned for her to answer on camera during production. Additionally, the list of questions was also used to inform the type of shots I would capture for the video. Typically, in this stage of pre-production, a script is written of exactly what I would be saying on-camera in the final video. Instead, I used the list of questions and a general outline of the shots I planned to capture (**Figure 4.1.1**). The captured audio and video footage was then used to develop the final script of the video described in **Section 4.1.3**.

4.1.2 Production

Production refers to all activities involved in the recording of audiovisual material. Two days were required for filming Dr. Grayson to capture enough footage for both videos. I recorded the on-camera interview on-location. The location for filming was in the wet lab Dr. Grayson worked in at Vanderbilt University. The lab was used as the "set" where Dr. Grayson is seen in her lab coat working in a research lab. Having the lab as the set establishes that the character is related to science. The lab had large windows that allowed natural light in, which worked as the light source in addition to the fluorescent lights installed in the lab. Since the fluorescent lights were intense overhead lights, using them as the only light source would have casted a shadow onto Dr. Grayson and myself from the top down. To prevent that, the windows were opened and lab lights were kept on during filming.

Audio and video equipment was rented out from Vanderbilt University Library's Gear2Go service. A RodeLink Wireless Transmitter and Receiver with the addition of a lavaliere microphone was used to capture Dr. Grayson's audio. An Insignia ^{T}M Omnidirectional Lapel Microphone connected to the microphone input to the main camera was used to capture my audio. These microphones allowed for he capturing of our voice without picking up the background noise of the lab. For video, the Panasonic Lumix DC-GH5 with a 12–35 mm, 1–2.5 aperture lens was used as the primary camera. A Canon XC15 with a 8.9–89 mm, 2.8–5.6 aperture lens was used as a secondary camera. This camera setup allowed for me to capture both Dr. Grayson and myself in frame with us and the background clear and in focus.

Day one of filming consisted of capturing footage for the scientist-centered video (**Figure 4.1.2**). I followed Dr. Grayson around the lab as she performed a mock-experiment. As she was carrying out the mock experiment, I asked her questions about her journey in becoming a scientist off-camera. I captured closeup and medium shots of her performing the experiment before settling into the final scene. The final scene captured that day had Dr. Grayson sitting in front of a lab bench, facing the camera, finishing out the interview. Day two of filming consisted of capturing footage for the science-centered video. For this footage, I interviewed Dr. Grayson on-camera. Both of us were in frame from the waist up, facing the camera, with our bodies slightly angled towards each other while talking. During this on-camera interview, I asked questions about her research. The footage captured for each video would fall under that category of 'Speaker Format' where the subject matter expert is the primary focus of the video mentioned in Castillo et al. (Castillo et al., 2021) and Choe et al. (Choe et al., 2019; Brame, 2016).

Figure 4.3: Production Behind-the-scenes. Screenshots of me interviewing Dr. Grayson in lab (top) and pictures of my camera handling and setup during production (bottom).

4.1.3 Post-Production

The final stage of production is post-production, which includes editing the footage to create two story narratives and adding visual elements, music, and other effects such as graphics and animation. The final videos were edited using the Adobe Creative Suite. Adobe Premiere Pro was used to edit together the footage to create one main storyline. Adobe After Effects was used to animate graphics that were made on Adobe illustrator to create an animated sequence for the science-centered video. Adobe Audition was used to capture voiceovers for animations and to mix sound effects and music for the video.

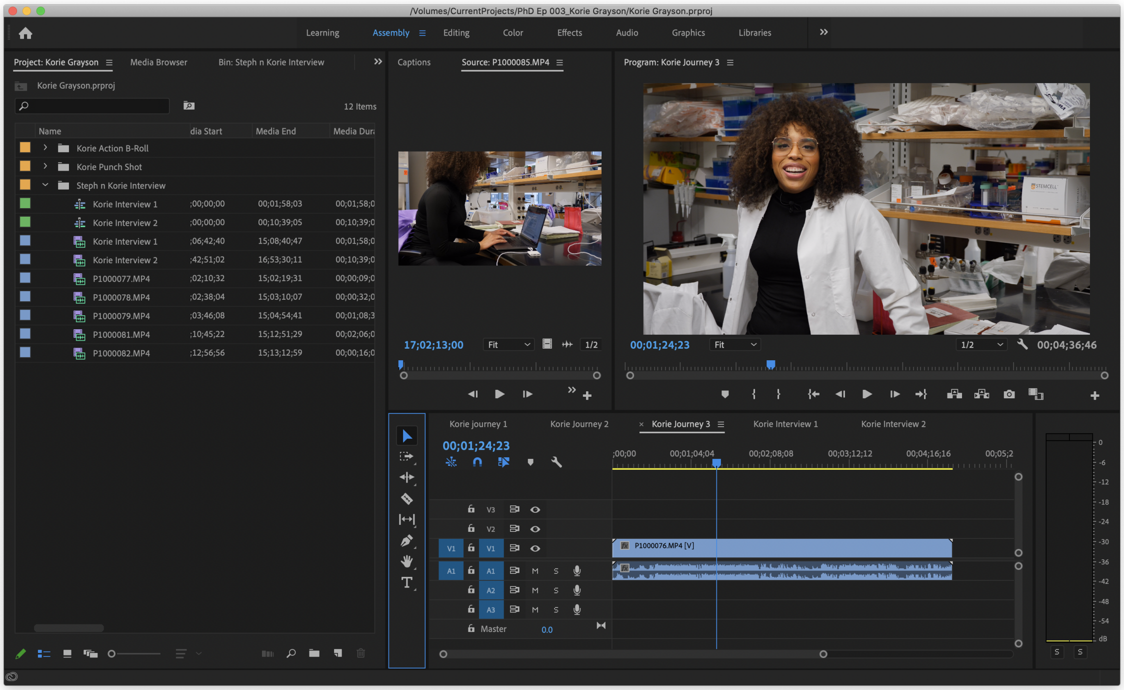
The post-production process started with reviewing the captured footage. Because the interview with Dr. Grayson was the main footage captured, selected clips were transcribed using Otter.AI to aid in the development of the final script and storyboard. I reviewed the transcripts and selected moments I believed were important to include in the final video. For the science-centered video, I drafted a script in which I introduce the topic as well as Dr. Grayson as the subject-matter expert. Quotes from Dr. Grayson are interspersed throughout the video to introduce or explain her research that was followed by me further clarifying the science. Writing the script revealed that we needed to re-interview Dr. Grayson to have her re-explain the science or concisely summarize her answer to better guide the story. We then drafted a storyboard from the script that laid out the shots that would be included in the video timeline, and the scenes that would require animations or additional filming.

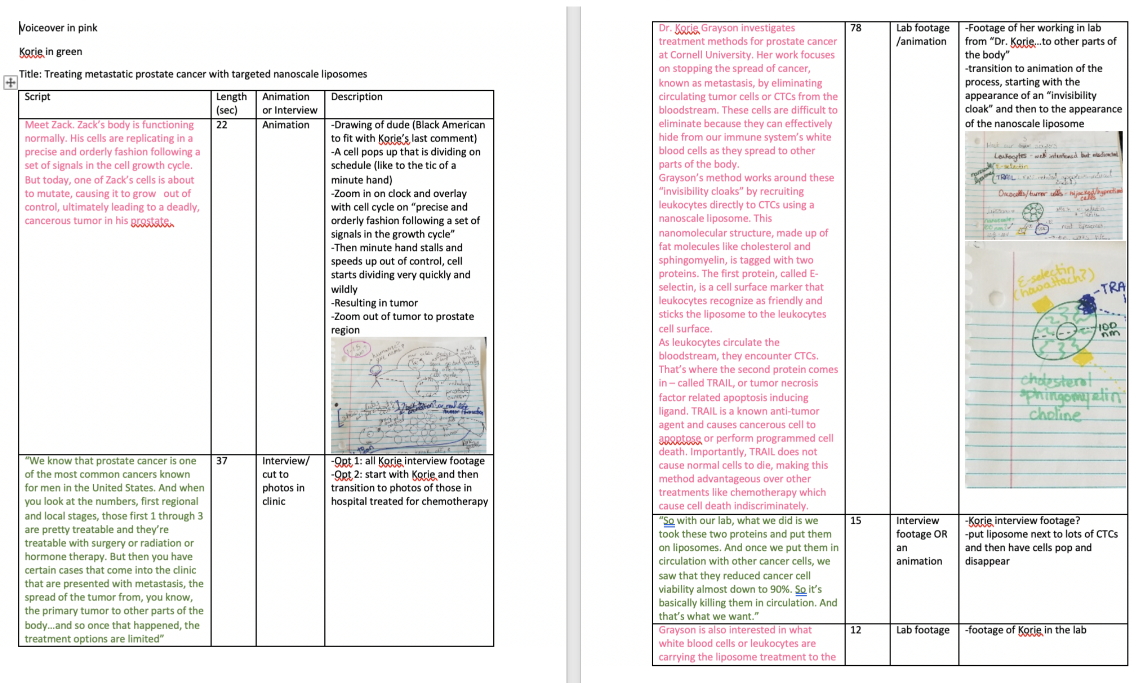
Identifying the missing footage I needed to capture, I started with conducting a follow-up interview with Dr. Grayson via Zoom. I provided her with a script to read from to guide her in concisely answering questions. The Zoom recording was uploaded to Adobe Premier Pro. Next, I recorded the scenes where I am talking straight to camera. The audio and video equipment used in capturing Dr. Grayson's footage was used to capture my talking head. The set of this scene was my home office as filming was happening during COVID-19 shutdown. The footage was captured within a day and uploaded to Adobe Premiere Pro. I then recorded the voiceover for the sections of animations planned for the video. A Yeti Nano Blue Yeti Nano Premium USB Microphone was used to record my voiceover on Adobe Audition. This USB mic has stronger input capabilities allowing me to clearly capture my voice without picking up any background noise. The audio was cleaned to remove background noise and then uploaded to Adobe Premiere Pro. Finally, graphics for the animations were created on Adobe Illustrator, which were then animated in in Adobe After Effects and timed to the voiceover. A total of three animated scenes were produced to explain how prostate cancer happens and how Dr. Grayson's treatment works.

After collection and upload of all footage, a rough cut of the video was made following the developed script and storyboard (**Figure 4.1.3**). The video was edited for clarity and reviewed to identify points in the video that would require additional graphics. Additional graphics that were added to the fine cut included: stock footage of general science videos (download from Storyblocks.com subscription service), name cards for me and Dr. Grayson, and text boxes to define science terms. With the addition of graphics, a fine cut of the video was produced. The footage was reviewed for mistakes, pacing, and final touches. Finally, sound effects to enhance the animations and background music was added (download from Storyblocks.com subscription service). Background music was selected to reflect a neutral, upbeat, and curious tone. The addition of the sound effects and music resulted in the final cut of the science-centered video. The final video was exported with pre-set settings provided by Adobe at 1080p resolution for the purpose of uploading to YouTube. The entire post-production process of the science-centered took three months.

Writing a script and storyboard for the scientist-centered proved to be more difficult as the initial footage of Dr. Grayson was captured the February before lockdown in March in 2020. The video wasn't reviewed and edited until late fall that same year. I was unable to capture additional footage of her working in the lab nor an on-camera interview due to COVID-19 restrictions, as well as the fact she moved out of state. A follow up interview was conducted via Zoom to capture more of her personal journey into becoming a scientist. After transcribing the interview and reviewing the footage, there was just not enough footage to create a more cohesive story narrated by the scientist. By default, I choose to work with the initial footage captured and structured it to be more of an interview where I am prompting a question to Dr. Grayson off-camera. My voice is heard in the video and displayed as text, with her responding on camera remaining as the focal point in the video. The post-production for the scientist-centered video followed the same workflow with minor changes.

The final videos were reviewed by my committee and revised based on their suggestions. Revision for the science-centered video included cutting the video down from eight minutes to five, as well as editing the ending to be more concise. Comments on the scientist-centered video were made about the pacing of the music and the order of the shots included. This video was revised to include music with a more up-beat tempo, and editing in more footage of Dr. Grayson working to breakup the monotony of the interview. The final videos both had a final length of time around five minutes, which falls within the suggested time to present to students according to Brame et al. Brame (2016) and Mayer et al. Mayer (2014a). Both videos were uploaded to YouTube and embeded in the final survey design. The final videos can be seen in the following section.





Voiceover in pink

Korie in green

Title: Treating metastatic prostate cancer with targeted nanoscale liposomes

Script	Length (sec)	Animation or Interview	Description
Meet Zack. Zack's body is functioning normally. His cells are replicating in a precise and orderly fashion following a set of signals in the cell growth cycle. But today, one of Zack's cells is about to mutate, causing it to grow out of control, ultimately leading to a deadly, cancerous tumor in his prostate.	22	Animation	-Drawing of dude (Black American to fit with Korie's last comment) -A cell pops up that is dividing on schedule (like to the tic of a minute hand) -Zoom in on clock and overlay with cell cycle on "precise and orderly fashion following a set of signals in the growth cycle" -Then minute hand stalls and speeds up out of control, cell starts dividing very quickly and wildly -Resulting in tumor -Zoom out of tumor to prostate region
"We know that prostate cancer is one of the most common cancers known for men in the United States. And when you look at the numbers, first regional and local stages, those first 1 through 3 are pretty treatable and they're treatable with surgery or radiation or hormone therapy. But then you have certain cases that come into the clinic that are presented with metastasis, the spread of the tumor from, you know, the primary tumor to other parts of the body...and so once that happened, the treatment options are limited"	37	Interview/ cut to photos in clinic	-Opt 1: all Korie interview footage -Opt 2: start with Korie and then transition to photos of those in hospital treated for chemotherapy

Dr. Korie Grayson investigates treatment methods for prostate cancer at Cornell University. Her work focuses on stopping the spread of cancer, known as metastasis, by eliminating circulating tumor cells or CTCs from the bloodstream. These cells are difficult to eliminate because they can effectively hide from our immune system's white blood cells as they spread to other parts of the body. Grayson's method works around these "invisibility cloaks" by recruiting leukocytes directly to CTCs using a nanoscale liposome. This nanomolecular structure, made up of fat molecules like cholesterol and sphingomyelin, is tagged with two proteins. The first protein, called E-selectin, is a cell surface marker that leukocytes recognize as friendly and sticks the liposome to the leukocytes cell surface. As leukocytes circulate the bloodstream, they encounter CTCs. That's where the second protein comes in – called TRAIL, or tumor necrosis factor related apoptosis inducing ligand. TRAIL is a known anti-tumor agent and causes cancerous cell to apoptose or perform programmed cell death. Importantly, TRAIL does not cause normal cells to die, making this method advantageous over other treatments like chemotherapy which cause cell death indiscriminately.	78	Lab footage /animation	-Footage of her working in lab from "Dr. Korie...to other parts of the body" -transition to animation of the process, starting with the appearance of an "invisibility cloak" and then to the appearance of the nanoscale liposome
"So with our lab, what we did is we took these two proteins and put them on liposomes. And once we put them in circulation with other cancer cells, we saw that they reduced cancer cell viability almost down to 90%. So it's basically killing them in circulation. And that's what we want."	15	Interview footage OR an animation	-Korie interview footage? -put liposome next to lots of CTCs and then have cells pop and disappear
Grayson is also interested in what white blood cells or leukocytes are carrying the liposome treatment to the	12	Lab footage	-footage of Korie in the lab

Figure 4.4: Post Production Screenshots. Screenshots of the video rough cut in Adobe Premiere Pro (top) and screenshot of the storyboard used for the science-centered video (bottom).

