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Addressing Gaps in Science Competencies: Incorporating Science Communication into Existing Classes

Amy J. Hawkins
University of Utah, amy.j.hawkins@utah.edu

Melissa Rowland-Goldsmith
Chapman University, rowlandg@chapman.edu

Nicole C. Woitowich
Northwestern University, Nicole.woitowich@northwestern.edu

Addressing Gaps in Science Competencies: Incorporating Science Communication into Existing Classes

Amy J. Hawkins, Melissa Rowland-Goldsmith, and Nicole C. Woitowich

Abstract*: Regardless of which career path a scientist decides to take, they must be able to communicate effectively with broad audiences. As such, science communication training has become an essential component of STEM professional development. While multiple national scientific societies have articulated the need to address these skills as in fundamental training, few undergraduate scientific training programs have formally addressed this in their degree programs. Here we present an innovative approach to teach this skill set by blending an online science communication course with existing curricula in the biomedical sciences. Online content from the American Society for Biochemistry and Molecular Biology (ASBMB) Art of Science Communication (ASC) course was integrated into an undergraduate setting. This new iteration utilized components from the successful online course format blended with an institutional course to foster science communication skills. We provide key insights into blended-course development and its impact on learners' professional development and science communication skills. We contextualize our approach with what others have learned from blended courses and online professional development opportunities for STEM students.*

Introduction

Dialogues between scientists and non-experts likely date as far back as the beginning of science itself. Certainly public understanding and appreciation of science are essential underpinnings of modern society, and scientific literacy provides benefits that span individual, community, and organizational levels. Yet gaps in public understanding of science as a process and profession persist, and the resulting misconceptions and mistrust of science have significant consequences across our society. Anti-science sentiments and growing mistrust of science have real-world implications on a global scale as recommendations from climate scientists are ignored, anti-vaccination movements are highly visible and vocal, and pseudo-scientific medical treatments, which have no scientific or clinical basis, are increasingly popular.

The activities which promote knowledge, interest, and understanding of science are broadly categorized into the fields of science outreach and communication, and may incorporate components of formal or informal education (American Association for the Advancement of Science). We contend here that the deficit model of communication historically used by the scientific community in its interactions with non-experts has significant limitations. Active listening and mutual learning between scientists and non-experts, where the emotions, beliefs, motivations, and interests of all parties are considered, become critical for effective communication. Communicators of science must learn how to engage their audience and to translate scientific content into accessible language with three goals in mind: (1) increase awareness of science by generating interest and positive attitudes, (2) create understanding of science, and, eventually, (3) foster an appreciation of and participation in science.

One of the main goals of science communication is to increase public engagement, awareness, and understanding of science (AAAS). In this text, we refer to our audience as non-experts, rather than non-scientists, general public, or lay public for several reasons. Using the terms non-scientists and general public establishes a barrier and unfavorable power dynamic which assumes scientists are in a distinct category of individuals separate from anyone else. The term lay public is typically used synonymously with genetical public but can also reference members of a religious organization, and we avoid using the term for both these reasons. The tern non-expert also encompasses science communication which occurs across scientific disciplines. Geophysicists and biochemists are both scientists, but they are not likely to be experts in both fields. Taking these nuances into consideration fosters inclusive communication that encourages the audience to be an active participant in science.

The realization of a need for effective science communication has led to a growing body of research in the theory and practice of science outreach and communication within academia and beyond, as demonstrated by the explosion of scholarly literature related to this emerging field. The next challenge is to incorporate these findings and this knowledge into the formal educational programs of scientists and to provide continuing education for those in the scientific workforce. Here we describe an approach to incorporate an online science communication course into existing classrooms and discuss lessons learned from these approaches.

Communicating Science

Scientists rely on various modes of communication in order to conduct, advance, and disseminate their research. Strong communication skills are necessary to establish collaborations, form research teams, obtain funding, and share research findings (Feliú-Mójer). Moreover, many scientists are required to demonstrate the broader impact of their work in order to obtain extramural funding (National Science Board). The addition of "Broader Impacts" to the criteria used to formally evaluate competitive National Science Foundation (NSF) grant proposals establishes an expectation that taxpayer-funded scientific research must engage the public and contribute more broadly to achieving societal goals (National Science Foundation).

