WOW STEM!

Addressing the STEM gender gap with accessible educational content

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1 A World of Women in STEM

Women are, and always have been, an essential part of science, technology, engineering, and math (STEM). But despite their innumerable contributions to these fields, their stories are not the ones commonly told in textbooks or popular culture. If you ask a search engine to provide a list of physicists, for example, only one female face–Marie Curie–looks back amid the grid of 51 photographs, an array of almost entirely male and overwhelmingly white scientists[1].

What impact does this have on the way young students conceptualize STEM and those who are a part of it? For one, a lack of role models makes it more difficult for students to conceptualize themselves in a field [1], contributing to the "leaky" pipeline of STEM where women and gender minorities (women+) make up less and less of each subsequent stage of STEM careers [2]. Conversely, exposure to role models in STEM fields has been connected to increased feelings of self-efficacy, empowering young girls to envision a path to a future in STEM [3].

The untold stories of historic and modern women+ in STEM are important for more than just addressing the missing fraction of women+ in STEM fields; they also have a crucial place in science education. Storytelling is a critical pedagogical tool that has been shown to be an efficient means of memory and learning [4]. Stories about scientists, especially underrepresented scientists, have

[1] For this example, we used Google to search "list of physicists."

the added benefit of highlighting the human experience in STEM. A human-centered approach to science education could better reach the broad, disinterested public, while also connecting the current practice of science to the traditions of our ancestors. Women in particular are more inclined toward careers that are socially relevant [5]. Thus, stories that emphasize a human approach to STEM and the real impact of historic and modern women+ in those fields could be a valuable tool for connecting to a wide audience and potentially bridging the STEM gender gap.

This presents an opportunity: by creating scientific content that focuses on the stories of past and present women+ in STEM, we can both educate and empower young women and girls, encouraging exploration, cultivating curiosity, and sparking a lifelong love of science. This philosophy led us to found A World of Women in STEM (WOW STEM, `www.wowstem.org`). WOW STEM is an online, multimedia platform of original educational content targeted for middle and high school girls, which explores the long history of women+'s participation in science. Our content tells diverse women+'s stories and celebrates historic knowledge traditions, while also providing accessible explanations of technical discoveries to teach our target viewers of 7th-10th graders fundamental science and cutting-edge research. We especially strive to highlight BIPOC (Black, Indigenous, people of color) scientists, as well as under-recorded scientific knowledge from historic cultures across the globe. Because online spaces are increasingly central to learning, we have focused on developing a digital platform that is accessible, cheap to maintain, and has a low barrier to interaction.

Here, we discuss our approach to science education and communication at WOW STEM, and how we have developed a library of content that centers the human experience of past, present and future women+ in STEM. We discuss three projects from WOW STEM that exemplify our pedagogical approach: a post on Dr. Marie Clark Taylor, a historic botanist [6]; a post on Dr. Rangi Te Kanawa, a modern textiles conservationist [7]; and a post on the science of baking for

Pi Day, which highlights the ancient knowledge contributions of countless unnamed women+ [8][2]. We explore our use of biographical detail combined with in-depth scientific explanations, creation of accessible short-form content for social media, and efforts to incorporate home learning and experiments. Finally, we consider how these scientific communication and education efforts fit into the quickly shifting landscapes of online information and social media, and anticipate the future role of accessible, interdisciplinary narratives as a means to honor and celebrate past, present, and future women+ in science.

2 Selections from WOW STEM

2.1 Dr. Marie Clark Taylor: Illuminating Beginnings

One of the most straightforward ways to incorporate storytelling into science education is by discussing the contributions of people whose work was underappreciated, forgotten, or even willfully buried. For much of history, women were denied the same level of education as men, and confounding factors like race and class also prevented many willing researchers from fully participating in the STEM fields. At WOW STEM, we have profiled many "firsts" in our Historical Figures series: the first American woman to earn a PhD in chemistry (Dr. Rachel Lloyd [9]), the first Mexican-American female botanist (Ynés Mexía [10]), the first known Native American female engineer (Mary Golda Ross [11]). It is important to frame these scientists' brilliant accomplishments in the context of their environment and the pressures they faced. Science, after all, is not done in a vacuum, but rather in the social and political atmospheres in which we are all embedded.