4.2 Final Videos

4.2.1 Science-Centered Video

Video A: Science-Centered Video Thumbnail. The goal of this video was to introduce the audience to Dr. Korie Grayson's research on developing a treatment for late-stage prostate cancer. Click on the image to watch video or visit https://www.phuturedoctors.com/video-portfolio/v/phuture-doctors-v4 .

4.2.1.i Science-Centered Video Transcript

SPEAKERS: Stephanie Castillo, Dr. Korie Grayson

Stephanie

Meet Zack. Zach's body is functioning normally. His cells are replicating in a precise and orderly fashion following a set of signals and the cell growth cycle. But today, one of Zach's cells is about to mutate, causing it to grow wildly out of control. Ultimately leading to a deadly cancerous tumor in his prostate. There are four stages of prostate cancer starting with stage one. In stage one, the doctor identifies that there's a tumor within the prostate. When it comes to stage four, the cells of the prostate kind of break up and travel throughout the body. So the cancer spreads throughout the body, and it goes to the either the bones the lymph nodes or other organs. For stages one through three, the cancer is actually treatable through surgery, radiation or hormone therapy. But the treatment options become so limited when the patient presents a stage four prostate cancer.

Dr. Grayson

Especially with African American men, they don't always present stage one. They usually present at later stages with more aggressive forms. So that is actually what's being presented in clinic. So how can we treat those stages in these cases? And so, in my research, I'm hoping to, I don't want to say cure, but I want to provide them more treatment options.

Stephanie

So that's my good friend, Dr. Korie Grayson. Dr. Grayson is a chemical engineer working at Cornell University slash Vanderbilt University, and she is studying prostate cancer. Specifically how to stop the spread of cancer and eliminate tumor cells that travel through the bloodstream. Could you explain to us a little bit more of the process of what your research entails?

Dr. Grayson

My research mainly focuses on studying prostate cancer. Normally, with most cancers, the primary tumor is not the issue or the problem, it's usually the spread. So 90% of cancer related deaths are due to the spread or what we call metastasis of cancer cells. So our work in this lab we look at targeting specifically CTCs, and CTCs are circulating tumor cells that have dislodged in the primary tumor, and they enter into your blood circulation, and then find other ways to invade and then metastasize or make smaller tumors in these organs.

Stephanie

It's the spread of tumor cells that leads to stage four cancer if it's not treated or caught in time. So the problem comes up is that tumor cells are really good at hiding from our white blood cells as they travel through our—through our bloodstream through other parts of our body. Our white blood cells are essentially our immune system's defense team. So if our tumor cells are able to hide from our white blood cells, then the question comes up, how can we come up with a treatment that is able to eliminate these circulating tumor cells and stop the spread of cancer?

Dr. Grayson

So we have developed a nanoparticle, or liposome. So it's very, very small. And we have decorated with two different proteins on it. One is E-selectin, I'll talk about later, and then TRAIL. So TRAIL is specific and special because it targets cancer cells specifically, while sparing normal healthy cells. And so that makes it good as a cancer therapeutic.

Stephanie

Alright, let's start off with the definition of liposomes. So liposomes are the small spherical particles that we can't see with our eyes, or with our naked eyes, and they have a similar structure as a bubble. So think of them as like a biological bubble. In the lab, Dr. Grayson decorates the surface of the liposomes with two proteins: E-selectin and TRAIL. E-selectin is a protein that white blood cells recognize as friendly and connect the liposomes to the surface of the white blood cells. Having the liposomes on the surface of the white blood cells creates a sort of invisibility cloak. When a white blood cell approaches a tumor cell, the second protein TRAIL attaches the light blue zone to the surface of the tumor cell. Once the TRAIL protein is connected, the tumor cell performs programmed cell death. The reason this invisibility method is considered a good treatment for prostate cancer is because it specifically targets tumor cells that are circulating through our bloodstream, and it doesn't attack any other fast-growing cells such as are cells that cause your hair to grow.

Dr. Grayson

What we did is we took these proteins specifically trail and put them on liposomes. And once we put them in circulation with other cancer cells, we saw that they reduce cancer cell viability, almost down to 90%. So it's basically killing them circulation. And that's what we want.

Stephanie

So why was this observation or this conclusion that Dr. Grayson came too exciting or interesting for them? In the long run when we're thinking about cancer treatments, we want to make sure that they're not going to interfere with the body's like natural system, the way it works naturally. So the fact that this invisibility cloak method, didn't interfere with the natural—with the body's natural function, and it kills circulating tumor cells up to 90% makes this a really exciting and potential solution to treat late stage prostate cancer for men. That sounded way too exciting *laughs* That sounded way too exciting! But there's still so much work that has to go into making sure that these treatments are actually good within—with—for humans and can actually treat, you know, not only mice, but—but humans. It's just still an exciting endeavor to know that we're at least one step forward to coming up with a new solution for such a challenging problem. This video was compact with a lot of information. And if you didn't take anything away or learn anything about prostate cancer, I hope you got to walk away with meeting a chemical engineer seeing the type of research that they do. And also meet Dr. Korie Grayson, who is an awesome scientist, and get to add her to the list of cool scientists that you know. Thank you so much for tuning in and I hope to catch you on the next episode of Phuture Doctors. Later, Fam!

4.2.2 Scientist-Centered Video

Video B: Scientist-Centered Video Thumbnail. The goal of this video was to introduce the audience to Dr. Korie Grayson's journey in becoming a biomedical engineer. Click on the image to watch video or visit https://www.phuturedoctors.com/video-portfolio/v/phuture-doctors-v3.

4.2.2.i Scientist-centered Video Transcript

SPEAKERS: Stephanie Castillo, Dr. Korie Grayson

Dr. Grayson

Hi, I'm Korie with a K, Future Dr. Grayson. I'm a biomedical engineer at Cornell University and a visiting scholar at Vanderbilt University. And my research focuses on prostate cancer.

Stephanie

Did you always knew you wanted to be a scientists?

Dr. Grayson

No. I had no idea.

Stephanie

When did you have that moment?

Dr. Grayson

That I knew when I wanted to be a scientist? When... Probably when I started applying to college, and then when I got into my scholarship group and we were all STEM majors, and when we had our APS, which is like a Wednesday meeting, every time we would have that was mostly med schools that would come and talk to us during that like meeting we would have every Wednesday. So a lot of us kind of been groomed to be doctors. And I was like, okay, so I'm a do it. I'm gonna take the MCAT. And I'm gonna, you know, be a doctor and treat people. And then I did a rotation with an OB-GYN at EVMS mass, which is like Eastern Virginia Medical School in Norfolk. Did that for almost two years. I just realized, maybe this isn't for me.

Stephanie

What was your stereotype of what a scientist was before becoming a scientist yourself?

Dr. Grayson

That's a good question. To me...the stereotype of what a scientist was, is either a white man or a white woman. Actually, my chemistry teacher in high school was this young white woman who just had a baby, she's actually pretty cool. She kind of got me into chemistry and how excited she was about it. And kind of kept us going even when we didn't understand things, she would take her time and just made sure that we understand how important it was and the like the applications that they could have in the future. And it wasn't like a thing until college when my G Chem professor was this very authoritative, and just confident black woman who again just reinforced the importance of understanding chemistry, what that means in life, and what that means in just everything that you do and how important it is. Matter fact she helped me get my research opportunity at the Naval Research Laboratory. And there when I was in college when I met my first PhDs, which were black females. And then from then that's when I saw people who like me who had their PhDs in like analytical chemistry or physical chemistry. So I'm a little bit bias against other sciences, like biology and stuff like that, I think chemistry is the best but *laughs*

So those were the first time I think I was exposed to black women scientists. But when I would go off and do research, all I saw was old white men, at these positions, and being professors. Now it's really changed. I have colleagues who have labs, and they're from young to, to older. Black to White, Hispanic, even Asian, like just seeing all different kinds of professors, but not necessarily, I still don't see a lot of me. So I don't see although it's growing a lot of Black women who are comfortable in their blackness and recruiting other people of color into their labs. And it's not that we don't want to, it's just get in a space where you're not well represented, so you don't feel like you can survive and thrive. Academia isn't the pathway that I would like to go down. But it would be nice to see more Black female professors, and that are actually running research groups and being rock stars and the science space.

Stephanie

What did you go into grad school wanting to get out of it compared to what you're trying to get out of it now?

Dr. Grayson

Right. Yep, yep.

So I think initially going into grad school, I don't know what I wanted out of it to be honest. I just knew that I wanted to go into this space that was new and was innovative, and was doing things that were helping people but not necessarily on the medical side. It wasn't until I started talking more like with my dad and finding out family members had this type of cancer, prostate cancer, colon cancer, especially the men in my family. And then I wrote a grant with my PI to address health disparities within men—specifically, African American men who are diagnosed with prostate cancer.

I didn't get the grant. But that actually fueled me to keep focusing on prostate cancer in my research. Along the way of lines and techniques to help me like reach to my conclusions and you know, kind of confirm or not confirm my hypothesis. But at the end of the day, I think it's just let me know that I can really do anything I put my mind to. Even if I don't continue doing this research, and when I move on to the legislative space, I have the skills that a PhD has taught me to as far as critical thinking skills, leadership skills, analysis, data analysis, and I can apply that to any job in any field that I want to work in.

4.3 Science vs. scientist: Narrative differences

The two videos presented to high school and early undergraduate students follow either science-centered and scientist-centered narrative. Both videos featured the same scientist represented as an expert in a STEM field. The main difference is the information being presented and the scientist's relationship to the information. In general, science-centered videos are driven by the research topic and how the scientist performs said research. For scientist-centered videos, the scientist highlights events on how they became a scientist, as well as self-reflection and perspective on what it means to be a scientist.

To differentiate between the two videos, the final video was transcribed using Otter.AI. The script was uploaded and coded for common themes using the web application ATLAS.ti. I first conducted open-coding where I labeled moments of the script that generally related to explaining the science, how is it explained, and the different stages of science or storytelling. On the second pass, I reviewed the open-code and noted patterns or commonality between the initial code. There were generally three themes that the open code fell under for each video script. In the third pass of the script, I coded for the proposed three themes identified.

Description of each theme for both videos is described below.

4.3.1 Science-centered.

"Prostate Cancer Research with Chemical Engineer Dr. Korie Grayson," was presented to the students as the science-centered video during the study (**Video A**). There are three main themes I extrapolated from the science-centered video script: research, scientist's role, and outlook.

The theme "research" describes the outcomes of the research after applying the scientific method; almost resembling the parts that go into a scientific paper. This includes background information that introduces the topic being discussed in the video, which then sets up the problem the scientists are facing. Identifying the problem sets up the scientist being introduced working towards solving that problem, which then sets up the methods. Animations and descriptive language are used to define technical jargon and explain how the science works. Lastly, the outcome of the research and the broader implications or future directions of the work is mentioned in the script.

The scientist featured in a science-centered video serves as a subject-matter expert to support the research explained in the video. Throughout this video, the scientist explains the science by stating the role they took in performing the science as a group effort and through action words. For example, "So we have developed a nanoparticle or liposome... And we have decorated with two different proteins on it." There is also a reference of self, or first-person identification, to show their relationship to science. For example, "And so in my research, I'm hoping to, I don't want to say cure, but I want to provide them more treatment options." When scientist refers to self in first-person, they also share personal perspective, opinion, or optimism about their research.

Finally, the theme "outlook" is found throughout the video to guide viewers through the narrative arc of the video. In the beginning, "So how can we treat those stages in these cases?" was asked to set up the problem the scientist is addressing in their research. In the middle of the video, there are two parts where questions are asked. The first question was directed towards the science communicator to the scientist, which serves as an introduction to the role of the scientist performing the science and leads into the research mechanism. The final question seen in the science-centered script sets up the resolution/conclusion of the video.

Overall, each theme contributes to the bigger picture of breaking down the science from the main research topic of interest which is determined by the scientist's subject matter expertise. The scientist's role is to provide context and or examples of how the science works using questions to help guide viewers along the process and understand the bigger picture or impact of the research being highlighted.

4.3.2 Scientist-centered.

"Becoming a Biomedical Engineer with future Dr. Korie Grayson," was presented to the students as the scientist-centered video during the study (**Video B**). There are four main themes extrapolated from the scientist-centered video script: guiding questions, life events, self-reflection, and perspective.

Similar to the science-centered video, the scientist-centered video also uses guiding questions to prompt the scientist's response and introspection. Unlike the science-centered video, the questions asked are not used to guide viewers into understanding the science but rather to learn about the scientist. The scientist featured in the video is still introduced as a subject-matter expert, but since the subject of the video is the scientist, viewers will hear personal stories about the scientist while seeing more personable characteristics. The guiding questions asked by the director/interviewer from behind the camera are used to prompt the scientist to answer through self-reflection, sharing their personal experience, and guide us through their scientific journey by highlighting life events.