Indeed, scientists overwhelmingly agree that public engagement with science is essential (Dang and Russo; Ecklund et al.; Johnson et al.; The Wellcome Trust). Yet discomfort with science communication techniques may limit scientists' participation in outreach (Committee on the Science of Science Communication: A Research Agenda et al.). Moreover, science communication efforts often fail to represent the diverse spectra of individuals involved with or impacted by science (Bevan et al.; Canfield et al.). As described by the Center for the Advancement of Informal Science Education (CAISE) task force on broadening participation in STEM (Bevan et al.): "Representations and instantiations of science are typically informed by the dominant cultural norms of STEM, which are mostly white, western, and male." In order to meet the need for effective science communication conducted by a diverse group of scientists, broadly accessible training should be available and required as part of undergraduate science curricula and training (Brownell et al.; Jandciu et al.; Kuehne et al.). Without an investment in culturally-relevant science communication training, created by and for members of diverse communities, we are faced with propagating outdated stereotypes of who can access, participate in, and benefit from science.

Furthermore, the call to develop science communication curricula has been articulated by stakeholders at every level of formal education. In 2011, The AAAS released *Vision and Change in Undergraduate Biology: A Call to Action* (American Association for the Advancement of Science). This report represents a seminal consensus from faculty, researchers, students, and representatives from professional societies. Together with pedagogy experts, these stakeholders articulated a vision for how undergraduate biology education must transform to meet the needs of the 21st century (McLaughlin and Metz). This includes a list of competencies that students must acquire in order to become biologically literate and practice science. Notably, two of the six core competencies include: "the ability to communicate and collaborate with other disciplines," and "the ability to understand relationships between science and society," underscoring the importance of science communication training as a critical component of undergraduate education.

Despite these recommendations, few undergraduate courses address science communication. While college courses on rhetoric and technical communication are plentiful, they are most often found in English or Communication departments and have not become standard components of scientific training. These "turf wars" between disciplines over certain competencies are doing a profound disservice to students, pulling in the opposite direction of where education needs to be headed, towards scientific literacy forged by interdisciplinary cooperation. As a result, students entering the scientific workforce will be unprepared to communicate effectively with broad audiences and may not have an opportunity to pursue such training at further points in their careers.

Course Context: The ASBMB's Art of Science Communication

To address the lack of oral science communication training geared towards non-expert audiences, the American Society for Biochemistry and Molecular Biology (ASBMB) Science Outreach and Communication Committee developed an online course entitled "The Art of Science Communication" (ASC) (Greer et al.). The ASC course was designed to provide scientists with the fundamental skills required to effectively communicate their research and scientific interests to non-expert audiences. The goal of the course is to increase learners' confidence and competence in science communication. The course is open to self-identified, "scientists and STEM professionals." There are no prerequisites and individuals of all career and educational stages may participate. While the course is hosted by the ASBMB, participants need not be society members.

The ASC curriculum was originally described by Greer and colleagues (Greer et al.). Briefly, the online course spans seven weeks, in which learners are assigned to small weekly group sessions, held online via a web conferencing platform, and moderated by experienced science communicators (Figure 1). The general format is the flipped classroom model: Learners access the pre-recorded, professionally produced lectures, homework assignments, and supplementary content on an online Moodle platform hosted by the ASBMB asynchronously, then utilize the synchronous virtual group meetings for discussion of the course content and assignments.

Figure 1: Timeline of the ASBMB Art of Science Communication Course. Adapted from Greer et al., 2018.

To start, learners receive detailed instructions on the format and expectations of the course, which include the production of a five-minute long pre-recorded oral presentation about their own research or a topic of their choice, *tailored to a non-expert audience*. The video recordings serve as a basis on which to apply concepts and ideas that are introduced throughout the course (Figure 1). The following weeks address major themes in oral science communication including framing, the use of analogies and metaphors, accessible language, and storytelling techniques. Each theme is evaluated within the context of the learners' pre-course presentation, which makes it immediately relevant to the students.

The course culminates with learners preparing and delivering a five-minute post-course video presentation of their topic, incorporating course concepts and group-feedback. These presentations are generally much improved and demonstrate the learners' newly acquired communication skills. Likewise, learners are more cognizant of their intended audience(s) and have tailored their post-course video accordingly.