One such profile on a groundbreaking first is our post on Dr. Marie Clark Taylor. Taylor was the first Black woman to be awarded a PhD in the field of botany, and was also the first woman to

[2] In these sections, we adapt our original research used for our blog posts on these three subjects. See posts for additional information, sources, and citations.

graduate from Fordham University with a PhD in any field of science. Born in 1911 in Sharpsburg, Pennsylvania, Taylor attended school during the process of desegregation in Pennsylvania's schools. She had an early passion for learning, and knew from a young age she wanted to pursue the highest levels of education. She went on to earn her Bachelor's (1933) and Master's (1935) degrees from Howard University, at which point she began teaching high school biology classes. Dedicated to her own education, she enrolled in a PhD program at Fordham in 1938 and graduated in 1941, after which she joined the war efforts by serving in the Army Red Cross (1942-1945). Taylor's PhD research involved experiments investigating the role of photoreceptors in flowering plants. She was interested in learning how a plant's growth and flower development is affected by exposure to light, a phenomenon called photomorphogenesis. This process drives a seedling's ability to know when it has reached the surface and can begin to sprout, as well as the longer seasonal patterns of bloom that depend on the length of the solar day.

Figure 1: Original portrait of Dr. Marie Clark Taylor by WOW STEM artist Dr. Jovana Andrejevic

In 1945, Taylor joined the faculty at her alma mater, Howard University. She was a highly esteemed member of her department and led Howard Botany for nearly 30 years. Under her guidance, the botany department flourished, inspiring countless young Black botanists. Taylor also advocated strongly for the continued education of high school teachers and the use of real biological research and experiments in the classroom. She worked with the National Science Foundation to train teachers during summers on experimental methods; the widespread use of light microscopes in classrooms is largely thanks to her efforts. President Lyndon B. Johnson specifically requested that her work in high school education be extended to overseas programs.

Despite her incredible and broad-reaching career, shockingly little is known about Dr. Marie Clark Taylor besides what has been detailed above. Much of her story and the extent of her contributions, like those of so many women of color throughout history, have been lost to time. In the development of our article, WOW STEM writers worked with archivists at Howard and Fordham Universities to obtain relevant articles and photos, but found that even current faculty of these universities' botany departments had not even heard of Taylor or her work. Her thesis is not available digitally, and the extent of her administrative and mentoring work may mean that her contributions to other academic papers were not formal enough to merit authorship – particularly given that women in the 1900s were rarely granted authorship, even for significant contributions to projects. The scientific narrative that WOW STEM writers were able to weave might be the closest we can get to widely accessible information about Dr. Taylor's research in botany, biology, and photomorphogenesis.

Contrasting Dr. Taylor's civic and academic achievements with the available biographical knowledge about her, we can begin to understand just how many "hidden figures" have been pushed to the margins of our history books. Marie Clark Taylor has a presence in nearly every high school biology classroom, but hardly any biology students know her name. The most powerful part of sharing her story is the implicit lesson that, even if we have never heard of them, there are countless marginalized people who have made foundational contributions to every STEM field. By sharing about Dr. Taylor's commitment to education and enthusiasm for botany, we hope to honor her legacy and inspire the next generation of scientists.

2.2 Dr. Rangi Te Kanawa: Conservation in Action

The power of storytelling is not limited to those whose stories have concluded. At WOW STEM, we extend our narrative-focused style to showcase currently active scientists who are making great strides in their fields. Our Modern Scientist series celebrates the diversity of the current STEM workforce and teaches readers fundamental concepts they need to know in order to understand cutting-edge research developments.

Dr. Rangi Te Kanawa is a textiles conservator with expertise in both the modern science of chemistry and the traditional science of Māori dyeing and weaving. Her mother and grandmother were esteemed Māori dyers and weavers, and through teaching and leadership all three of them have done great work to preserve this knowledge and strengthen their community. They have worked to revitalize *mātauranga Māori*: the traditional ways of knowing and learning of the Māori, the indigenous people of New Zealand. Mātauranga Māori is an interdisciplinary knowledge system that centers the Māori community's relationship with their land and the environment.

Inspired by her upbringing in the traditional dyeing and weaving community, Te Kanawa earned her PhD in chemistry in order to understand the science behind traditional dyeing practices. Her experience with mātauranga Māori and modern science uniquely qualify her to study and conserve precious Māori textiles. Her work has been instrumental in the development of new chemical techniques for preservation of textiles. When studying textiles woven from black and reddish-brown fibers, she found the black fibers had strongly degraded, causing the garments to fall apart. Te Kanawa found that the mud used to create the black color was acidic and was corroding the dyed plant fibers, causing their accelerated wear. To preserve and restore the traditional Māori garment, she treated the fibers with a base that neutralized the dye's acidity, ensuring the survival of this important cultural artifact.

Figure 2: Dr. Rangi Te Kanawa examining a piupiu, a short kilt usually made of strips of flax and worn by Māori for native dances and on ceremonial occasions. Photograph courtesy of Te Kanawa.

