ECO 101

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Animating the Primary Literature for Students and Other Curious People

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Abstract

The increasing availability of digital technology in biology classrooms has facilitated an on-going transition from traditional lectures to the use of multimedia tools such as videos and interactive software. While most existing educational multimedia focus on illustrating textbook concepts, few address the process of science by linking those concepts with the researchers and their studies as reported and received in the primary literature. With the support of a 2015 ESA Centennial grant, we teamed up with students and university-affiliated artists to create four original animated videos of classic ecology papers of the last century. The videos were showcased at the 2015 Centennial Meeting Sunday Plenary and continue to be available for free viewing and sharing at http://ecomotionstudios.com/. Since their debut, the videos have received over 8000 views, have been employed as educational tools in undergraduate classrooms, and have been promoted as outreach tools by science media outlets including on the homepage for the journal, The American Naturalist. Here, we argue that the potential for artistry, narrative structure, and connection to the research process make animation an invaluable and underutilized medium for sharing primary literature with students and public audiences. We envision the future of ecology as one where decreasing video production costs and the opportunities for interdisciplinary collaboration available at universities lead to increased production of visual media to supplement education and broadly communicate primary ecological research.

Introduction

Animated videos can be an entertaining and informative introduction for students and the general public to ecological thinking, allowing these audiences to explore the many facets of ecology and the people who study it without the barrier of reading the primary literature. In addition, the production of animated videos brings together artists and scientists for interdisciplinary collaborations that can help the producers hone their abilities to translate scientific understanding into publicly accessible knowledge as they endeavor to craft the most communicable narrative. We used the occasion of ESA's Centennial celebration as an opportunity to bring together artists and scientists to capture some of the past century's landmark achievements in ecological research in a medium that could act as an invitation to students and the public to discover what ecology is all about.

ESA's Centennial celebration centered on celebrating the past and looking forward to the future. Our ecological past is full of excellent papers documenting brilliant breakthroughs and innovative thinking, yet students entering the field each year are less likely to be familiar with the "classics" as they are met with an ever-expanding back-catalog of literature. Foundational works such as Huffaker's (1958) predator–prey cycle experiments with oranges and Simberloff and Wilson's (1969) island biogeography investigations are at risk of losing readership among the next generation of ecologists. In *Foundations of Ecology*, Real and Brown (1991) connect readers with fundamental ecological literature, along with commentary and insight. However, the book does not shorten the papers nor make them more easily accessible for students; it merely compiles them into a single edition (Real and Brown 1991). While this text is an essential resource for scientists already interested in the classics, it can be challenging for beginning students of ecology to get excited about and absorbed in the most important messages contained within these articles.

Our goal for the Centennial was to showcase some of the field's "big ideas" in a brief, engaging format. Thus, as a gateway to the stories, studies, characters, and concepts of the classic primary literature, we created short animated videos of several papers selected by Real and Brown (1991). Each video was 2–4 minutes long and showcased the key findings of the selected paper with custom artwork and an original soundtrack. Through this medium, students daunted by or unaware of the classics can still benefit from a narrative, scientifically sound introduction to the key innovations of past researchers.

Our animated videos were unique in that their focus was on translating primary literature into a broadly and easily communicable format, as opposed to focusing purely on concepts or terms. Highlighting studies from the primary literature may be particularly important in order to maintain awareness of classical papers in ecology in light of the multitude of contemporary ecological publications competing for the limited attention of researchers and students. For educational purposes, the emphasis on primary research also serves as an important connection not only to biological content, but to the process of science as an exciting human endeavor.

Here, we explore the current state of animated videos in science education, describe the nuts and bolts of our video production process, and present some opportunities for integration of animations into academic research and outreach. We conclude with a discussion on the role of multimedia in translating primary literature in the future.