Developing and hosting an online course through a scientific society offers considerable benefits. The course exists independent of an academic institution and remains open and accessible to all who are interested in participating, regardless of location, affiliation, or career stage. Unlike the traditional MOOCs, the course benefits from weekly interaction with expert mentors, skilled in science communication, and with members of the discussion group. This allows for feedback and discussion in real time and has proven very beneficial to the participants. From 2015 – 2022, there have been 35 sessions of the course, interacting with a cumulative participation of 905 learners, employing 110 trained mentors, and achieving an average course completion rate of 74%. Most participants hail from the biological or life sciences, with graduate students being the most common type of learner.

Transitioning to Blended Learning

Early in ASC course development, it became clear that academic institutions could utilize the course within their scientific training programs by offering a blended version. The online content would be fused with in-person discussion groups and integrated into existing courses at academic institutions. Offering the course in both blended and online-only formats further extends the accessibility of science communication training.

Since the onset of the COVID-19 pandemic, the teaching world has undergone a rapid revolution. Educators are no longer engaged in a theoretical discussion on the merits of online and/or blended learning. Rather, we addressed an immediate need for adopting existing curricula to what was rapidly becoming the most prominent mode of teaching. To this end the ASC provides an innovative and integrative approach to blend online science communication training with existing biomedical curricula.

While there is no single accepted definition for blended learning, here we evoke this definition: blended learning courses (1) thoughtfully integrate different instructional methods such as lecture, discussion group, self-paced activity; and (2) contain both face-to-face and computer-mediated portions (Alammary et al.). The accepted understanding of what qualifies as blended learning is variable, and different practices have been studied for their effectiveness. In general, meta-analyses indicate that blended learning may be more effective than either online learning or face-to-face instruction since it takes advantage of some of the best aspects of both synchronous and asynchronous activities: synchronous learning offers spontaneity and the opportunity for a participant to feel "in sync" with a community of learners, while asynchronous activities allow for flexibility (Means et al., "Effectiveness"). When designing blended versions of the ASC course, we adopted some of these best practices such as focusing on synchronous activities within a small community of learners and utilizing asynchronous time for delivery of didactic content. We designed educational interventions that would be useful to students, given resource constraints of both the instructors and students.

Approaches to blended learning can be categorized as "medium-impact," in that activities are integrated into an existing face-to-face course. The activities described in this blended ASC course aim to meet the goals of creating specific materials (a 5-minute presentation), active learning (continually improving the presentation by applying newly acquired knowledge and skills), community building (each student's work is critiqued by each member of the class in a thoughtful and respectful manner), and participant reflection (by continually re-examining their work as the course progresses). By (1) recording an initial presentation on a scientific topic, (2) participating in interactive science communication training where they evaluate outside materials, (3) receiving feedback on their own scaffolded attempts at science communication, and (4) recording a revised final presentation, students build their own understanding of a scientific topic and learn to avoid using jargon in their explanations. By completing the communication exercises, conducting peer-to-peer feedback, and building off of their initial presentation, students also participate in metacognition by engaging in reflection and recognizing the conceptual change in their communication.

Here we describe a case study in which the online ASC course is blended within an existing classroom setting at the undergraduate level. We describe the development and evolution of the blended course and its impact on participants. Throughout this collaborative project we learned that the online ASC course lends itself to many different iterations, and hope that this example will inspire the science teaching community to adopt some of these concepts and techniques into their own classrooms or programs.

Case Study: Integrating the ASC into an Undergraduate Biology Course

Developed by Melissa Rowland-Goldsmith, Schmid College of Science and Technology at Chapman University

Course Context

The ASC course was integrated into an upper division undergraduate "Biology of Cancer" course at Chapman University. The class is offered to junior and senior biochemistry and biology majors and covers the fundamentals of cancer biology. Specifically, this course focuses on the biological mechanisms of cancer formation and progression. It is an interactive course where students read primary literature and deliver presentations to the class. Since most students plan for careers in biomedicine, the skill of communicating complex scientific topics to non-expert audiences is an indispensable necessity. Here, I describe the development of the blended ASC, Biology of Cancer course from 2018–2020 and its impact on students.

Course Structure

Prior to the first class, students completed homework that provided a framework for the importance of learning science communication skills. This included watching the Ken Burns PBS miniseries "Cancer: Emperor Of all Maladies;" reading Rebecca Skloot's book, "The Immortal Life of Henrietta Lacks;" and reading Anna Leahy's book, "Tumor."