With the use of guiding questions, the scientists reference life events as they share the various stages of their academic or professional journey in becoming a scientist. The life events provide context as to who they were as an individual during that time and the actions they took, which leads into the second theme of self-reflection—the third theme seen in scientist-centered videos. Self-reflection is driven by a first-person narrative where scientists share emotions, characterizations, values, and goals. For example, in this sentence "Even if I don't continue doing this research, and when I move on to the legislative space, I have the skills that a PhD has taught me to as far as critical thinking skills, leadership skills, analysis, data analysis, and I can apply that to any job in any field that I want to work in," Dr. Grayson hits all three points of sharing future goals, the skills she has and demonstrates characteristics of determination or ambition.

The last theme scene reveals the scientist's perspective. Different than the self-reflection theme where Dr. Grayson is talking about her own characteristics and motives, the perspective theme reveals her outlook of her field and the people she encounters. The people scientists may refer to are role models or other scientists in their field. They may also mention people who may have influenced their decision to continue to pursue a scientific career, such as other professionals or close family members. When it comes to reflecting on the scientific field itself, scientists may mention the general research landscape or their place within the scientific field. For example, in Dr. Grayson's story, she references how as an African American woman she did not encounter other Black scientists until later in her career. Even then, she mostly saw older White men in higher educational settings and went on to describe how that is changing the more she sees marginalized scientists becoming professors in institutions. Dr. Grayson is not referring herself, but rather describing what she sees in the field and people she has encountered at some point in time.

In summary, science-centered videos use guiding questions to direct viewers through understanding the research mechanisms. The role of the scientist in this video is to serve as a subject matter expert and describe the research they carried out. For scientist-centered videos, questions are used to prompt the scientist to self-reflect on their journey in becoming a scientist. Scientists' reference life events to set the scene of who they were at that time and then begin to reflect on their motives, emotions, and actions. They also share their perspective on the scientific field they are in, the people they encounter, and their perspective on where the field is or going.

CHAPTER 5

Assessing Audience Response to Produced Science Videos

5.1 Survey Design

To receive feedback from my audience, I distributed the videos through an online survey using Qualtrics as the survey tool. Participants were recruited via email (Vanderbilt University) and social media (Instagram and Twitter). To participate, students signed up for the survey at bit.ly/scivid2021 and greeted with a welcome screen. The welcome screen informs participants on the purpose of the study and general rules in participating in the survey. Once they select continue, they must agree to participate after reading our confidentiality and privacy statement and confirm that they are at least 18 years or older and enrolled in a U.S. college to participate. Once they agree, they begin the survey on Qualtrics.

The survey includes a pretest, a video, and post-test designed to be completed within 20 minutes. Participants were not required to answer all the questions but suggested to answer. The pretest includes questions used to measure students' motivation to pursue scientific careers developed and verified by Kirn et al. (2016); Shin et al. (2016); Maktoufi (2020) and understand their YouTube use. Before watching the video, participant's demographics were collected. Demographics collected include age, class year, gender identity, race, and highest level of parent/guardian education.

Participants were randomly assigned video A (*science-centered*) or B (*scientist-centered*) and given the same instructions (e.g., "In this video, we'll learn about biomedical engineer Dr. Korie Grayson and her journey into becoming a scientist"). The videos were embedded into the survey platform using YouTube provided HTML code. With using YouTube as the video source, participants had access to replay, rewind, or change the pacing of the video, as well as the option for close captioning. Participants had to wait 60 seconds before they were allowed to proceed forward in the survey.

Post watching the video, participants answered two attention check questions followed by video feedback. Students were asked about their perceptions of the science and scientist. The survey is automatically saved and submitted. Once participants reach the final question, a "thank you" screen appears; they then were prompted to exit the survey.

5.1.1 Participants

A total of 238 people participated in the video survey, but after filtering for completion, below 25 years old, and attending a school in the U.S., I was left with a total of 211 participants between the ages of 18–24. Of the accepted participants, 27.0% are male, 71.6% are female, and 1.5% identified as non-binary (n = 57, 151, 3, respectively). Around 57.3% of the students were in their first year of college with 10.9% in their second year, 13.7% in their third, 14.2% in their fourth, and 3.8% in their fifth (n = 121, 23, 29, 30, 8). For race and ethnicity, participants were given eight categories to choose from with the choice to not say as option nine. About 45.5% of students identified as white, 15.6% Hispanic, 9.5% Black, 18% Asian, 7.1% Multi-racial/ethnic, with 1 to 3 students identifying as Middle Eastern or North African, American Indian or Native Alaskan, Native Hawaiian or Pacific Islander, or choosing not to say (n = 96, 33, 20, 38, 15, 9). Finally, 87.7% have chosen a major in STEM and 12.3% in a non-STEM major. STEM majors included chemistry, physics, biology, computer science, biochemistry, geology, and pre-med for example. Non-STEM majors included psychology, communications, history, political science, and humanities for example. With Qualtrics automatically randomly assigning participants to watch Video A or B, there was approximately equal representation of all demographics distributed for each video.

5.1.2 Limitations

Access to students became a challenge as recruitment occurred during strict work from home protocols and institutions across the country having different pandemic measures in place. The majority of my network is made up of STEM professionals or those who are already pursuing a STEM profession, so the majority of students who participated already show a high interest in STEM and STEM-related content.

5.1.3 Final Survey

The following pages are screenshots of the survey designed in Qualtrics:

About you

Let's start with getting to know a little bit about you!

What University/College are you currently attending?

What is your current major?

How **excited** do you feel about your major?

	Not at all excited					Extremely excited
	1	2	3	4	5	6	7
How excited?							

Do you feel like you **fit in** with your major?

	I don't fit in at all					I definitely fit in
	1	2	3	4	5	6	7
How do you fit in?							

STEM interest

The next set of questions will explore your relationship with STEM (science, technology, engineering, and math)

Reminder, this is an anonymous survey and there is no right or wrong answer.
Answer as truthfully as you can!

How **likely** are you to pursue a career in STEM?

	Extremely unlikely					Extremely likely
	1	2	3	4	5	6	7
How likely?							

How **excited** are you about a potential career in STEM?

	Not at all excited					Extremely excited
	1	2	3	4	5	6	7
How excited?							

How **likely** are you to pursue a career **NOT** in STEM?

	Extremely unlikely					Extremely likely
	1	2	3	4	5	6	7
How likely?							

How **excited** are you about a potential career **NOT** in STEM?

	Not at all excited					Extremely excited
	1	2	3	4	5	6	7
How excited?							

How frequently have you done the following activities outside of formal courses?

(How many total times in your lifetime?)

	Never	1-2 times	3-4 times	5-6 times	6+ times
Participated in STEM clubs, camps, or competitions	○	○	○	○	○
Watched/Read STEM programs or literature	○	○	○	○	○
Watched/Read science-fiction programs or literature	○	○	○	○	○
Gave an in-person or virtual presentation on a STEM topic	○	○	○	○	○

STEM identity

The next set of questions will ask you about being a science person.

A science person is "someone who likes to learn about, engage in activities, or talk about science-related topics such as biology, zoology, chemistry, earth & environmental sciences, etc."

To what extent do you agree with the following statements?

	strongly disagree					strongly agree
	1	2	3	4	5	6	7
I see myself as a science person							
I will feel like a science person in the future							

	strongly disagree 1	2	3	4	5	6	strongly agree 7
My parents see me as a science person							
My instructors see me as a science person							
My friends see me as a science person							
I have had experiences in which I was recognized as a science person							
I am interested in learning about science							
I find fulfillment in doing science							
I am interested in learning more about engineering and technology.							

YouTube Use

You're almost done with Part 1!

The next set of questions will explore your relationship with YouTube.

How often do you watch YouTube videos every month?

- never
- rarely
- a few times a month
- 1-2 times a week
- 3-5 times a week
- 1-2 times daily
- 3+ times daily

Have you ever used YouTube as a tool to explore different types of careers?

For example: What does a ___ do? How much money does a ___ make? A day in the life of a ___?

- Yes
- No

How likely are you to use YouTube as a resource to explore different types of careers?

	Extremely unlikely 1	2	3	4	5	6	Extremely likely 7
How likely?							

How likely are you to use YouTube as a resource to explore different careers **in STEM**?

	Extremely unlikely 1	2	3	4	5	6	Extremely likely 7
How likely?							

Do you watch STEM-based videos on YouTube?

- Yes
- No

Are you currently subscribed to STEM-based YouTube channels?

Example: SmarterEverday, Veratasium, Mark Rober, Vsauce, Physics Girl, It's Ok to Be Smart, SloMo Guys, SciShow, etc...

- Yes
- No

Do you watch STEM-based videos for entertainment purposes?

- Yes
- No

Do you watch STEM-based videos to work through homework assignments?

- Yes
- No

Break

That's it for Part 1 of the survey!

Take a breath, shake out your arms.

Move forward to continue

Demographics

Before moving on to Part 2, we need to collect some demographics for data purposes.

How old are you?

Current class standing?

Gender Identity?

What is the highest level of education completed by either of your parents (or those who raised you)?

Which category best describes you? Check all that apply.

- ☐ White/European (i.e., German, Irish, English, Italian, Polish, French, etc.)
- ☐ Hispanic, Latine, or Spanish origin
- ☐ Black or African American
- ☐ Asian
- ☐ American Indian or Alaskan Native
- ☐ Middle Eastern or North African
- ☐ Native Hawaiian or Pacific Islander
- ☐ Some other race, ethnicity, or origin
- ☐ I prefer not to say

Part 2

Welcome to Part 2 of the science video survey!

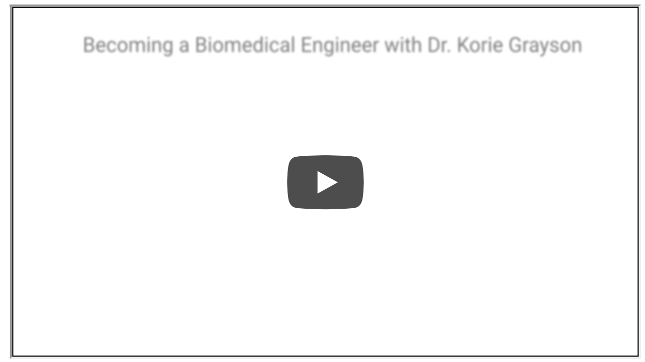
You'll start by watching a 5 min STEM-based video and then answer questions about what you watched (~10 min)

Ready?

Video A

In this video, we'll learn about prostate cancer research with chemical engineer, Dr. Korie Grayson.

Feel free to replay or rewind the video. Select "CC" for close captioning. Select the gear icon to change the playback speed or caption setting. Please do your best to watch to the end as we will be asking you questions about the video after. When you're done with the video, hit "continue" to move on.



Video B

In this video, we'll learn about biomedical engineer Korie Grayson and her journey into becoming a scientist.

Feel free to replay or rewind the video. Select "CC" for close captioning. Select the gear icon to change the playback speed or caption setting. Please do your best to watch to the end as we will be asking you questions about the video after. When you're done with the video, hit "continue" to move on.

Attention check

Let's make sure we watched the same video!

Which sentence best summarizes the video you just watched?

- ○ This video was about a new cancer therapy using liposomes to treat late-stage prostate cancer.
- ○ This video was about how future Dr. Korie Grayson got into chemistry and what being a scientist means to her.
- ○ This video is about Dr. Korie Grayson's research experience at the Naval Institute of biomedical engineering.

What type of scientist is Dr. Korie Grayson?

- ○ Chemist
- ○ Surgeon
- ○ Biomedical/Chemical Engineer
- ○ Biochemist

Feedback

Now that we got that out of the way, let's move on to your feedback

Overall, did you enjoy this video?

rate with stars

Pick up to **three** of the following words that best describe the video?

- ☐ Entertaining
- ☐ Boring/Dull
- ☐ Dramatic
- ☐ Inspirational
- ☐ Fun
- ☐ Positive/Uplifting
- ☐ Confusing
- ☐ Motivational
- ☐ Dark/Sad
- ☐ Educational
- ☐ Funny
- ☐ Cheesy

Were there any moments/scenes you particularly **liked**?

Were there any moments/scenes you particularly **disliked**?

Overall, how **relevant** is this video to your career interest?

	Not at all relevant						Completely relevant
	1	2	3	4	5	6	7
How relevant?							

Did you learn anything new while watching this film?

- ○ Yes
- ○ No

What did you learn?

How well did you **understand** the science in this video?

	Did not understand					Completely understood
	1	2	3	4	5	6	7
Understandable?							

How **well** did this video do at explaining the science?

	Very poorly					Extremely well
	1	2	3	4	5	6	7
How well?							

Korie

How much did you **relate** to future Dr. Korie Grayson?

	Did not relate					Completely relatable
	1	2	3	4	5	6	7
Did you relate?							

What was relatable about Dr. Grayson? If you did not relate, please state why not.

How **knowledgeable** was Dr. Grayson as an expert in her field?

	Not at all knowledgable					Very knowledgable
	1	2	3	4	5	6	7
How knowledgeable?							

How **clear** was Dr. Grayson at presenting scientific information?

	Not clear at all					Clearly understandable
	1	2	3	4	5	6	7
How clear?							

How **likable** did you find Dr. Grayson?

Someone is likable when they come off friendly, agreeable, and/or genuine. Dr. Grayson will never see your answer, so you can be honest.

	Not at all likable					Completely likable
	1	2	3	4	5	6	7
How likable?							

How cold (0) or warm (10) do you feel towards Dr. Grayson?

What vibe are you catching?

	Cold					Warm
	1	2	3	4	5	6	7
How warm?							

breather

Ready for the last set of questions?

Recommend

After watching this video, how **excited** are you about a potential career in STEM?

	Not at all excited					Extremely excited
	1	2	3	4	5	6	7
How excited?							

After watching this video, how **likely** are you to pursue a career in STEM?

	Not at all likely					Extremely likely
	1	2	3	4	5	6	7
How likely?							

After watching this video, how **likely** are you to seek STEM-based videos?

	Not at all likely					Extremely likely
	1	2	3	4	5	6	7
How likely?							

After watching this video, how **likely** are you to use YouTube as a resource to explore careers in STEM?