Part I: The current state of animations in science education

Animated videos are used widely in biological sciences education. Cellular and molecular biology educators frequently employ animation to explain difficult concepts or microscopic-scale processes. In medicine, "patient education" animations (e.g., nucleusanimationlibrary.com) are very common, illustrating a range of subjects and procedures. Most textbook publishers offer a limited array of digital resources to complement the physical text, which may include interactive virtual labs and short, animated concept videos (e.g., McGraw Hill's *Biology*, highered.mheducation.com) or chapter summaries with static diagrams (e.g., Sinauer's *Ecology*, sinauer.com). Additionally, a cottage industry of education and entertainment organizations such as Howard Hughes Medical Institute (biointeractive.org), Simbio.com, and PhD Comics (phdcomics.com) produce or support the production of animated videos for the life sciences. There are also a handful of individuals that create works independently and make them available through personal websites or video sharing repositories such as Molecularmovies.org or Bio-alive.com. However, the animated videos currently produced for life sciences education generally focus on animating basic concepts rather than studies from the primary literature, many lack artistic depth or engaging narrative structure, and most are not freely available. Additionally, the few videos that specifically address ecological topics are overwhelmingly focused on conservation issues rather than basic science. In this landscape, videos such as ours fill a unique gap.

Alongside these professionally made videos, the ranks of scientist-filmmakers are growing. Annual events such as the Evolution Society Film Festival (evolutionfilmfestival.org) and Beneath the Waves Festival (beneaththewaves.org), hosted by the Benthic Ecological Meeting Society, receive many submissions from scientists who are making their own outreach media. The success of these programs demonstrates the capacity for creative and effective communication that already exists in the field. While our focus has been explicitly on creating teaching tools based on the primary literature, our process can be adapted to produce all kinds of resources.

Part II: Producing the animations

The nuts and bolts

The principles guiding the production of our videos were simple: be accurate, be informative, and be entertaining. In order to be useful, any educational supplement must concentrate and communicate information more effectively than the time it takes to explain the same concepts verbally. Combining information with animation and sound has a long track record of enhancing attention and retention (e.g., Hegarty and Just 1993, Mayer 2001), but it is a delicate task to simplify primary literature into catchy sound bytes without sacrificing essential nuiance.

The process of making a video began with the selection of papers by a team of biology doctoral students. Within the canon of classic ecology papers, we looked for those with broad appeal that would be visually compelling to present. We then carefully read the papers, supplementary information (including background on each paper's authors), and commentaries on their influence and used these details to write scripts aimed at both explaining the scientific content of the papers and introducing viewers to the researchers involved. The scripts and summaries compiled during this initial phase were used in meetings with the artists to inspire a cohesive look and feel for the visuals and the accompanying soundscape.

Through a collaborative and iterative process, we developed a creative vision for each animation, which was then borne out by the lead artists, their collaborators, and the biology students.

Each of our four videos was created according to a slightly different process in order to accommodate each animator's individual style. In general, the process began with matching visual action to the scripted scientific material by drawing out a storyboard. Voice actors recorded the narration, which animators used to gauge the timing of each scene. In some cases, several artists were involved to paint backgrounds and prepare fine line work and color based on the principal animators' hand-drawn, frame-by-frame animations. For other videos, all of the visual art was completed by a single artist. As the artwork and story took shape, musicians developed a score to reflect the aesthetic of each video. Finally, each video's director stitched all of the elements together into a final product.

All of the visual art and audio were produced with personally owned, relatively low cost equipment. At each step, the unique training and perspectives of the artists and the scientists helped us keep the balance between artistry and content, conceptual clarity and scientific accuracy, entertainment value, and educational value. By capitalizing on the diverse skill sets available on a university campus, we were able to conceive of, produce, market, and distribute a useful set of teaching tools with minimal resources while maintaining total control of the quality and content of the final product.