Our WOW STEM post on Te Kanawa and her research was completed in collaboration with Galactic Polymath, an organization that translates current academic research into creative, interdisciplinary lessons for grades 5+ that are free for everyone. Colourful Solutions, the associated Galactic Polymath lesson, is designed to be completed over the course of a week, and teaches students how to think like chemical engineers [12]. The project was sponsored by faculty at the University of Canterbury, and was specifically designed to center Māori culture and history, much like Dr. Te Kanawa's story and research do. This lesson plan has been successfully deployed in classrooms throughout New Zealand, an example of the successful integration between science and storytelling in pedagogy.

2.3 Ancient Cooking: Pi(e) Day

There are many traditional ways of learning and knowing beyond mātauranga Māori. Many ancient cultures independently developed counting and computing systems capable of sophisticated calculations. Similarly, many types of trades and housework passed down through formal and informal knowledge transfer, such as metallurgy, knitting, and medicine, are also systematic methods of storing knowledge which far predate Western science. At WOW STEM, we strive to highlight these ancient scientific practices in addition to our profiles on specific individuals in STEM. By expanding readers' preconceived definitions of science, we further humanize science as an accessible and socially relevant subject, giving us yet another tool to attract girls to STEM.

One opportunity for expanding the definition of science is in celebration of Pi Day, named in honor of the approximation of the transcendental number, π (3.14 ...) and celebrated on March 14. For our first Pi Day, WOW STEM dove into the ancient knowledge tradition of cooking. Demonstrated through the process of baking a celebratory pie, we explored the science of stretchy gluten, immiscible liquids, carbohydrates in plant cells, colloidal suspensions, and the Maillard reaction. While some of these scientific concepts have only been understood within the past decade, most of the recipes we used have foundations that are millennia old.

Though cooking is often not considered a formal science, we highlight in our Pi Day post that it depends on physics, chemistry, and biology at every step of a recipe. Baking and cooking require careful scientific experimentation. Creating a recipe from scratch requires highly specialized knowledge and plenty of failures. At some point in history, someone (or, perhaps, many people) developed the recipes for foods we eat every day, and the chances are high that person was a woman who spent years of her life experimenting in her kitchen and perfecting her recipes.

Though women were historically not invited into the laboratory or the scientific lecture, "women's work" has always been scientific. Celebrating that long history of women's scientific thinking vali-