	Not at all likely					Extremely likely
	1	2	3	4	5	6	7
How likely?							

Would you be willing to participate in a paid interview to further talk about your response to this survey?
If so, what is the best email to contact you at? If not, leave blank.

email

5.2 Qualitative Feedback

The objective of the science-centered video was to explain the science of Dr. Grayson's research, whereas the goal of the scientist-centered video was to share how Dr. Grayson became a biomedical engineer. I expected for there to be a difference in the themes of the responses for the scientists- versus science-centered video because each had a different objective and narrative despite featuring the same scientist. For example, Dr. Grayson talks about her journey into STEM in the scientist-centered video, which is not mentioned in the science-centered video. I predicted that the science-centered comments would be more about how interesting Dr. Grayson's research is and that the scientists-center comments would have been more about how Dr. Grayson's journey was not linear. Since both videos featured the same scientist, I expected there to be similarities in how students described Dr. Grayson's features and relate to the work she does as a scientist. I also anticipated a difference in the specifics on how the students related to Dr. Grayson because of the difference in narrative structure.

The survey was designed to collect both quantitative and qualitative feedback. While there is potential to do a deeper analysis on the survey findings, here I evaluate the qualitative feedback provided from the open-ended questions. The goal is it gain descriptive insights into what the audience thought about the videos. There were four open ended questions. These included: (1) asking what participants liked and (2) disliked about the video, (3) what they learned, and (4) how did they relate to Dr. Grayson (the featured scientist). In this section, I summarize the feedback for these open-ended questions and identify the common themes.

5.2.1 Approach for Analyzing Qualitative Feedback

For the liked and disliked questions, responses were sorted into two main categories; production and narrative. Production refers to any of the visual and audio elements presented in the video. This would include things like the audio and visual effects, editing, music, and graphics and animations. Narrative refers to the information or story told in the video, and how it was told. This would include things like Dr. Grayson's journey or research explanation. This descriptive approach contracts the two different narratives established in the video production: science- versus scientist-centered videos.

For the relatability question, how students related to Dr. Grayson fell into five different categories: character, communication, journey, physical traits, and motives and interests. Comments that described the qualities of Dr. Grayson fell under character. Comments on how Dr. Grayson spoke or explained the science fell under communication. Comments on how students related to Dr. Graysons story fell under journey. Comments on relating to Dr. Grayson's identity fell under physical traits. Finally, comments on how students related to Dr. Grayson's desire to pursue STEM or learn about science fell under motives and interests.

5.2.2 Where there any moments/scenes you particularly liked? disliked?

5.2.2.i Frequency of comments on narrative versus production

The number of times students' comments referred to production and/or narrative is seen in **Figure 5.1**. For the *science*-centered video, out of 109 comments, 78 mentioned production and 25 mentioned narrative with 6 leaving no comment. For the *scientist*-centered video, out of 119 comments, 15 comments mentioned production and 86 mentioned narrative with 18 leaving no comment. Based on the frequency of responses referring to the two categories, the majority of the students liked the production of the science-centered, whereas majority of the student's liked the narrative of the scientist-centered video.

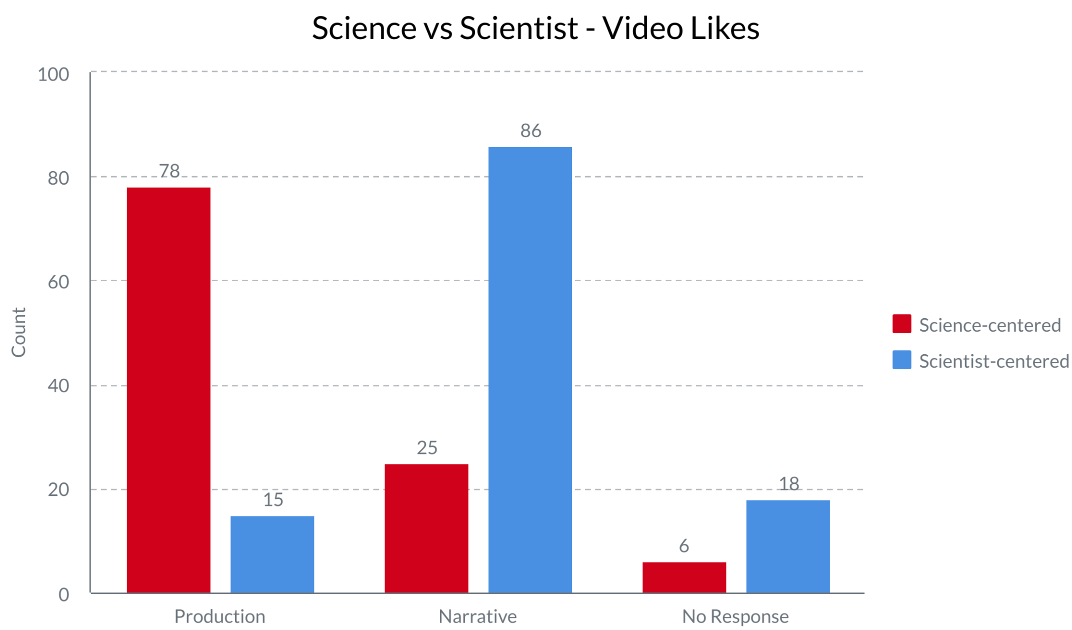


Figure 5.1: Frequency of Likes. Comparing the frequency of participants' comments about production and narrative in the science-centered (red) and scientist-centered (blue) video.

5.2.2.ii Qualitative evaluation of open-ended responses: Liked

Science-centered

For the production elements participants liked about the science-centered video, students commented on the graphics and footage used, how the scientists were presented on-screen, and the use of the animation sequence. Some examples quotes that demonstrate this include, "I enjoyed the cut to animations as I felt they added some more editing interest to the video. I also liked the inclusion of another researcher/doctor as it was nice to see interactions between two people talking about the topic as opposed to one person lecturing." Another example was, "I liked the animation segments in the video as it helped visualize what there were talking about. Especially when they were talking about E-selectin and TRAIL on the liposome." Yet another response was, "I also enjoyed the cinematography of the interview with both Stephanie and Korie on-screen at once." Finally, "I was impressed with the graphics employed by the video."

The frequency at which production of the video was referenced in what the video likes suggest that the quality of the video is important to them to see in watching science videos. The fact that majority of the students under this category liked the animations in the video possibly implies the importance of using motion graphics to explain the details of the science. Lastly, the likes suggest that students value seeing scientists explain the science in addition to the human interaction between the scientists on-screen.

In terms of narrative, comments from the science-centered video focused on how well the science was explained and interest in the topic and its impact. Responses ranged from very concise and general to detailing exactly what they liked about the production. Some examples included, "I really liked when the bigger words were broken down to those who may not be familiar with them." Another comment said, "I liked hearing about the overarching motivations to focus on this treatment and late-stage prostate cancer/late-stage cancers in general. It overall felt like a scientific paper in video form, we had an introduction to the subject, the method of approach, the results of the approach, and a discussion of the results as well as the future of this research." Yet another example was, "I thought the research she was conducting was very interesting." Finally, one last comment said, "I liked when the host would explain what Korie had said in a more understandable way."

Not as many students commented on the narrative of the video compared to production. However, from what was commented, their responses suggest that students seem to value how well the science is communicated. Though students liked how Dr. Grayson talked about her science, students seemed to like how the host/science communicator "broke down" her science. Interestingly, students seemed to like the video for the sole purpose of liking the topic or general interest in cancer research or learning about science.

Scientist-centered

There were many differences between the scientist-centered and science-centered video comments that diverged from what was anticipated. In the scientist-centered videos, students are watching a different story narrative, with visuals to support that narrative. For production, students liked the overall cinematography, seeing Dr. Grayson in a lab setting working, and images of the people that influenced Dr. Grayson in her journey. For example, "I liked that it was filmed in the lab" and "I liked all the moments where Dr. Grayson was shown doing work around the lab. I also really liked the images of the people she was referring to along her journey." In regards to the supplemental images, "I loved seeing the picture flashbacks of her former experiences and especially her professors - representation is so important and I loved that it was captured." As well as "I liked when she was describing her high school/early college experience and how it was reinforced with pictures to show the people who inspired her."

Production was not heavily mentioned compared to the science-centered video, but the comments are similar in that students' attribute liking the video for the quality of the footage. Students liked having footage of Dr. Grayson in lab setting talking about her journey, providing insight into her life as a scientist. Additionally, including graphics of the people that impacted Dr. Grayson in her journey seemed to be a visual that students liked to personalize and humanize her story.

As for the narrative, students really gravitated towards different elements of Dr. Grayson's journey and how she shared her perspective about diversity in STEM. Responses ranged from very concise and general, to specifying what aspect of her journey they liked. Examples of detailed quotes include, "Dr. Grayson finding her passion/drive to research into prostate cancer and health disparities in the African American community. Also seeing Dr. Grayson meeting the right professors to help her succeed than drown in failure." As well as, "I liked hearing about how she found her focus point by studying prostate cancer because the men in her family struggled with prostate cancer." An example for liking Dr. Grayson's perspective, one student said "I like when future Dr. Grayson talked about what she would like to see in the future of STEM and how women in STEM can get more involved and prosper in their field." Then there were general comments such as, "I liked hearing about how she chose to not become a medical doctor and sort of forged her own path."

Students predominately commented on the narrative in the scientist-centered video compared to the science-centered video where students predominately commented on production. This could be because of the narrative structure of this video; it appears that there were more opportunities for students to talk about the narrative compared to the science-centered video. The details in the comments about what they liked about the narrative also showed a level of depth they grasped from the video.

5.2.2.iii Qualitative evaluation of open-ended responses: Disliked

Science-centered

Next, I reviewed the students' comments on moments or scenes they disliked in the video. For the production of the science-centered video, students mentioned how they wish there were more visuals to supplement what's being said and felt that there were moments where I or Dr. Grayson was talking on screen for too long ("I think there was too much screen time with just one or more people talking"). There were comments on how editing and graphic choices were distracting. For example, "I didn't like when Korie's Zoom video was playing how the background graphic was moving and there was a flashing thing in the upper right corner."

Another student said, “I’m not a fan of a moving background behind reading a sentence. The effect of the crumpled paper looked neat but distracted me while reading.” There were also comments on the quality of the video, or lack-thereof, when it came to the Zoom interview.

The dislikes regarding the narrative, some students thought the explanations were too simple. For instance, ‘While I enjoyed the animated section, I do wish that it had gone slightly deeper into the science.” On the other hand, a few felt that the concepts were confusing and hard to understand. One student mentioned, “There were some concepts that were confusing for me, being a person who had little prior knowledge about prostate cancer.”

With respect to production, low quality visuals and audio seem to distract how students engage with the media, further validating the importance of video quality. Additionally, when there are too many elements on the screen or poor choice in visual and graphics contributes to the distraction. As for disliked regarding the narrative, these comments seem to be in the minority. So in thinking how the video was written for a college educated audience, I am curious if other variables about the individual contribute to their preference of more science explanations versus the simplification of the topic.

Scientist-centered

A majority of the participants who watched the scientist-centered video mentioned that there were no moments or scenes they particularly disliked. For those that did, the dislikes towards production was that the video was boring, monotone, or not engaging. There were a few comments on scenes of the video being distracting, “I didn’t like when the camera was walked through the doorway at the start. It was distracting.” There were also comments on quality of the audio, “The audio was very difficult to understand when it came to the questions.”

For the scientist-centered dislikes about the narrative, there were a handful of students who wish that Dr. Grayson didn’t talk about race and shared her perspective on representation in STEM. They felt it was unnecessary and that we were pushing a social justice agenda. They wish that Dr. Grayson instead went more in depth about how she got into her current position and mentioned steps on how to get there. For example, “I didn’t really care for the part of the video talking about race. While I understand acknowledging the racial component in stem (how most of science was done by old white men) is very important, I thought the video would be more about the steps she took, what schools she went too, what the application processes are etc.” And “I kinda disliked the social justice portion of the video. I am not against that kind of thing, it just seemed forced in the video.”

The dislikes in the production of the scientist-centered video validated some concerns I after producing

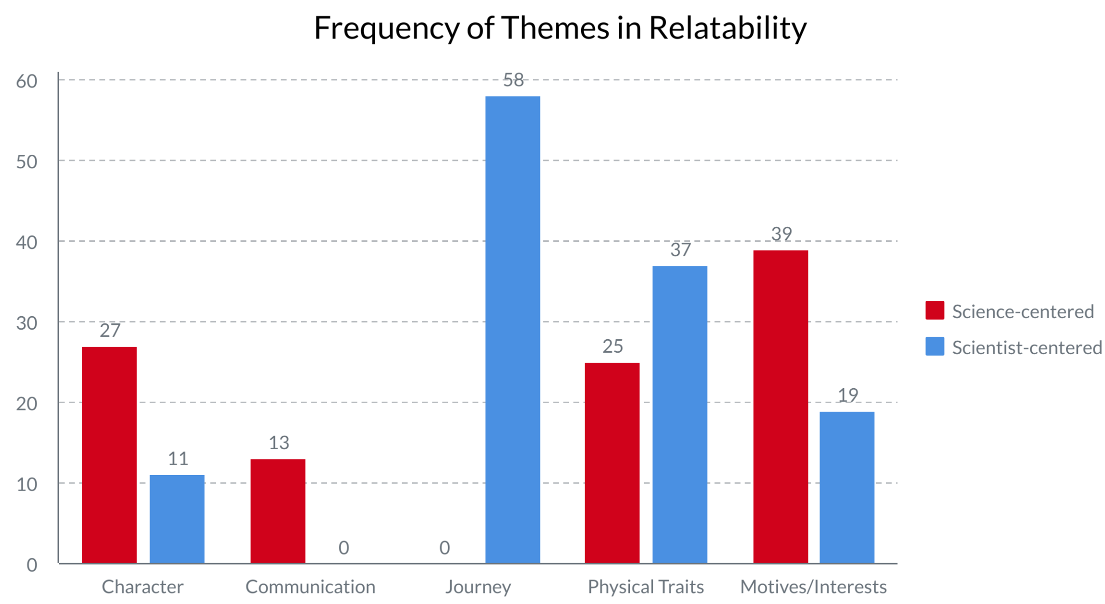


Figure 5.2: Frequency of Themes in Relatability. Comparing the frequency of themes in participants' comments about how they related to Dr. Grayson in either the science-centered (red) and scientist-centered (blue) video.

the videos. The video is slower paced matching the cadence of Dr. Grayson, informing my music choice, which may have contributed to the monotone and not engaging comments. Comments on the distracting scene and poor audio further supports how video quality is important to students. With respect to the dislikes towards the narrative, it seems like it comes down to preference. Again, dislikes on the video were in a minority compared to like, but it is difficult to assume that students predominately did not like Dr. Grayson talking about representation and race in STEM. It seems to be a personal preference, but common enough that a handful of students had a similar dislike.