During the first few weeks, students were required to read three journal articles co-authored by a physician-scientist who specializes in pancreatic cancer. Each student selected an article and a key figure that would serve as their research topic for the ASC section of the course and recorded a 5-minute pre-course presentation, explaining their literature-based research topic. Next, students met with the physician-scientist who co-authored the papers. They explained the methods and results of each paper and emphasized concepts of accessible and effective communication in relation to their career. After this meeting, students participated in the ASC portion of the course and developed strategies to present their selected figure to a non-expert audience. Upon completion of the course, each student generated an improved version of their presentations and delivered them to a non-expert audience consisting of a panel of pancreatic cancer survivors and caregivers.

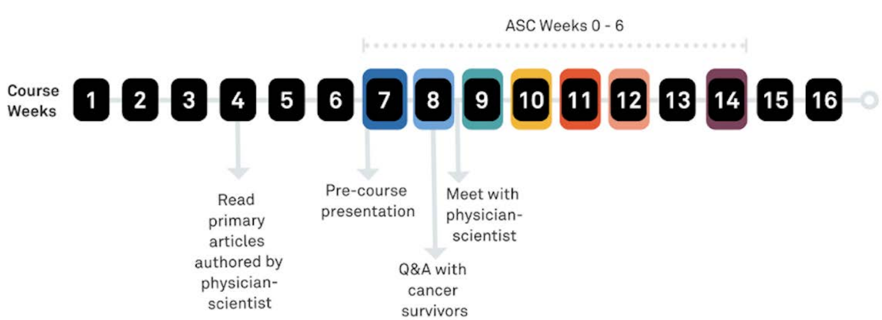

Figure 2: Timeline of Iteration 1 - ASC Course Blended in the Biology of Cancer Course

Year One. In year one, the course included seven in-person, one-hour sessions that took place outside of the scheduled cancer biology course. Students were required to read three articles (Ankeny et al., 2016, Girgis et al., 2011, Elliott et al., 2017) co-authored by Dr. Mark Girgis, a physician-scientist at the University of California, Los Angeles. Students chose a figure from one of the articles as their focus for the ASC course. The articles were relevant to the content they were studying in the cancer biology course. The students met with Dr. Girgis after week two of the ASC course (Figure 2). Students were required to watch the online lectures, complete homework assignments, and review the additional materials offered by the online ASC course platform. During the in-person class sessions, students discussed highlights from the online course content, mirroring the small group sessions of the online version of the course. Significant time was dedicated each week to discussion and interpretation of the homework assignments. These discussions were extremely useful when students started to work on their final presentations. First, students shared their proposed presentation title and discussed ways to remove jargon and/or make it creative and enticing. In addition, students discussed their "mission statement" and "leveling the playing field" statements and received individualized feedback. Since students were required to read all of the articles associated with the presentation topics, they felt comfortable giving constructive feedback to their peers. The collaborative nature of this course also helped students learn from one another in order to modify their presentation content accordingly.

Each student met with me privately prior to the final presentation to discuss additional ways to make the presentation understandable and interesting to a non-expert audience. Students were not allowed to use slides during their presentations but were encouraged to use visual aids to explain their topic. During these consultations, several students developed creative demonstrations. One student used a Velcro shoe to illustrate a device called the NanoVelcro Chip which captures circulating tumor cells from a blood sample. During their presentation, the student showed the Velcro portion of a strap on a shoe, and stated it was similar to the NanoVelcro chip. He demonstrated that Velcro only binds to specific material on the other half of the strap and does not bind to any other part of the shoe, establishing an analogy as to how the NanoVelcro chip only binds to circulating tumor cells and not to other kinds of cells in the body. These types of analogies are encouraged by the ASC course and this specific example demonstrates how everyday objects can be used to distill complex biological topics.

Year Two. Year two built on the experiences acquired during year one. I invited three former students who took the initial course to serve as co-instructors for year two. This follows the instructor recruitment model from the online ASC course, where outstanding learners are invited to become future instructors. Each co-instructor was assigned a cohort of three students. Once again, students read articles co-authored by Dr. Girgis as described above and met with him in week two of the course. In year two, all ASC instruction took place via Zoom. Importantly, this was prior to the Covid-19 pandemic, and Zoom was chosen because it allowed more flexibility with students' schedules. Students reported that the small cohorts provided them with individual attention from their co-instructor, that they encouraged participation and were convenient to attend. As former students, the co-instructors also provided key insights and agreed that the small cohorts allowed for more personalized feedback during class. Lastly, in year two, the ASC-related material was delivered in five meetings instead of seven: the content from weeks three and four was merged (see Figure 2), and the pre-course orientation was eliminated.