The cost and feasibility

One problem hindering the production of animation for ecological research is the associated cost. Commercially outsourcing animated videos costs between $1000–$3400 for every minute of animation, which often does not include a soundtrack. The lower end of this range generally results in simple animations with low action (i.e., camera movements around a still image rather than animated subjects) while the upper bound results in detailed, colorful and fluid animations with a much greater dynamism. By tapping into the resources available at a university, namely the time and enthusiasm of science and art students, we were able to reduce the cost of our four animations to fit the $2500 grant we received and produce a total of 14 minutes work similar in quality to the highest price tier of commercially produced animations. In order to pay our now-graduated artists fair compensation for their work on future projects, however, we estimate that similar projects would cost about $1700 per minute of animation. Given the long potential shelf life of animations, especially those created based on well-vetted and often-cited papers, we think that this level of upfront cost is a reasonable investment to achieve the goals of greater student and public engagement with the primary ecological literature. But in addition, our positive experience recruiting student volunteers and working with art department faculty suggests that projects like ours could be designed to minimize costs while still being rewarding for all involved.

Part III: Animation reception

Since the inaugural debut of our four animated videos at the ESA Centennial and online via our website and YouTube channel six months ago, they have received over 8000 views. The highest viewed animated video was "Life of Every Color and Kind" based on Paine (1966) with 2437 views, followed by "The World is Green" based on Hairston et al. (1960) with 2298 views. The "Mangrove Melody" animated video based on Simberloff and Wilson (1969) and "Huffaker's Balancing Act" based on Huffaker (1958) were viewed 2277 and 1018 times, respectively.

Qualitative feedback from ESA attendees was positive overall. Members of ESA's Committee on Diversity and Education anticipated a strong potential of these animated videos to popularize classic papers and serve as educational tools in general. Many faculty members expressed interest in supplementing their courses with our animated videos and several already have. Additionally, feedback from students was very positive both in general and in the classroom setting. Finally, we have received several requests from ecologists looking to animate research from their labs, as well as one request to animate a citizen science project to help introduce participants to the natural history of the system, project goals, and general research protocol.

A quantitative evaluation of the effect of educational animations is very difficult and simple questions as to their efficacy are rarely answered with confidence (Goldman 2008), if at all. This is largely due to the complexity of animated videos and their ability to stimulate different senses simultaneously. In addition, consciously and subconsciously introduced cultural references can make their effectiveness context-dependent. Consequently, our ability to evaluate the success of these videos is limited at this time to qualitative descriptions of their reception within the ecological community.

Part IV: Integrating animation in academia

General public awareness of ecological theories and concepts

Scientists often struggle to propose and fulfill broader impacts as required by all National Science Foundation (NSF) grants (National Science Board 2011). The NSF's "Broader Impacts" merit criterion calls for broad and impactful initiatives to complement the proposed research. Educational animations based on real research provide an opportunity to share a glimpse of the research process with public audiences. Animated videos can be broadly disseminated through social media and other websites where information sharing in video format is growing rapidly (e.g., Cheng et al. 2008, Smith 2009). We realize that animation alone may not satisfy the "Broader Impacts" criterion (particularly due to the difficulty associated with evaluating their effectiveness (Goldman 2008)); however, animations could complement local-scale "Broader Impacts" measures by addressing audiences on a larger (even global) scale. Additionally, existing outreach could be paired with short animations as an educational component with wide appeal. For example, citizen science projects and public seminars could incorporate animations to provide the target audience with a project overview and visual learning of important concepts, respectively.

Ecology education

Short science videos could have an immense impact in the realm of high school and undergraduate ecology education. Many young learners prefer visual learning (e.g., Benedict and Pence 2012, Reilly 2012), which animations provide. The enhanced stimuli of videos and their associated soundtracks have a tendency to capture students' attention and would likely work well as a supplement to lectures or reading assignments. Furthermore, videos based on primary scientific literature keep the research process front and center in the minds of students, including the people, experiments, organisms, and real-world problems that characterize scientific inquiry. A strong artistic style and narrative structure can additionally provide context to complicated ecological material, making it more memorable.