5.2.3 What was relatable about Dr. Grayson?

5.2.3.i Frequency of themes in students' comments on relatability

The difference in frequency of common themes in how students relate to Dr. Grayson is seen in **Figure 5.2**. For the *science*-centered video, students relating to Dr. Grayson's motives is referenced more than her character, physical trait, and communication. For the *scientist*-centered video, majority of the students referenced relating to Dr. Grayson's journey over her physical traits, motives, and characters. More students related to Dr. Grayson's character and motives in the *science*-centered video compared to scientist-centered. While more students related to Dr. Grayson's physical traits in the *scientist*-centered video than science-centered.

5.2.3.ii Qualitative evaluation of open-ended responses

Science-centered

There was a broad range of common themes found in how students related to Dr. Grayson. There were four recurring themes in the responses for those who watched the science-centered video. Students mentioned sharing Dr. Grayson's character, communication style, physical traits, and motive/interest. Descriptive words such as passion, drive, down-to-earth, approachable, etc., were used to describe Dr. Grayson, with students tying those qualities back to themselves. For instance, "Dr, Grayson was passionate about her job and I am passionate about my career path right now." Comments such as, "She felt like a normal person and didn't use a bunch of fancy words that were hard to understand," fell under the communication theme. Comments referring to Dr. Grayson's race, gender, age, and overall appearance fell under the physical trait theme. One student said, "She looked just like an everyday person. She had her nails done and makeup on, which, in my experience, is rarely seen. I love makeup and wearing cute outfits, but rarely are scientists portrayed as your"everyday person." Finally, comments about how students share the same interest in careers, research, desire to solve problems, and help people fell under the motive/interest theme ("I related to her by being motivated and interested in learning how to treat cancer"). For those that mentioned that they did not relate to Dr. Grayson either commented on their difference in motives/interest or communication style. This student mentioned a difference in communication style as their reason, "She wasn't very relatable in this video, though, because she explained the process and did not elaborate much. I didn't get to see much of her perspective, opinion, or enthusiasm."

Referring back to **Figure 5.2**, it appears that students related to Dr. Grayson's interest in science, cancer research, solving problems, helping others, and working adjacent to the medical field. Student comments also showed that they were able to see and pick up on different qualities of Dr. Grayson in addition to relating to her physical appearance. For the students who did not relate, it seems that it was not attributed to Dr. Grayson, but more of personal preference such as not being interest in the topic or science in general. It is also difficult to attribute students to not relating to Dr. Grayson because of how she communicated rather than how well the students comprehended the narrative.

Figure 5.3, (a) is a word cloud with all the descriptors that students used to explain what they found relatable in Dr. Grayson. The word's size directly relates to the number of times it was used. The biggest words are science, research, field, cancer, STEM supporting that interest and motives is what most students found relatable about Dr. Grayson. Something unexpected I saw from the student's responses was how they described Dr. Grayson's character. Many students mentioned how they related to Dr. Grayson's passion or stated that she was passionate. The words woman, female, and color appeared around the same frequency as the words describing Dr. Grayson's character.

Scientist-centered

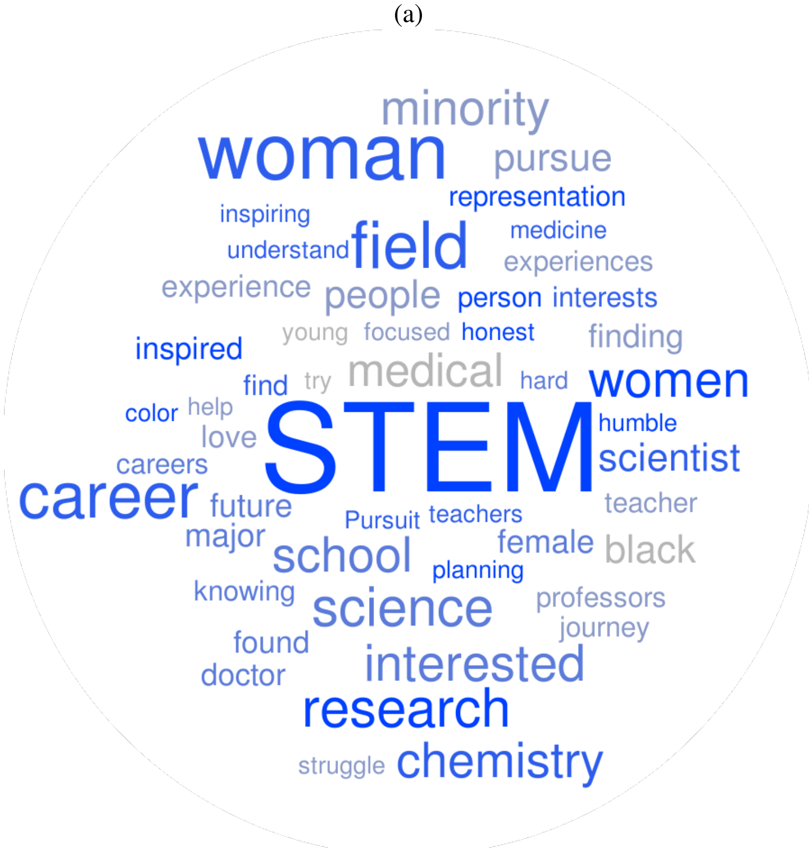
The same themes, minus communication, appeared in students' response in how they related to Dr. Grayson in the scientist-centered video. Instead of communication, students related to Dr. Grayson's STEM journey. Within the journey theme, student's specified which part of her journey they related to and why, or how they shared the same perspective on representation in STEM. Some examples quotes include, "Generally her experience in finding teachers that encouraged her to become a scientist, along with her being someone who is interested in the subject of gynecology, cancer, chemistry, and the like." "I relate in the aimless adventure that Grayson had. Much like Grayson, I too struggle to see myself in an industry that is dominated by old, white professors. Also, I relate in that exposure to an aspect of my potential career caused me to change it," said another student. There were instances when another theme was mentioned along with journey, such as physical trait: "Although I don't relate to her heritage, I do relate to her journey as a woman in a male STEM space. I also relate to her desire not to be in academia and wonder why it is that so many of use STEM females choose non-academic paths. Perhaps it is a difference in our values and what types of careers give us a sense of purpose."

Physical traits and motive/interest had comments similar to those seen in the science-centered video ("As a black person in STEM, I understand the impact of having someone who looks like me in my field and how that can motivate me"). As for character, there were different descriptive words used to describe Dr. Grayson such as determined, focus, driven, and hard worker that students related to. For those that did not find Dr. Grayson relatable attributed it to differences in motives/interests or not holding the same perspective on representation in STEM. For example, "I do not relate to her at all in the video, even though I am a minority as well in this country, I do not like the terms she used to refer to the people in the STEM path, like white male scientists dominating the field. She should not indirectly imply that Science is racist."

Referring back to **Figure 5.2**, a majority of the students related to Dr. Grayson's journey. It was interesting to see how students related to different parts of her journey depending on if they shared the same or a similar experience. It was also interesting to see how relating to Dr. Grayson's physical traits were tied into how the students related to her journey. Included in students relating to Dr. Grayson's journey, is sharing the same perspective like the importance of representation in STEM. The exact opposite was seen with students who did not relate, as they did not share the same experience, identity, or perspective.

Looking at the word cloud of common words seen in student's responses (**Figure 5.3, b**), the most common word used was STEM. The word STEM was used in conjunction with physical traits such as "women

(a)



(b)

Figure 5.3: Relatability Word Cloud. Word cloud of frequently used descriptors seen in relatability responses for (a) science-centered and (b) scientist-centered video.

in STEM," "Black woman in STEM," and "minority in STEM." Words that related to Dr. Grayson's journey are the second biggest words seen are career, pursue, school, field, science, and chemistry. Descriptive words used to describe was less commonly seen, but this category included the words honest and humble.

5.2.4 Did you learn something from the video? If yes, what did you learn?

5.2.4.i Percentage of students who replied "yes"

Finally, when students were asked is if they learned anything from the video they watched. 96% of students answered yes after watching the science-centered video, and 68.5% for scientist-centered depicted in **Figure 5.4**. If they selected yes, they moved on to an open-ended question asking them what they learned, which is discussed later in this section. However, having a yes or no question provides a general idea is students walked away learning something from the produced educational science videos.

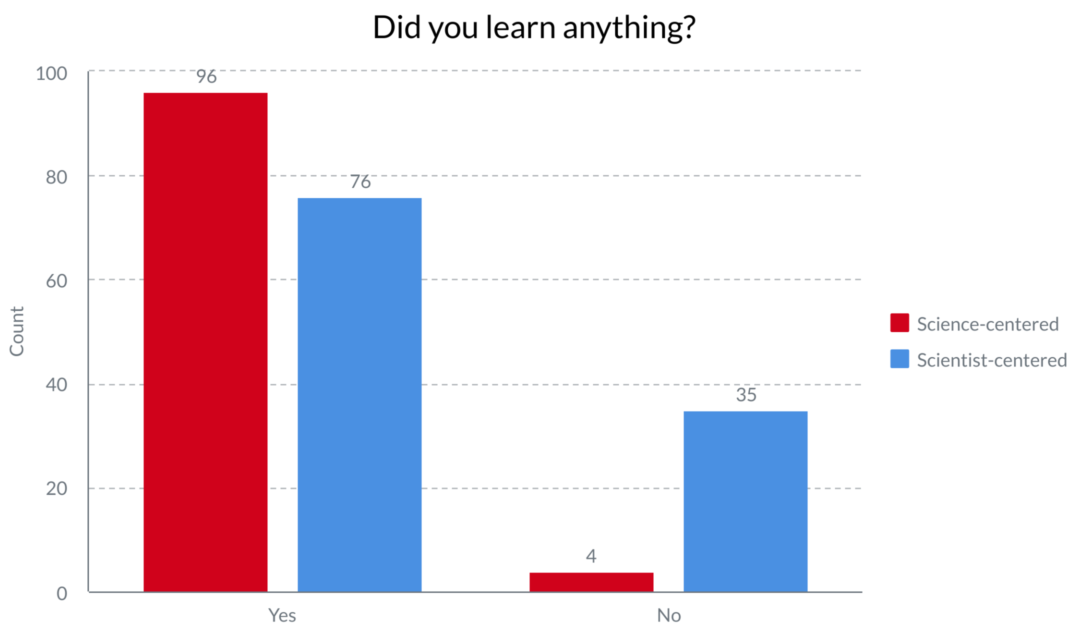


Figure 5.4: Total Responses. Chart showing the number of students who answered yes and no when asked if they learned something from the science-centered (red) and scientist-centered (blue) video.

5.2.4.ii Qualitative evaluation of open-ended responses

Science-centered

The open-ended responses to the question were used to see if the students-self identified learning outcomes matched the video objectives that I identified during production. The overwhelming response on what they learned from the science-centered video is that late-stage prostate cancer is difficult to treat in African American men; and the development of a new therapy using liposomes to treat late-stage prostate cancer. Some examples of what students said were, “I learned a little about the benefit and the function of the proteins attached to the liposome and how this results in the death of the cancer cells while sparing the healthy cells.” Another student said, “I learned about a new novel treatment to approach metastasized cancer cells.” Last example of what a student learned, “I learned about how some of the treatments that are used to combat cancer are now starting to evolve even more than I had previously thought. I also learned the interesting statistic of African American males and prostate cancer, which seemed like it should be something that should be researched a bit more, such as going into more demographics, or even researching into if certain races are more receptive towards different types of cancers.” These comments indicated that students met the learning objective I set out for the video during its development, and that the video was produced in a way to facilitate that learning outcome.

Scientist-centered

For the scientist-centered video, students took away different aspects of Dr. Grayson’s journey as their takeaway such as: that you don’t necessarily need to know what you want to be when you grow up; or that it’s okay to switch tracks to pursue your desired career. They also mentioned how representation and diversity is important in STEM. Some examples of what students said were, “I learned how broad the area of science is and how diverse it is. I also found it encouraging that Dr. Korie has been driven by what interests her and hope to deal with things that interest me in my future.” “I learned it’s ok to not know exactly what you want from school and people like Dr. Korie did medical school and found out it wasn’t for her. I want to give it a go and do my best but if it’s not for me then find my other passions. I also learned that qualities from STEM can apply to a plethora of jobs,” said another student. A final comment mentioned that “The representation is important, seeing people who look like you is motivating to join a field of study.” Interestingly, since the comments on what students learned were broad, it implies that my video objective was not specific enough for students to share the same learning outcome. However, it is interesting to see what parts of Dr. Grayson’s story resonated with the students.

5.3 Discussion

The goal of my study was to produce two different science video narratives and see what elements of the video students identified. The qualitative feedback received by the participants provided insight to into what students liked and disliked about each narrative, and how they identified with the character of the story. Although there are more opportunities to analysis the data collected from the survey instrument, the descriptive findings presented here have yielded incredible insights. A table summarizing the results are shown in **Table 5.1**.

The two videos were produced to have different narratives but still maintain a level on consistency by having the same character featured. A narrative can be broken down into four elements: the setting, the characters, the plot, and the moral (Cohen, 2011; D. Jones and Anderson Crow, 2017). Using narratives in science communication video allow for students to be transported into the story or identify with the characters. The character is Dr. Korie Grayson, a scientist with expertise in biomedical engineering and cancer research who so happens to be a Black woman in STEM. However, the setting, plot, and moral of the narrative were quite distinct for each video. The difference in how the videos were produced was extensively discussed in **section 4.2**.