Year Three. As a result of the Covid-19 pandemic, the Fall 2020 iteration of this course was taught fully online to 18 students. Five ASC co-instructors were selected from the year two class section. Just like in year two, each co-instructor taught the course to groups of three-to-four students via Zoom. For this iteration, I created groups within the online course learning management system of the college. Each group had their own home page where they could post discussions, collaborate, and establish additional student-led meetings. The students read a total of four scientific articles co-authored by Dr. Girgis and Dr. Murray Korc from the University of California, Irvine (Girgis et al.; Gore et al.; Stuparu et al.). Including another co=author during year three allowed the students to have more choices about which paper and figure to select as their research focus for the ASC course. As in years one and two, I worked with each student at the end of the course to refine their final presentation. The final presentations were delivered via Zoom and attended by cancer survivors or caregivers. Other than these changes, year three followed the general organization and timetable of year two.

Final Presentations

All three years of the blended ASC-Biology of Cancer course provided students with an opportunity to practice their science communication skills with non-experts. To humanize an otherwise molecular biology-focused course, I invited pancreatic cancer survivors and caregivers to share their experiences with the class and asked them to help grade the students' final presentations. Each year, reviewers graded presentations using a rubric that was adapted from the 2018 ASC Instructor Manual. For each question, the reviewers provided a numerical score and written feedback. At the end of the semester, each student received approximately ten evaluations from both their instructors as well as the non-expert stakeholders. Students indicated that they would make changes based on this feedback to deliver better presentations in the future. At the end of the course, all participants received a certificate of completion from the ASBMB. We believe that this blended course leads to a substantial improvement in student presentations and promotes science communication with non-experts.

Discussion

While the broadscale adoption of science communication training at the undergraduate level has remained minimal, the ASC course serves a useful resource for students and faculty, and if adopted, can benefit their respective departments and academic institutions. The ASC course can be seamlessly integrated into a variety of classroom settings or workshop formats and provides professional development opportunities to its students.

Reflections from Blended Course Students

A mixed-methods survey of ASC alumni found that their participation increased their comfort in communicating science with non-expert audiences (ASBMB Science Outreach and Communication Committee, *in preparation*). As one student from Chapman University (ASC) notes:

> After taking the course, I have felt more confident in my ability to properly explain scientific topics to all crowds and types of people with varying backgrounds. I feel like I can apply the knowledge I learned to other public events.

While another Chapman University student (ASC) highlights their newfound awareness of the intersectionality of science and society:

> Through the course, I realized how important science is for people in general. Science is not for scientists; it is for all people, no matter what their background is. What is the point of doing science if the people you are performing the studies for don't understand why or how it [is] important to them.

In addition, the majority of surveyed ASC alumni from blended courses indicated that their participation in the course helped them achieve some type of personal (96%, n=26) or professional (85%, n=23) goal. Another Chapman University student (ASC) shared their personal goal of communicating science with their non-expert family members:

> While I am a first-generation college student, and the rest of my family does not come from a science background at all. My personal goal was to be able to better explain my research to my family, and this course definitely taught me useful skills that help me do so every day.

Other students' professional goals focused on employment or the development of long-term skills. A student from Chapman University (ASC) shares:

> I got my dream job doing research that combines bench work and community engagement based on my experiences in the course.

Taken together, these reflections highlight the impact of the blended ASC course on students' professional development.