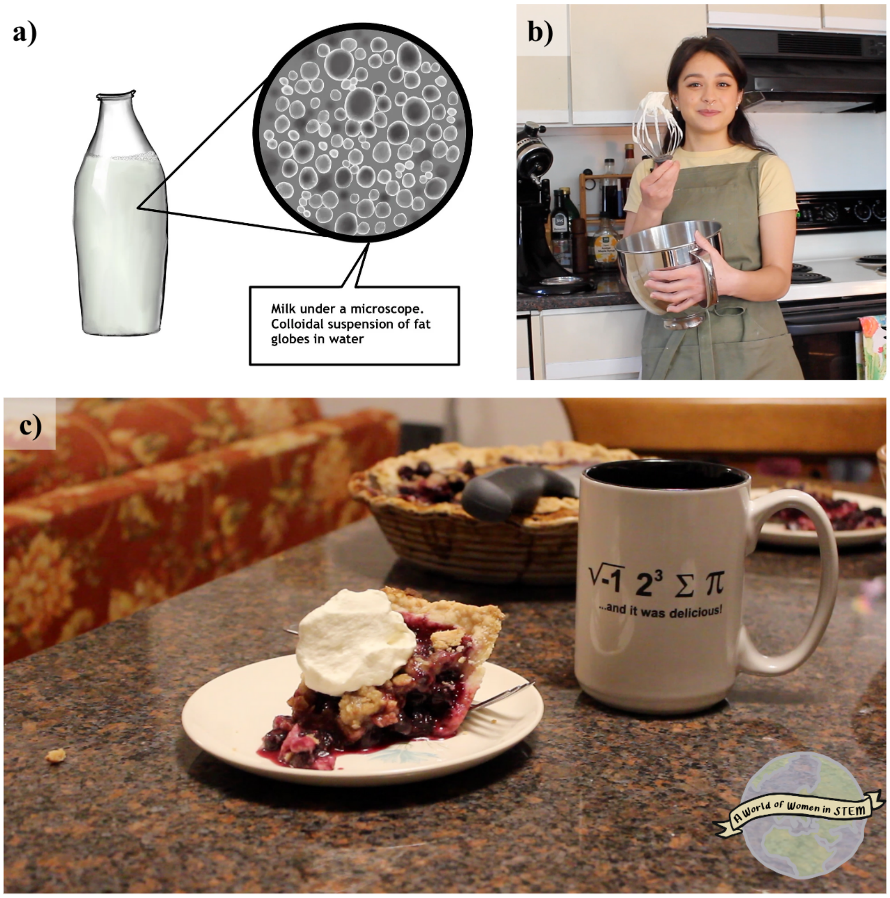

Figure 3: a) Illustration of the science involved in making whipped cream for pie. Milk is a suspension of micrometer-scale spheres of fat suspended in water, making it a colloidal suspension. Illustration by Sachi Weerasooriya [8] b) Image from video showing host, Madelyn Leembruggen, making whipped cream. Breaking up the fat globs of milk and forcing air into the cream results in a stiff, light, and fluffy mixture. c) After a lot of hard work and science, we have a delicious pie.

dates their contributions to collections of cultural knowledge. We hope that by highlighting the way that people of all genders from all over the world have always been engaged in scientific thinking, we are empowering our audience to imagine the scientific world in the everyday. Sharing these stories invites readers to imagine themselves, and all their ancestors, participating in the age-old tradition of expanding our collective knowledge.

3 Reflections on Pedagogy

We are intentional with our use of narrative to communicate the stories and research of the figures we cover in a way that is both accessible and compelling. Our posts are balanced between biographical detail and scientific explanations so that readers are left with historical context for the scientific landscape as well as an understanding of the technical mechanics of the research we discuss. We thread our content with opportunities for home learning in order to cultivate everyday curiosity and a lens of scientific thinking. Finally, to ensure that our stories have broad reach, we create visually appealing, accessible, short-form content to meet our audience where they are: on fast-paced social media platforms. Here, we expand on our motivation and implementation of each of these strategies.

Through biographical detail, we invite our readers to imagine themselves in the lives of the women+ we profile. Because visible role models are such a strong component of forming a scientific identity [3], WOW STEM's content allows girls to envision themselves in a successful STEM career and chart a corresponding academic trajectory. To humanize our subjects and present them as relatable characters, we often refer to them by their first names, particularly when we discuss their childhoods. This presents an opportunity for young female readers to more easily see similarities between themselves and the subject. The academic standard of referring to researchers by their last name often acts to objectify and depersonalize research from the researcher; while this has its place in some academic settings, it is contrary to the storytelling approach to humanize researchers and their career choices that we know can successfully attract girls to STEM narratives. Furthermore, many of the researchers we profile were as accomplished and educated as men with PhDs, but were not permitted to hold the title of PhD or MD. When discussing our subjects' research and accomplishments, we primarily refer to our subjects by their last name, and title if they hold a doctorate, but carefully balance this respectful and standard referencing with the more personal use of their first or full name.

We find that most projects similar to ours which profile women+ in STEM focus only on the subject's journey to STEM and personal history, with little to no explanation of their research. On the other end of the spectrum, academic descriptions of their work are typically far too technical for a general audience, let alone our audience of 7th-10th graders with limited scientific background. By contrast, our content includes equal parts biographical and scientific information. Our readers gain fundamental knowledge necessary to understand the research of the subject and related topics, building their STEM literacy and presenting important concepts in a non-threatening and low-risk setting. We understand that our readers might not immediately understand all the technical details in a post, but our goal is that they will be more familiar and confident with concepts when they eventually come across them in a formal class, bolstering their assessments of their own skills.

One of the strengths of informal learning is the chance to explore at one's own pace. To encourage this kind of self-guided investigation, our posts are accompanied by activities and experiments that can easily be done at home. Our content is particularly well-suited to at-home experiments, since most of the science our subjects completed was performed with limited resources and often outside of the traditional academic setting, in their personal kitchens or basements. Younger students may require support, but more advanced students are typically equipped to complete our activities on their own. Home learning highlights that science, technology, engineering, and math are all around us and part of every aspect of our lives. These low-pressure, student-driven activities develop students' ability to view their surroundings through a lens of scientific inquiry, and prepare them to ask investigable questions and independently pursue the answers.