5.3.1 Production

The *science*-centered video was produced to resemble a "science explainer" type video seen throughout science-based YouTube channels. Consistent with the features of what makes science videos popular mentioned in Munoz Morcillo et al. (2016), the scientist-centered video had moderate production quality, high complexity of how the video was edited, and driven by storytelling. Features of the video include a talking head, interview, animation, and supplemental graphics and footage. The video was set in two different locations, the host's home studio and at the scientist's lab.

Based on the feedback from students, I would include more animation sequences to explain the science, in place of a drawn-out talking head. The animations in conjunction with clear explanation of science is what students really appreciated seeing since majority of them are unfamiliar with the research topic and are learning something new. I would also be more intentional with the decorative elements I include in the video as it was more distracting—something I should have remembered to do if I was following Mayer's principles 2014a. Finally, I would opt out of including a Zoom interview as both the audio and video quality did not translate well. However, I did have to include the Zoom interview as there were gaps in the story and because of the pandemic, I was unable to go back to the lab to shoot more scenes with Dr. Grayson. If I had to use Zoom again, I would make sure my Internet connection is strong.

The *scientist*-centered video was produced to resemble a documentary type commonly seen in the science filmmaking industry. The character is of course the same with the same production quality and that it's driven by storytelling. However, the editing is not as complex as the scientist-centered video's features are slightly different. In this video, there is no science communicator driving the narrative forward. Instead, the story is driven through the first-person point-of-view of the character. Other features of the scientist-centered video include footage of Dr. Grayson working in the lab, interview, and with some supplemental pictures. The video was shot in one-location, which was the lab Dr. Grayson worked in, seen throughout the entirety of the video.

Based on the feedback from students, I should not have not prompted Dr. Grayson to talk about stereotypes she's seen in STEM. However, as the producer, my goal was to capture Dr. Grayson's story that so happens to include her personal opinions, which are a reflection of her lived experience. However, I could have included more moments of the steps Dr. Grayson took to become a biomedical engineer. Though in doing so, would change the objective of the video and perhaps serve the students differently than to just hear the journey of the scientist.

5.3.2 Narrative

The three acts in the *science*-centered video were: (1) the science communicator (the host) introduces audience to the problem with prostate cancer, (2) introduction to Dr. Korie Grayson who is developing a new treatment for late-state prostate cancer, (3) and explanation of how the treatment works and the impact of her work. The character in this narrative, took on more of a supporting role with the science and the cancer treatment explained in the video as the main characters.

Reflecting on what students like about the science-centered video, majority of the students like the animation sequence explaining how the treatments works, which makes sense as that was the main character and an important plot in the story. Dr. Grayson's role as a supporting character was used to set up the plots of the story. Dr. Grayson was presented as an expert and mentions about her were kept at a surface level (i.e. she's a scientist who cares about cancer research and is developing a treatment). How students related to Dr. Grayson also reflects how most students related to the surface level of Dr. Grayson. They related to her interest in STEM or motive to treat cancer, and her physical traits such as race, gender, and age. Further, because no backstory of Dr. Grayson was provided, students commented on her communication style, another surface level comparison.

From the word cloud (Figure 4.7) it is interesting to note that she was presented as a supporting character yet students were still able to pull out that she was passionate, approachable, a problem solver, and excited about her work is eye-opening. Interestingly, assuming surface level connection, representation seemed to be an equal factor with the characteristics with woman, female, color suggesting that representation and identity may be important for students to relate to a character.

The three acts in the scientist-centered video were: (1) when Dr. Grayson realized she wanted to be a scientist, (2) her perspective on what is a scientist, and (3) what are her future plans as a scientist. Dr. Grayson in the main character in this narrative as it is her first-person experience driving the story forward. Although I was technically in the video, I was behind the camera and there to prompt her with a question to slightly guide the direction of her journey.

Dr. Grayson's journey was what majority of the student's liked about the video, as well as how they related to Dr. Grayson. Students who watched the scientist-centered video were a lot more detailed in their response and provided examples of moments where they either shared the same experience and perspective. Their comments lead me to believe that students identified with both the narrative and the character, resulting in a deeper connection compared to the science-centered narrative. This is seen in the lack of comments regarding how Dr. Grayson communicated to majority of the comments talking about her journey. There is a lower number of comments relating to Dr. Grayson's motives compared to the science narrative. Yet, physical traits remained the second-most common theme implying that representation is a factor that is relevant to students despite the narrative.

5.3.3 Conclusion

My dissertation study first looked at the qualitative feedback U.S. college students provided after watching two different science videos. The goal of this study was not to determine if one narrative is better than the other, but to look at how students identify to two different narratives and the characters. One observation is that the science-centered narrative helped students learn new terminology and understand the science behind the research being conducted if explained well and supported by animations. Additionally, when the narrative was centered around the science, students shared a surface-level or superficial connection to character, relating to their motives and interests. Students did note how they shared racial and gender identities with the character but again, in a superficial way in that that's the only feature they share in common with the character. On the other hand, students showed a deeper connection to both the character and narrative when the video's narrative centered around the scientist's journey. Students were able to relate to moments of her journey and reflect on their own experience. Some students even explained how their identities tie into their related experience.

Again, the goal was not to prove that one video narrative is better than the other. For science educators and communicators who want to use video to explain how science is performed and studied, the science-centered narrative would be preferable. If the goal is to humanize scientists and have the audience reflect on their own journey, a scientist-centered narrative is more suited here. Furthermore, how the scientists present themselves in the video plays a role in how students relate to the narrative and identify with the character. Choosing a scientist that embodies characteristics such as passion and honesty can improve how students engage with the video. Future work will look into the quantitative data collected from the survey to understand if student's responses correlate to their demographics, YouTube use, and science identity.

Table 5.1: Result Synthesis

Science-centered synthesis

- Production:
  - For the production elements participants liked about the science-centered video, students commented on the graphics and footage used, how the scientists were presented on-screen, and the use of the animation sequence.
  - What students disliked about production were the lack of visuals to supplement what's being said and too much talking on screen. Students also did not like when the video or audio quality is poor, and how some visual and audio elements were distracting.
- Narrative:
  - As for narrative of the science-centered video, responses focused on how well the science was explained and interest in the topic and its impact.
  - The dislikes regarding the narrative, some students thought the explanations were too simple while others felt confused.
- Relatability:
  - There were four reoccurring themes in the responses for those who watched the science-centered video. Students related to Dr. Grayson's character, communication style, physical traits, or motives/interests.
- Learning outcomes:
  - The overwhelming response on what they learned from the science-centered video is that late-stage prostate cancer is difficult to treat in African American men; and the development of a new therapy using liposomes to treat late-stage prostate cancer.

Scientist-centered synthesis

- Production:
  - For production, students liked the overall cinematography, seeing Dr. Grayson in a lab setting working, and images of the people that influenced Dr. Grayson in her journey.
  - The dislikes mentioned for production was that the video was boring, monotone, or not engaging; distracting scenes; or that the video and audio quality was poor.
- Narrative:
  - As for the narrative, students really gravitated towards different elements of Dr. Grayson's journey and how she shared her perspective about diversity in STEM.
  - Dislikes regarding the narrative, a handful of students wished that Dr. Grayson did not talk about race nor shared her perspective on representation in STEM. They felt it was unnecessary and that we were pushing a social justice agenda.
- Relatability:
  - For the scientist-centered video, students related to Dr. Grayson's character, physical traits, or motives/interests.
  - There was no mention of communication style, instead students related to Dr. Grayson's journey.
- Learning outcomes:
  - For the scientist-centered video, students took away different aspects of Dr. Grayson's journey as their take-away such as: that you don't necessarily need to know what you want to be when you grow up; that it's okay to switch tracks to pursue your desired career; or that representation and diversity in STEM is important.

CHAPTER 6

Future Direction

6.1 Future Work

The goal of my future study will be to look into how students identify with representation and narratives in science videos and to learn whether identification leads to motivation in pursuing STEM careers. If identifying with the narrative or characters of a story influence people's beliefs and attitudes, can they be used to persuade and change behavior? Previous studies explored the effectiveness of engaging with different media portraying a diversity of people and STEM careers in changing students' perspectives of scientists and their career choices. Yonas et al. (2020) explored how podcasts impacted students' views of the people who do science and found that the podcasts changed student perceptions of the sort of people who do science. Rosenthal et al. (2013) exposed women in college to successful female physicians and reported higher perceived identity compatibility, sense of belonging, and interest in medical careers as compared to those who weren't exposed to identity-compatible role models. Schinske et al. (2016), Hong and Lin-Siegler (2012), and Shin et al. (2016) each evaluated homework assignments that featured counter-stereotypical examples of scientists in an introductory biology class at a diverse community college. After the course, students shifted their perspectives of scientists and reported higher abilities to personally relate to scientists, greater interest in science, and better course grades. However, Jackson (2018) found no statistically significant associations between using video as an intervention to change middle school students' perceptions of scientists and choices of STEM careers. The study found that the majority of students in the study currently hold a broader-than-traditional view of the appearances and activities of scientists.

The aim of my future study will be to test whether *after watching the scientist-centered video, marginalized students' motivation will be more positively impacted compared to non-marginalized students.* I have already collected this data through the survey designed in **Chapter 4**, which was distributed to undergraduate and high school students and measured using methods established in Godwin et al. (2018); Godwin and Kirn (2020) and Shin et al. (2016).

6.2 The Future of Phuture Doctors

When I first launched Phuture Doctors in 2017, I envisioned my YouTube channel to be used as a resource for students who have limited or no opportunities to tour research facilities, or who lack support and mentorship at their schools. I pitched my YouTube channel to the Humanities, Arts, Science and Technology Alliance and Collaboratory (HASTAC) on campus, which partnered me with the Vanderbilt Institute of Digital Learning (VIDL). With VIDL's partnership, I gained access to their built-in studio and recording equipment to record my first ever science video for Phuture Doctors. My very first video was a science-explainer about my chemistry master's research on quantum dots. I had prior experience in camera handling as I learned photography in high school and college, but I did take the initiative to teach myself how to edit videos using the Adobe Creative Suite through YouTube tutorials. My first video included: a talking head (which was recorded in the studio), animations made in After Effects, and on-location footage of me performing science in a lab. This experience sparked my passion in producing videos and motivated me to continue dedicating my time in building up Phuture Doctors.

Phuture Doctors was the key to opening the door in building a career in science communication. There was no one else doing anything remotely similar and science communication was yet the large community that we see today. My proof of concept and mission to increase representation in science media landed me several opportunities to learn about the field of science communication, as well as establish my place in this space. From launch of Phuture Doctors in 2017 to now:

- I became a AAAS Mass Media Fellow
  - Awarded a $7,000 stipend to be a summer science reporter for the Las Vegas Review-Journal
  - Wrote, edited, and published 9 stories for the newsroom, with three stories making front cover on newspaper
  - Filmed and produced four videos complementary to three larger stories, with one garnering over 25,000 views
- Emerging Producer Bursary Fellow
  - Attend, network, and pitch Phuture Doctors as a digital series at the World Congress of Science and Factual Producers.
  - This network opportunity led to me becoming an advisor on an NSF grant and future producer for PBS Digital Studios
- Jackson Wild Media Lab Fellow
  - One of 17 students selected from an application pool of 700 to receive science filmmaking training for 10 days by leaders in the science documentary and wildlife production space
- Vanderbilt Institute for Digital Learning Fellow
  - $5,500 fellowship to continue to produce videos for Phuture Doctors
- Humanities Arts Science and Technology Alliance and Collaboratory Scholars Fellow
  - $600 towards the launch of Phuture Doctors under the mentorship of the Vanderbilt Institute for Digital Learning
- I organized the 2019 and 2020 STEM Success Summit
  - A three-day virtual conference for undergraduate, graduate, and early career science professionals who are underrepresented in STEM
- I attended, organized, then chaired ComSciCon-Atlanta in 2018, 2019, and 2020

  - A two-day workshop for graduate students to explore science communication. Received training in science writing, interviewing, science policy and advocacy, as well as improve and data visualization.

- Won First Place and $1,000 at the 2019 Materials Research Society's Science in Video Competition
  - Produced 2-minute video featuring the Vanderbilt Institute of Nanoscale Science and Engineering
- Won a total of $14,000 pitching Phuture Doctors at multiple local student pitch competitions
  - Prize money went towards my research, production, equipment, customer discovery, and professional development

Finally, I featured 18 science profiles of young and diverse scientists on Phuture Doctors' website and social media. Led workshops, participated in panel, and as a featured keynote for over twenty events centered around STEM Careers, Science Communication, Mental Health in Graduate School, and Entrepreneurship. I also built a small online community of 5,000+ followers who have followed my journey in becoming a science communicator and developing Phuture Doctors. Although all of the opportunities led to my growth as a science communicator, it came at the cost of my chemistry Ph.D.. However, if it wasn't for me establishing myself in this space and showing passion for my work, I wouldn't have been able to switch Ph.D. programs. This opportunity allowed me to eventually develop a Ph.D. track in science communication and turn Phuture Doctors into my dissertation. Something that I am extremely proud of accomplishing and has helped me solidify myself as an expert and pioneer in the field of science communication.

I have big goals in growing Phuture Doctors to be a media company that informs and connects the next generation of STEM leaders to their future jobs solving tomorrow's problems. I want to be the updated version of Bill Nye the Science Guy and have the opportunity to highlight thousands of scientists from all intersections of life to serve as virtual role models. To accomplish this, I plan to use the work I conducted in my dissertation to inform how I will produce content that celebrates diversity and resonates with young adults to inspire and motivate them to pursue a future in STEM.

Figure 6.1: Phuture Doctors Logo.

References

Ahlqvist, S., London, B., and Rosenthal, L. (2013). Unstable Identity Compatibility. *Psychological Science*, 24(9):1644–1652.

Amarasekara, I. and Grant, W. J. (2019). Exploring the YouTube science communication gender gap: A sentiment analysis. *Public Understanding of Science*, 28(1):68–84.

Anderson, J. M., Aylor, M. E., and Leonard, D. T. (2008). Instructional design dogma: Creating planned learning experiences in simulation. *Journal of Critical Care*, 23(4):595–602.

Anderson, M. and Jiang, J. (2018). Teens, social media and technology 2018. Technical report, Pew Research Center.