Communication between scientists

Research articles will always be the central means of communication within the scientific community. However, videos can take advantage of stimuli simply unavailable in written communication (e.g., sound, motion) and allow one to pack more information into a shorter amount of time. In addition, some concepts are very difficult to illustrate verbally or in a static visual form (e.g., a diagram or PowerPoint slide). For example, terraces in phylogenetic tree space (Sanderson et al. 2011) and the storage effect (Chesson and Warner 1981) are concepts that many scientists and graduate students struggle to understand fully. Animation could help broaden understanding of these and other complex theories by providing new, particularly visual, perspectives.

By incorporating visual and auditory learning, narrative structure, and an appealing artistic aesthetic, animated videos have the potential to complement the use of written and verbal communication, leading to more effective science education and public outreach. Animations certainly do not act as replacements for outreach, live instruction, or research articles. However, well-designed videos can supplement these efforts to share ideas and demonstrate the usefulness of important papers, perhaps inspiring others to read them firsthand. In the future, as video production costs continue to decrease, it may become feasible for any scientist to produce their own videos to accompany their papers. In the meantime, animating the classics should be a priority.

Students and faculty as active participants in the development of animations

The production of animations themselves need not be limited to a small group. As technology continues to advance, the cost and difficulty of producing animated videos will likewise decrease. The videos we created for the ESA Centennial were a highly collaborative effort between students of ecology and art, as well as faculty members. In total, six biology graduate students, six art undergraduates, two recently graduated art majors, and two biology faculty were involved in activities ranging from storyboarding to video direction to voice work.

Being an active, hands-on participant in the animation process can be greatly beneficial for researchers. Translating research into a new medium requires a thorough grasp of a study's scientific content and historical context, while collaboration with a group of artists offers new perspectives on familiar (and often complicated) material and provides opportunities to jointly craft a narrative, monitor scientific accuracy, and give feedback on stylistic interpretation. There is also tremendous creative value in getting to know animation as a means of communication and expression. Just as written, oral, and visual presentations involve communicative trade-offs, animation has unique strengths and limitations that pose a creative challenge for those involved.

In the future we hope that others initiate collaborations similar to ours between art and science departments at many universities. We see this as a ripe opportunity for students of both disciplines to hone their respective skills while also broadening their horizons by learning about subjects with which they might never otherwise engage.

Conclusions

Animated videos serve as vessels for communication that appeal to both the auditory and visual senses and have the potential for great artistry and entertainment. We suggest that ecologists can take

advantage of animation as a powerful tool to supplement outreach and education. In particular, one underrepresented application is the animation of the primary literature. In this paper we have focused on the animation of the classic primary literature, in an effort to link ecological concepts with the stories of the scientists who discovered and explored them. We see this as ripe opportunity to supplement existing efforts to promote classical papers in ecology, such as Real and Brown's *Foundations of Ecology* book (1991), so that the important messages of these writings are not lost amidst an ever-growing "foundational" base that confronts current students.

We acknowledge the difficulty often associated with evaluating the efficacy of animations on learning (Goldman 2008) and for this reason do not suggest that animations can ever serve as a "magic bullet" solution for science education. Nevertheless, animations are yet another tool from the ever-expanding tool box of science educators and should be employed in conjunction with other established teaching methods. Ultimately, by providing learners with multiple ways to perceive similar information, we provide them with the best chance of retaining the material and learning from it.

Finally, as production costs continue to decrease and video production tools are democratized, we anticipate further opportunities to animate important papers in the more recent and even current literature as a means of broadening their impact and increasing public exposure to ecological research. The university setting in particular provides a breadth of talent and resources that make interdisciplinary collaborations more feasible and cost-effective. By capitalizing on this unique set of resources, we as researchers can more fully use the medium of animation to illustrate and effectively communicate difficult and socially relevant concepts to students, colleagues, and lay audiences alike.

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