But it is not enough for this type of content to exist online; we want it to be accessible and discoverable by our target audience. In an attempt to meet our audience where they already gather, we have focused on the creation of short-form video and graphical content to supplement

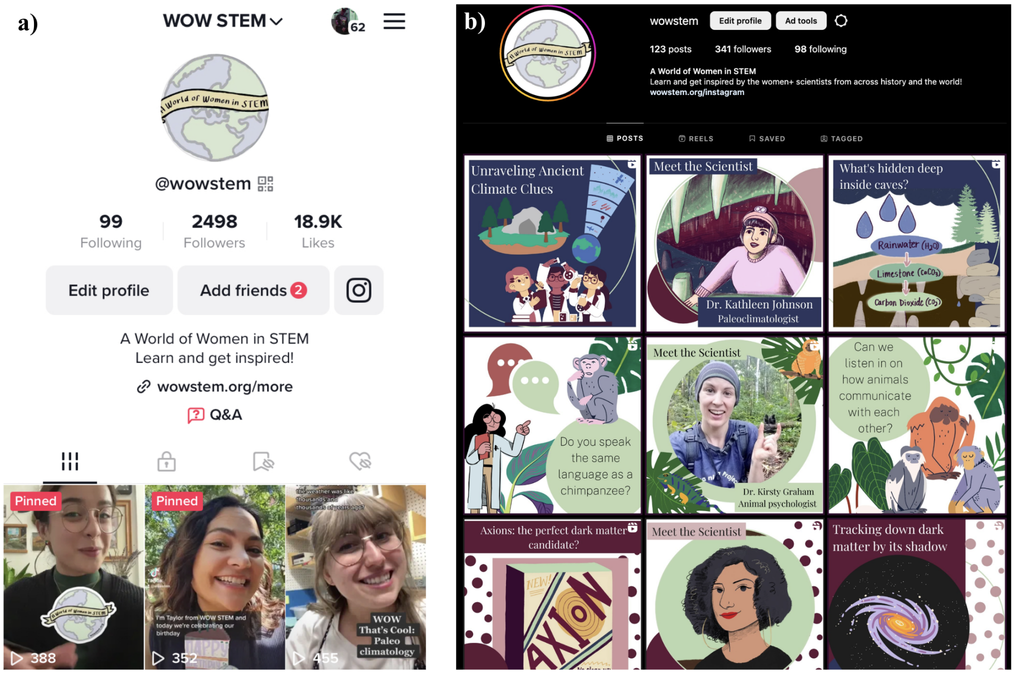

Figure 4: Social media outreach is an important component of our pedagogical strategy. Images of our a) Tiktok page and b) Instagram page. We strive to make our content accessible, friendly, and engaging to our target audience.

our long-form, more traditional text posts and videos. This content, which we post to social media sites like TikTok and Instagram, has been broadly successful at reaching our audience. While our website has seen traffic of around 25,000 site visits in just over a year since launch, our video content has amassed a total of around 180,000 views across TikTok and Instagram, indicating a broad demand for entertaining and educational short-form content on these new media platforms. Part of our strategy for building engagement has been creating a cohesive visual aesthetic and presentation style. We supplement the biographical and technical aspects of our blog posts and videos with aesthetic and eye-catching illustrations and diagrams that are designed to appeal to our target audience of young girls. We also format our videos to be warm and friendly, presenting science in an inviting and exciting tone to welcome everyone, including those with limited scientific background.

4 The Future of Learning

The past few years have seen an upheaval in the role of online spaces for learning. Beyond virtual school and online classes, there has also been a broad adoption of social media platforms by science educators. While these platforms are certainly fraught with issues–from disinformation and misinformation to questions about effects on mental health and well-being–it is undeniable that they play a central role in the lives of young people. This presents an opportunity for both scientific education and broadening the possible futures girls can envision for themselves. Though it can be difficult to reach underrepresented groups in the classroom, informal learning is uniquely positioned to meet young people where they are, and convey encouraging, empowering messages. Storytelling has long held a place in education [13], and WOW STEM's content seeks to bring STEM directly to our audience through the lens of inspiring stories that spark curiosity, exploration, and discovery.

Our quickly-shifting digital landscape demands pedagogical strategies that are flexible and adaptable. As we transition to digital-first learning, now is the time to recenter storytelling in our educational narratives [14]. The decentralized nature of social media platforms means that science communication is now open to everyone; any scientist can directly communicate their work to the public using only the tool they carry around in their pocket everyday. For these communications to succeed in reaching and impacting a broad audience, however, scientific educators must think carefully about the content they are creating. In this increasingly digital age, the public is craving more compassion and personal connections in the content they consume. Young people today have the broadest access to connection and education in history, but are subject to isolation and depersonalization in the modern learning arena. The future of scientific communication will depend on accessibility, interdisciplinary approaches, and human-centered storytelling that emphasizes social connections. We anticipate that WOW STEM will be just one example of this approach to bring science to girls and hopefully bring girls into science.

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