Angelone, S., Soriguer, R. C., and Melendo, A. (2019). Modes of documentary films produced by the future generation of 'scientists-as-filmmakers'. *International Journal of Science Education, Part B*, 9(4):285–295.

Angelone, S., Soriguer, R. C., and Melendo, A. (2020). Filmmaking courses for scientists help promote richer alternatives to chronological narratives. *Studies in Higher Education*, 45(9):2001–2010.

Antonietti, A., Colombo, B., and Di Nuzzo, C. (2015). Metacognition in self-regulated multimedia learning: integrating behavioural, psychophysiological and introspective measures. *Learning, Media and Technology*, 40(2):187–209.

Asai, D. J. and Bauerle, C. (2016). From HHMI: Doubling down on diversity. *CBE Life Sci. Educ.*, 15(3):1–3.

Ashley, M., Cooper, K. M., Cala, J. M., and Brownell, S. E. (2017). Building better bridges into stem: A synthesis of 25 years of literature on stem summer bridge programs. *CBE Life Sci. Educ.*, 16(4).

Besley, J. C. and Hil, D. (2020). Science and technology: Public attitudes, knowledge, and interest. Technical report, National Science Board, National Science Foundation.

Black, P. and Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice*, 5(1):7–74.

Blonder, R., Jonatan, M., Bar-Dov, Z., Benny, N., Rap, S., and Sakhnini, S. (2013). Can You Tube it? Providing chemistry teachers with technological tools and enhancing their self-efficacy beliefs. *Chem. Educ. Res. Pract.*, 14(3):269–285.

Brame, C. J. (2016). Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE Life Sci. Educ.*, 15(4):es6.1–es6.6.

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences*, 110(Supplement_3):14096–14101.

Bruns, A. (2008). The future is user-led: The path towards widespread produsage. *The Fibreculture Journal*, 11(11).

Byars-Winston, A., Rogers, J., Branchaw, J., Pribbenow, C., Hanke, R., and Pfund, C. (2016). New measures assessing predictors of academic persistence for historically underrepresented racial/ethnic undergraduates in science. *CBE Life Sci. Educ.*, 15(3):1–11.

Cairncross, S. and Mannion, M. (2001). Interactive Multimedia and Learning: Realizing the Benefits. *Innovations in Education and Teaching International*, 38(2):156–164.

Canfield, K. N., Menezes, S., Matsuda, S. B., Moore, A., Mosley Austin, A. N., Dewsbury, B. M., Feliú-Mójer, M. I., McDuffie, K. W. B., Moore, K., Reich, C. A., Smith, H. M., and Taylor, C. (2020). Science Communication Demands a Critical Approach That Centers Inclusion, Equity, and Intersectionality. *Frontiers in Communication*, 5(January):1–8.

Carmichael, M. C., St. Clair, C., Edwards, A. M., Barrett, P., McFerrin, H., Davenport, I., Awad, M., Kundu, A., and Ireland, S. K. (2016). Increasing URM undergraduate student success through assessment-driven interventions: A multiyear study using freshman-level general biology as a model system. *CBE Life Sci. Educ.*, 15(3):1–14.

Carpi, A., Ronan, D. M., Falconer, H. M., and Lents, N. H. (2017). Cultivating minority scientists: Undergraduate research increases self-efficacy and career ambitions for underrepresented students in STEM. *Journal of Research in Science Teaching*, 54(2):169–194.

Castillo, S., Calvitti, K., Shoup, J., Rice, M., Lubbock, H., and Oliver, K. H. (2021). Production Processes for Creating Educational Videos. *CBE—Life Sciences Education*, 20(2):es7.

Chang, B. L. and Hirsch, M. (1994). Videotape intervention: producing videotapes for use in nursing practice and education. *Journal of continuing education in nursing*, 25(6):263–267.

Chemers, M. M., Zurbriggen, E. L., Syed, M., Goza, B. K., and Bearman, S. (2011). The Role of Efficacy and Identity in Science Career Commitment Among Underrepresented Minority Students. *Journal of Social Issues*, 67(3):469–491.

Choe, R. C., Scuric, Z., Eshkol, E., Cruser, S., Arndt, A., Cox, R., Toma, S. P., Shapiro, C., Levis-Fitzgerald, M., Barnes, G., and Crosbie, R. H. (2019). Student satisfaction and learning outcomes in asynchronous online lecture videos. *CBE Life Sciences Education*, 18(4):1–14.

Clark, C. (2015). Comparing Asynchronous and Synchronous Video versus Text Based Discussions in an Online Teacher Education Course. *Online Learning*, 19(3):1–22.

Cohen, S. D. (2011). The art of public narrative: Teaching students how to construct memorable anecdotes. *Communication Teacher*, 25(4):197–204.

Corbally, M. A. (2005). Considering video production? Lessons learned from the production of a blood pressure measurement video. *Nurse Education in Practice*, 5(6):375–379.

Cundiff, J. L., Vescio, T. K., Loken, E., and Lo, L. (2013). Do gender–science stereotypes predict science identification and science career aspirations among undergraduate science majors? *Social Psychology of Education*, 16(4):541–554.

Currie, J. (2003). A Background to Video Production for Health Education. *American Journal of Health Education*, 34(5):302–307.

D. Jones, M. and Anderson Crow, D. (2017). How can we use the 'science of stories' to produce persuasive scientific stories? *Palgrave Communications*, 3(1):53.

Dahlstrom, M. F. (2014). Using narratives and storytelling to communicate science with nonexpert audiences. *Proceedings of the National Academy of Sciences*, 111(Supplement_4):13614–13620.

de Graaf, A., Hoeken, H., Sanders, J., and Beentjes, J. W. J. (2012). Identification as a Mechanism of Narrative Persuasion. *Communication Research*, 39(6):802–823.

Deobhanj, S. (2017). Telling Stories in Science — For Better Communication. *Journal of Scientific Temper*, 05:45–58.

Dortch, D. and Patel, C. (2017). Black Undergraduate Women and Their Sense of Belonging in STEM at Predominantly White Institutions. *NASPA J. About Women High. Educ.*, 10(2):202–215.

Dou, R., Hazari, Z., Dabney, K., Sonnert, G., and Sadler, P. (2019). Early informal STEM experiences and STEM identity: The importance of talking science. *Science Education*, 103(3):623–637.

Dreon, O., Kerper, R. M., and Landis, J. (2011). Digital Storytelling: A Tool for Teaching and Learning in the YouTube Generation. *Middle Sch. J.*, 42(5):4–10.

Dunn, R. and Griggs, S. (2007). *Synthesis of the Dunn and Dunn Learning-style Model Research: Who, What, When, Where, and So What?* St. John's University.

Dunn, R. and Rundle, S. (2000). Building excellence (BE) survey: Research manual. *Retrieved October*, 30:2010.

eGan, M. E. (2011). Global diversity and inclusion: Fostering innovation through a diverse workforce. Technical report, Forbes, Insights.

Engel, A., Lucido, K., and Cook, K. (2018). Rethinking Narrative: Leveraging storytelling for science learning. *Childhood Education*, 94(6):4–12.

Estrada, M., Hernandez, P. R., and Schultz, P. W. (2018). A longitudinal study of how quality mentorship and research experience integrate underrepresented minorities into STEM careers. *CBE Life Sci. Educ.*, 17(1):1–13.

Farley, J., Risko, E. F., and Kingstone, A. (2013). Everyday attention and lecture retention: The effects of time, fidgeting, and mind wandering. *Frontiers in Psychology*, 4(SEP):1–9.

Fayer, S., Lacey, A., and Watson, A. (2017). Stem occupations: Past, present, and future. Technical report, U.S. BUREAU OF LABOR STATISTICS.

Foelske, M. (2014). *Digital storytelling: The impact on student engagement, motivation and academic learning*. PhD thesis, University of Nothern Iowa.

Francis, M. F. (2018). *Digital Storytelling with Project-Based Learning : Engaging High School Males in Space Science to Improve Academic Achievement*. Dissertation, Northcentral University.

Godwin, A. and Kirn, A. (2020). Identity-based motivation: Connections between first-year students' engineering role identities and future-time perspectives. *Journal of Engineering Education*, 109(3):362–383.

Godwin, A., Verdín, D., Kirn, A., and Satterfield, D. (2018). RACE : EXPLORING CHEMICAL ENGINEERING STUDENTS ' ATTITUDES. *Chem. Eng. Educ.*, 52(2):89–97.

Green, M. C. and Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology*, 79(5):701–721.

Guenther, L. and Joubert, M. (2017). Science communication as a field of research: identifying trends, challenges and gaps by analysing research papers. *Journal of Science Communication*, 16(02):A02.

Hoeken, H. and Sinkeldam, J. (2014). The Role of Identification and Perception of Just Outcome in Evoking Emotions in Narrative Persuasion. *Journal of Communication*, 64(5):935–955.

Holliman, R. (2011). Telling science stories in an evolving digital media ecosystem: from communication to conversation and confrontation. *Journal of Science Communication*, 10(4):3–6.

Hong, H.-Y. and Lin-Siegler, X. (2012). How learning about scientists' struggles influences students' interest and learning in physics. *Journal of Educational Psychology*, 104(2):469–484.

Hosbein, K. N. and Barbera, J. (2020). Development and evaluation of novel science and chemistry identity measures. *Chemistry Education Research and Practice*, 21(3):852–877.

Huang, L., Xu, M., Chen, Z., and Liu, F. (2019). Syllabus design for teacher education MOOCs (massive open online courses): A mixed methods approach. In *Communications in Computer and Information Science*, volume 1048, pages 156–168. Springer Verlag.

Isberner, M.-B., Richter, T., Schreiner, C., Eisenbach, Y., Sommer, C., and Appel, M. (2019). Empowering Stories: Transportation into Narratives with Strong Protagonists Increases Self-Related Control Beliefs. *Discourse Processes*, 56(8):575–598.

Issa, N., Schuller, M., Santacaterina, S., Shapiro, M., Wang, E., Mayer, R. E., and DaRosa, D. A. (2011). Applying multimedia design principles enhances learning in medical education. *Medical Education*, 45(8):818–826.

Jackson, W. (2018). *The Effects of Digital Media Exposure within Science, Technology, Engineering, and Mathematics Careers on Middle School Students' Perceptions of Diversity in the STEM Profession*. Dissertation, The University of Mississippi.

Jenkins, H. (2006). *Convergence culture : where old and new media collide*. New York : New York University Press.

Jenkinson, J. (2017). The Role of Craft-Based Knowledge in the Design of Dynamic Visualizations. In *Learning from Dynamic Visualization*, pages 93–117. Springer International Publishing, Cham.

Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. *J. Coll. Stud. Dev.*, 53(2):336–346.

Johnson, G. and Hertig, S. J. (2014). A guide to the visual analysis and communication of biomolecular structural data. *Nature Reviews Molecular Cell Biology*, 15:690–698.

Jordan, B. and Henderson, A. (1995). Interaction Analysis: Foundations and Practice. *Journal of the Learning Sciences*, 4(1):39–103.

Jordt, H., Eddy, S. L., Brazil, R., Lau, I., Mann, C., Brownell, S. E., King, K., and Freeman, S. (2017). Values affirmation intervention reduces achievement gap between underrepresented minority and white students in introductory biology classes. *CBE Life Sci. Educ.*, 16(3):1–10.

Kahan, D. (2015). What is the "science of science communication"? *Journal of Science Communication*, 14(03):Y04.

Katz, L. A., Aloisio, K. M., Horton, N. J., Ly, M., Pruss, S., Queeney, K., Rowen, C., and Dibartolo, P. M. (2017). A program aimed toward inclusive excellence for underrepresented undergraduate women in the sciences. *CBE Life Sci. Educ.*, 16(1):1–9.

Khan, B., Robbins, C., and Okrent, A. (2020). The state of U.S. science and engineering 2020. Technical report, National Science Board.

Kietzmann, J. H., Hermkens, K., McCarthy, I. P., and Silvestre, B. S. (2011). Social media? Get serious! Understanding the functional building blocks of social media. *Business Horizons*, 54(3):241–251.

Kim, A. Y., Sinatra, G. M., and Seyranian, V. (2018). Developing a STEM Identity Among Young Women: A Social Identity Perspective. *Review of Educational Research*, 88(4):589–625.

Kirn, A., Godwin, A., Benson, L., Potvin, G., Doyle, J., Boone, H., and Verdin, D. (2016). Intersectionality of Non-normative Identities in the Cultures of Engineering. In *2016 ASEE Annual Conference & Exposition Proceedings*, volume 2016-June. ASEE Conferences.

Kitchen, J. A., Sonnert, G., and Sadler, P. M. (2018). The impact of college- and university-run high school summer programs on students' end of high school STEM career aspirations. *Science Education*, 102(3):529–547.

Kricorian, K., Seu, M., Lopez, D., Ureta, E., and Equils, O. (2020). Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets. *International Journal of STEM Education*, 7(1).

Kromka, S. M. and Goodboy, A. K. (2019). Classroom storytelling: using instructor narratives to increase student recall, affect, and attention. *Communication Education*, 68(1):20–43.

Landrum, A. R. and Hallman, W. K. (2017). Engaging in Effective Science Communication: A Response to Blancke et al. on Deproblematizing GMOs. *Trends in Biotechnology*, 35(5):378–379.

Lane, T. B. (2016). Beyond academic and social integration: Understanding the impact of a STEM enrichment program on the retention and degree attainment of underrepresented students. *CBE Life Sci. Educ.*, 15(3):1–13.

León, B. and Bourk, M. (2018). *Communicating Science and Technology Through Online Video*. Routledge.

Luong, K. T., Knobloch-Westerwick, S., and Niewiesk, S. (2020). Superstars within reach: The role of perceived attainability and role congruity in media role models on women's social comparisons. *Communication Monographs*, 87(1):4–24.

Maktoufi, R. (2020). *Dialogue and Curiosity: A Science Communicator's Toolkit for Engaging Science Communication*. PhD thesis, Northwestern University.

Mayer, R. E. (2014a). Cognitive Theory of Multimedia Learning. In Mayer, R., editor, *The Cambridge Handbook of Multimedia Learning*, pages 43–71. Cambridge University Press, Cambridge.