Pedagogical Strategies to Engage Students

We posit that key aspects of the blended ASC course contribute to positive student outcomes via several pedagogical approaches. With regards to many aspects, the experience undergraduate students had with the blended ASC course reflects the professional development initiatives developed for STEM graduate students and postdoctoral scholars (see Hokanson et al.). Members of the Center for the Integration of Research, Teaching and Learning Network designed and implemented several online synchronous professional development workshops which integrated active learning, participant reflection, skill development, and commitments to follow-up actions. For example, the workshops focused on helping participants to create specific materials that pertained to career development. Workshop participants indicated that they chose to participate "because they wished to take ownership of their own professional development and career trajectory," and "completing a tangible assignment and building a sense of community through structured time for reflection were the principle elements of our ICE [inform-create-evaluate] workshop design that they valued" (Hokanson et al.). The CIRLT workshop participants highlighted that they particularly valued time for reflection, echoing what was reported as the practice with the strongest evidence for learning effectiveness in blended learning (Means et al., "Evaluation"). This same meta-analysis also reports on a body of preliminary evidence that supports the hypothesis that conditions in which learners have control of their learning (via active learning experiences) produce larger learning gains than do instructor-directed conditions (such as expository learning experiences) (Means et al., "Evaluation"). We used some of these strategies in achieving successes in our blended ASC course: students had the opportunity to take ownership of their learning by choosing their scientific topics and developing a tangible product (e.g., a five-minute presentation).

We argue that our results support those of others who have applied a social constructivist theory of learning to the online environment, according to which human development is socially situated and knowledge is constructed through social interaction with others (Huang). The facilitated, small group learning communities that are intrinsic to the structure of the ACS course are critical for fostering the students' motivation. Similarly, other research suggests that student interaction with an instructor affects MOOC learner retention, a format that has elements in common with our online course (Hone and El Said). In the online ACS course, personalized mid-week reminders, or "nudges," and individual feedback from an experienced instructor deliver the positive reinforcement to sustain motivation to engage in the asynchronous content, knowing that once a week, they'll encounter a synchronous social learning environment with peers who expect their engagement (Manturuk). Students' self-directed learning is empowered through the weekly assignments and final presentation, learning tasks that others describe as supporting constructivist collaboration in both physical and virtual learning spaces (Sze-yeng and Hussain).

Suggestions for ASC Integration

Potential blended course instructors should spend several months preparing to teach this course due to the logistics involved with its execution. Faculty members are required to take the online ASC course three to six months in advance of the blended course. In addition, instructors must work with their departments to ensure a funding model is available for the course, as the ASBMB charges a small fee per student taking the course.

Sharing expectations and coordinating the timing of the blended ASC course is critical and includes several key points. The course description should highlight the ASC component and indicate that five to seven additional sessions will be held outside of the traditional class hours. This can be reiterated by the instructor prior to the start of classes, so that students who do not wish to participate in this component can enroll in a different course. These expectations should be reiterated in the syllabus and describe what portions of the ASC course are graded. For example, the final presentation in the ASC-Biology of Cancer course was worth 15% of the overall grade.

Another difficult task is finding appropriate time within the semester to integrate the ASC course content. Students need to have enough foundational knowledge in the scientific content area in order to develop their presentation. While instructors can let students choose their own scientific presentation topics, we suggest using primary research articles that align with the course topic and learning objectives. To create added value, the faculty member can arrange to have the co-author(s) of each assigned paper meet with the class. This meeting should take place early within the ASC course so that the students have the remaining time to work on their final presentation.

It is also useful to recruit outstanding former students to serve as co-instructors. By doing so, the class can be divided into smaller learning environments. Though they may not get paid for this role, they gain teaching experience which can be leveraged for professional development purposes. Lastly, if possible, the instructor should invite a panel of non-experts to grade each presentation. These suggestions help create a blended course which is differentiated from the online version and provides numerous aspects to humanize science by working with their peers, meeting the scientists who author publications, and communicating with non-experts impacted by science. Together, these emphasize the important relationship between science communication and society.

Conclusion

The blended ASC course exemplifies the statement that, "It takes a village to educate our students." The robust partnership between the ASBMB and the academic institutions which have blended the ASC course into their existing curricula has led to a bespoke method of teaching science communication to undergraduate students. Faculty teaching other discipline-based science courses can use this model to successfully blend ASC into their curriculum. There are several key logistical considerations that faculty should be aware of which require coordination and planning between the ASBMB and the partnering institution. As blended and virtual learning becomes more commonplace, following the COVID-19 pandemic, this strategy to promote science communication training may appeal to a broader number of stakeholders within the STEM education ecosystem.

Science communication is no longer considered a soft skill, but rather a linchpin of the scientific enterprise, connecting science and society. The development and dissemination of effective science communication training is of critical importance and must rapidly evolve to meet learners and educators needs in a technology-driven environment. As more academic institutions seek to formalize science communication as a key component within their curricula to meet the recommendations set forth by the scientific community, the ASC course, and its blended iteratives, provide one example of how to successfully scale and sustain science communication training.

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