Mayer, R. E. (2014b). Cognitive Theory of Multimedia Learning. In Mayer, R. E., editor, *The Cambridge Handbook of Multimedia Learning*, Cambridge Handbooks in Psychology, pages 43–71. Cambridge University Press, Cambridge, 2 edition.

Mayer, R. E. and Estrella, G. (2014a). Benefits of emotional design in multimedia instruction. *Learning and Instruction*, 33:12–18.

Mayer, R. E. and Estrella, G. (2014b). Benefits of emotional design in multimedia instruction. *Learning and Instruction*, 33:12–18.

Mayhew, M. A. and Hall, M. K. (2012). Science Communication in a Café Scientifique for High School Teens. *Science Communication*, 34(4):546–554.

McDonald, M. M., Zeigler-Hill, V., Vrabel, J. K., and Escobar, M. (2019). A Single-Item Measure for Assessing STEM Identity. *Frontiers in Education*, 4(July):1–15.

McGarr, O. (2009). A review of podcasting in higher education: Its influence on the traditional lecture. *Australasian Journal of Educational Technology*, 25(3):309–321.

McGill, G. G. (2017). Designing Instructional Science Visualizations in the Trenches: Where Research Meets Production Reality. In *Learning from Dynamic Visualization*, pages 119–150. Springer International Publishing, Cham.

Meador, A. (2018). Examining Recruitment and Retention Factors for Minority STEM Majors Through a Stereotype Threat Lens. *School Science and Mathematics*, 118(1-2):61–69.

Metcalfe, J. (2019). Comparing science communication theory with practice: An assessment and critique using Australian data. *Public Understanding of Science*, 28(4):382–400.

Morais, C. (2015). Storytelling with Chemistry and Related Hands-On Activities: Informal Learning Experiences To Prevent "Chemophobia" and Promote Young Children's Scientific Literacy. *Journal of Chemical Education*, 92(1):58–65.

Morgenroth, T., Ryan, M. K., and Peters, K. (2015). The Motivational Theory of Role Modeling: How Role Models Influence Role Aspirants' Goals. *Review of General Psychology*, 19(4):465–483.

Moyer-Guse, E. and Nabi, R. L. (2010). Explaining the Effects of Narrative in an Entertainment Television Program: Overcoming Resistance to Persuasion. *Human Communication Research*, 36(1):26–52.

Muller, D. A. and Sharma, M. D. (2005). Determining the factors affecting student perceptions of a popular science video. *Australas. J. Educ. Technol.*, 21(4):491–509.

Munoz Morcillo, J., Czurda, K., and Robertson-von Trotha, C. Y. (2016). Typologies of the popular science web video. *Journal of Science Communication*, 15(04):A02.

Murphy, M. C., Steele, C. M., and Gross, J. J. (2007). Signaling Threat. *Psychological Science*, 18(10):879–885.

National Academies of Sciences, Engineering, and Medicine, . (2016). *Communicating Chemistry*. National Academies Press, Washington, D.C.

National Research Council (2009). *Learning Science in Informal Environments*. National Academies Press, Washington, D.C.

National Science Board, N. S. F. (2019). Science and Engineering indicators 2020: Science and Engineering labor force. Technical report, National Science Foundation.

Nemirovsky, R. and Galvis, A. (2004). Facilitating Grounded Online Interactions in Video-Case-Based Teacher Professional Development. *Journal of Science Education and Technology*, 13(1):67–79.

Nisbet, M. C. and Markowitz, E. (2016). Science Communication Research: Bridging Theory and Practice. Technical report, Alan Leshner Leadership Institute.

Obar, J. A. and Wildman, S. (2015). Social media definition and the governance challenge: An introduction to the special issue. *Telecommunications Policy*, 39(9):745–750.

O'Brien, L. T., Blodorn, A., Adams, G., Garcia, D. M., and Hammer, E. (2015). Ethnic variation in gender-STEM stereotypes and STEM participation: An intersectional approach. *Cultural Diversity and Ethnic Minority Psychology*, 21(2):169–180.

Olmedo-Torre, N., Sanchez Carracedo, F., Salan Ballesteros, M. N., Lopez, D., Perez-Poch, A., and Lopez-Beltran, M. (2018). Do female motives for enrolling vary according to STEM profile? *IEEE Transactions on Education*, 61(4):289–297.

Ong, M., Smith, J. M., and Ko, L. T. (2018). Counterspaces for women of color in STEM higher education: Marginal and central spaces for persistence and success. *Journal of Research in Science Teaching*, 55(2):206–245.

Orr, K. L., Golas, K. C., and Yao, K. (1994). Storyboard development for interactive multimedia training. *Journal of Interactive Instruction Development*, 6(3):18–31.

Paas, F. and Sweller, J. (2014). Implications of Cognitive Load Theory for Multimedia Learning. In Mayer, R. E., editor, *The Cambridge Handbook of Multimedia Learning*, Cambridge Handbooks in Psychology, pages 27–42. Cambridge University Press, Cambridge, 2 edition.

Patall, E. A., Steingut, R. R., Freeman, J. L., Pituch, K. A., and Vasquez, A. C. (2018). Gender disparities in students' motivational experiences in high school science classrooms. *Science Education*, 102(5):951–977.

Peer, L. and Ksiazek, T. B. (2011). Youtube and the challenge to journalism. *Journalism Studies*, 12(1):45–63.

Peleg, R., Yayon, M., Katchevich, D., Mamlok-Naaman, R., Fortus, D., Eilks, I., and Hofstein, A. (2017). Teachers' views on implementing storytelling as a way to motivate inquiry learning in high-school chemistry teaching. *Chem. Educ. Res. Pract.*, 18(2):304–309.

Petrosino, A. (2006). Teachers as Designers : Pre and In-Service Teachers' Authoring of Anchor Video as a Means to Professional Development. In *Video Research in the Learning Sciences*.

Pietri, E. S., Moss-Racusin, C. A., Dovidio, J. F., Guha, D., Roussos, G., Brescoll, V. L., and Handelsman, J. (2017). Using Video to Increase Gender Bias Literacy Toward Women in Science. *Psychology of Women Quarterly*, 41(2):175–196.

Pinsky, L. E. and Wipf, J. E. (2000). A picture is worth a thousand words. *Journal of General Internal Medicine*, 15(11):805–810.

Pitrelli, N. (2011). Science journalism and digital storytelling. *Journal of Science Communication*, 10(04):C01.

Pritchard, A. (2018). Multiple intelligences and learning styles. *Ways of Learning*, 106(1):38–58.

Quitadamo, I. J. and Brown, A. (2001). *Effective Teaching Styles and Instructional Design for Online Learning Environments*. Distributed by ERIC Clearinghouse [Washington, D.C.].

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., and Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *Int. J. STEM Educ.*, 5(1):10.

Rajadell, M. and Garriga-Garzón, F. (2017). Educational videos: After the why, the how. *Intangible Capital; Vol 13, No 5 (2017)DO - 10.3926/ic.1042*.

Ratner, M. and Ucko, D. (2016). *Effective Chemistry Communication in Informal Environments*. National Academies Press, Washington, D.C.

Rincón, B. E. and George-Jackson, C. E. (2016). Examining department climate for women in engineering: The role of STEM interventions. *Journal of College Student Development*, 57(6):742–747.

Robin, B. R. (2008). Digital storytelling: A powerful technology tool for the 21st century classroom. *Theory Into Practice*, 47(3):220–228.

Robinson, K. A., Lee, Y.-k., Bovee, E. A., Perez, T., Walton, S. P., Briedis, D., and Linnenbrink-Garcia, L. (2019a). Motivation in transition: Development and roles of expectancy, task values, and costs in early college engineering. *Journal of Educational Psychology*, 111(6):1081–1102.

Robinson, K. A., Perez, T., Carmel, J. H., and Linnenbrink-Garcia, L. (2019b). Science identity development trajectories in a gateway college chemistry course: Predictors and relations to achievement and STEM pursuit. *Contemporary Educational Psychology*, 56(January):180–192.

Rohde, J. A., Verdin, D., Doyle, J., Godwin, A., Kirn, A., Benson, L., and Potvin, G. (2018). Investigating the Intersection of Career Aspirations and Engineering Beliefs in First Year Engineering Students. In *2018 IEEE Frontiers in Education Conference (FIE)*, volume 2018-Octob, pages 1–8. IEEE.

Rosenthal, L., Levy, S. R., London, B., Lobel, M., and Bazile, C. (2013). In Pursuit of the MD: The Impact of Role Models, Identity Compatibility, and Belonging Among Undergraduate Women. *Sex Roles*, 68(7-8):464–473.

Rosenthal, S. (2018). Motivations to seek science videos on YouTube: free-choice learning in a connected society. *International Journal of Science Education, Part B*, 8(1):22–39.

Schinske, J., Cardenas, M., and Kaliangara, J. (2015). Uncovering Scientist Stereotypes and Their Relationships with Student Race and Student Success in a Diverse, Community College Setting. *CBE Life Sci. Educ.*, 14(3):ar35.

Schinske, J. N., Perkins, H., Snyder, A., and Wyer, M. (2016). Scientist Spotlight Homework Assignments Shift Students' Stereotypes of Scientists and Enhance Science Identity in a Diverse Introductory Science Class. *CBE—Life Sciences Education*, 15(3):ar47.

Schuster, C. and Martiny, S. E. (2017). Not Feeling Good in STEM: Effects of Stereotype Activation and Anticipated Affect on Women's Career Aspirations. *Sex Roles*, 76(1-2):40–55.

Shen, F., Sheer, V. C., and Li, R. (2015). Impact of Narratives on Persuasion in Health Communication: A Meta-Analysis. *Journal of Advertising*, 44(2):105–113.

Shin, J. E. L., Levy, S. R., and London, B. (2016). Effects of role model exposure on STEM and non-STEM student engagement. *Journal of Applied Social Psychology*, 46(7):410–427.

Simon, R. M., Wagner, A., and Killion, B. (2017). Gender and choosing a STEM major in college: Femininity, masculinity, chilly climate, and occupational values. *Journal of Research in Science Teaching*, 54(3):299–323.

Singer, A., Montgomery, G., and Schmoll, S. (2020). How to foster the formation of STEM identity: studying diversity in an authentic learning environment. *International Journal of STEM Education*, 7(1):57.

Skinner, E., Saxton, E., Currie, C., and Shusterman, G. (2017). A motivational account of the undergraduate experience in science: brief measures of students' self-system appraisals, engagement in coursework, and identity as a scientist. *International Journal of Science Education*, 39(17):2433–2459.

Smeda, N., Dakich, E., and Sharda, N. (2013). The effectiveness of digital storytelling in the classrooms: A case study. *2013 IEEE 13th International Conference on Advanced Learning Technologies*, pages 491–492.

Smith, D. K. (2014). iTube, YouTube, WeTube: Social Media Videos in Chemistry Education and Outreach. *Journal of Chemical Education*, 91(10):1594–1599.

Smith, J. L., Brown, E. R., Thoman, D. B., and Deemer, E. D. (2015). Losing its expected communal value: how stereotype threat undermines women's identity as research scientists. *Social Psychology of Education*, 18(3):443–466.

Stets, J. E., Brenner, P. S., Burke, P. J., and Serpe, R. T. (2017). The science identity and entering a science occupation. *Social Science Research*, 64:1–14.

Sugimoto, C. R. and Thelwall, M. (2013). Scholars on soap boxes: Science communication and dissemination in TED videos. *Journal of the American Society for Information Science and Technology*, 64(4):663–674.

Sunny, C. E., Taasoobshirazi, G., Clark, L., and Marchand, G. (2017). Stereotype threat and gender differences in chemistry. *Instructional Science*, 45(2):157–175.

Thelwall, M., Kousha, K., Weller, K., and Puschmann, C. (2012). Chapter 9 Assessing the Impact of Online Academic Videos. In *Social Information Research (Library and Information Science*, chapter 9, pages 195–213. Emerald Group Publishing Limited, 5 edition.

Torres, D. H. and Pruim, D. E. (2019). Scientific storytelling: A narrative strategy for scientific communicators. *Communication Teacher*, 33(2):107–111.

Um, E., Plass, J. L., Hayward, E. O., and Homer, B. D. (2012). Emotional design in multimedia learning. *Journal of Educational Psychology*, 104(2):485–498.

US Department of Education (2016). Future Ready Learning; Reimagining the Role of Technology in Education. *Office of Educational Technology*, pages 1–106.

van Aalderen-Smeets, S. I. and Walma van der Molen, J. H. (2018). Modeling the relation between students' implicit beliefs about their abilities and their educational STEM choices. *International Journal of Technology and Design Education*, 28(1):1–27.

Welbourne, D. J. and Grant, W. J. (2016). Science communication on YouTube: Factors that affect channel and video popularity. *Public Underst. Sci.*, 25(6):706–718.

White, A. M., DeCuir-Gunby, J. T., and Kim, S. (2019). A mixed methods exploration of the relationships between the racial identity, science identity, science self-efficacy, and science achievement of African American students at HBCUs. *Contemporary Educational Psychology*, 57(December 2018):54–71.

Williams, S. N., Thakore, B. K., and McGee, R. (2017). Providing social support for underrepresented racial and ethnic minority phd students in the biomedical sciences: A career coaching model. *CBE Life Sci. Educ.*, 16(4).

Wilton, M., Gonzalez-Niño, E., McPartlan, P., Terner, Z., Christoffersen, R. E., and Rothman, J. H. (2019). Improving academic performance, belonging, and retention through increasing structure of an introductory biology course. *CBE Life Sciences Education*, 18(4).

Yonas, A., Sleeth, M., and Cotner, S. (2020). In a "Scientist Spotlight" Intervention, Diverse Student Identities Matter. *Journal of Microbiology & Biology Education*, 21(1):25.

Young, D. M., Rudman, L. A., Buettner, H. M., and McLean, M. C. (2013). The Influence of Female Role Models on Women's Implicit Science Cognitions. *Psychology of Women Quarterly*, 37(3):283–292.

Zumbrunn, S., McKim, C., Buhs, E., and Hawley, L. R. (2014). Support, belonging, motivation, and engagement in the college classroom: a mixed method study. *Instructional Science*, 42(5):661–684.