ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #36529

On the Use of Video in Support of a Maritime Robotics STEM Outreach Program

Dr. Leigh S McCue, George Mason University

Leigh McCue is an Associate Professor and Chair of George Mason University's Department of Mechanical Engineering.

Stacey Rathbun, George Mason University Television

Stacey is a Senior Producer/Director at George Mason University Television.

Dr. Ali Khalid Raz, George Mason University

Dr. Ali Raz is an Assistant Professor at George Mason University Systems Engineering and Operations Research department and an Assistant Director of Intelligent Systems and Integration at the C4I and Cyber Center. Dr. Raz research and teaching interests are in understanding collaborative autonomy and developing systems engineering methodologies for integrating autonomous systems. Raz's research brings a Systems Engineering perspective, particularly inspired by complex adaptive systems, to information fusion and artificial intelligence/machine learning technologies that form the foundations of collaborative and integrated autonomous systems. Prior to joining Mason, he was a Visiting Assistant Professor at Purdue University School of Aeronautics and Astronautics where he taught courses in aerospace systems design and led research projects for introducing machine learning techniques in high-speed aerospace systems. He holds a temporary faculty appointment with the U.S. Navy Naval Surface Warfare Center at Crane, Indiana and has worked with Naval Postgraduate School, John Hopkins University Applied Physics Laboratory (JHU-APL), the United States Missile Defense Agency, and Honeywell Aerospace. He holds a BSc. and MSc. in Electrical Engineering from Iowa State University, and a Ph.D. in Aeronautics and Astronautics from Purdue University. He is a co-chair of International Council of Systems Engineering (INCOSE) Complex Systems Working Group and a Certified Systems Engineering Professional (CSEP). He is also a senior member of the American Institute for Aeronautics and Astronautics (AIAA) and Institute of Electrical and Electronics Engineers (IEEE).

Dr. Daigo Shishika, Department of Mechanical Engineering, George Mason University

Daigo Shishika is an assistant professor in the Department of Mechanical Engineering. He obtained his bachelor's degree from the University of Tokyo, Japan, and his master's and PhD from the University of Maryland, College Park, all in Aerospace Engineering. Before joining George Mason University, Shishika was a postdoctoral researcher in the GRASP Laboratory at the University of Pennsylvania. His research interest is in the general area of autonomy, dynamics and controls, and robotics. More specifically, his past work has focused on multi-agent systems including animal groups and swarms of autonomous vehicles. He is currently studying how to cooperatively control large teams of robots in various adversarial environments.

Cynthia Smith PhD, George Mason University

Associate Professor - Environmental Science and Policy; K12 Education Director, Potomac Environmental Research and Education Center

Erin Hagarty, George Mason University
Richard Wood, George Mason University

General Manager/Executive Producer, George Mason University

Prof. Cameron Nowzari, George Mason University

Dr. Nowzari's research interests are in the broad area of dynamics, controls, and robotics. More specifically, he is interested in the analysis and control of complex distributed and/or networked systems and spreading processes. A large motivation for the specific problems include minimizing energy or wireless communication, efficient computation of control strategies or decisions, and the use of sparse sensing and/or control. His work has applications in a wide number of areas including mobile sensors, autonomous robots, allocation of resources, public health and epidemiology, network protection, and marketing campaigns.

Mr. James Yang, George Mason University

PhD Student at George Mason University, Electrical Engineering

Erin Williams, George Mason University

On the Use of Video in Support of a Maritime Robotics STEM Outreach Program

Leigh McCue, Stacey Rathbun, Ali Raz, Daigo Shishika, Cynthia Smith, Adrian Hagarty, Richard Wood, Erin Williams, Cameron Nowzari, James Yang
George Mason University

Abstract

This paper describes the development of educational videos designed to supplement a kit-based hands-on STEM program that uses lighter than air vehicles to introduce 9th-12th grade aged learners to biologically inspired maritime robotics. Under an ONR-supported effort described in[1], the research team utilized biological inspiration to develop an engaging robotics kit with three hull shapes (a notional tuna, ray, and jellyfish) and two propulsion mechanisms (propellers and flapping). A standards aligned curriculum was developed in parallel to teach learners about structural mechanics, fluid dynamics, biologically-inspired propulsion, system design, and swarming. To increase engagement with the text-based and hands-on content, a series of videos were produced in partnership with Mason's professional video studio, GMU-TV. This paper describes the iterative scripting process involving researchers and video production professionals, the recording sessions, postproduction work, and video launch.

Keywords

Biologically-inspired robotics, STEM, outreach, video

Overview

To support the developed curriculum, videos were professionally produced by GMU-TV. This partnership leverages the engineering and scientific expertise of the research team, professional production skills and equipment of GMU-TV, and on-air talent of student researchers to explain the content in a manner that is compelling for high school aged learners.

The videos were intended to supplement written curricular content related to structural engineering, aero/hydrodynamics, systems engineering, swarm dynamics, biologically inspired propulsion, and to support construction of the actual BLIMPs. At the time of this writing, eight of ten planned videos are completed, and are freely available via Vimeo, YouTube, and the program website. The content, with links, are summarized in Table 1. Additionally, two more videos are pending. One video demonstrating aerodynamic concepts using kites is completed though not yet reviewed for public release, and the final video supports the biologically inspired propulsion lessons, which is in the final stages of production. With the exception of the complete build video, which necessitates longer-form content, videos were intentionally designed to deliver specific, targeted information in a short format which can either stand-alone, or be woven into written curricular content. Target video lengths are in line with studies by TechSmith[2] which finds an optimal video length to be between 3-6 minutes, and Wistia[3], which notes that "[a]fter 2 minutes, every second counts."

Topic	Brief description	Video links	Run time
Free body diagrams	This video guides learners through sketching a free body diagram of the tuna blimp.	https://vimeo.com/747705561/e749884920 https://youtube.com/watch?v=_2tHqOPI0zM	3:48
Structures in nature	This video provides a narrated walk in a park highlighting interesting man-made and natural structures we observe.	https://vimeo.com/749710039/2d626cdc71 https://youtube.com/watch?v=ftFc75xyB_M	2:07
Centers	This video provides demonstrations of a handful of center finding activities.	https://vimeo.com/747733423/ddbd1e8215 https://youtube.com/watch?v=DRcq27c7WJA	2:56
Helium and buoyancy	In this video, we demonstrate how the quality of helium influences the rate at which a balloon rises.	https://vimeo.com/747726743/79229dee48 https://youtube.com/watch?v=hvmOh7gMAmc	2:08
Introduction to coding with hydrostatic pressure	In this video, we demonstrate how to calculate hydrostatic pressure using MATLAB.	https://vimeo.com/749707680/4e5e66eb6c https://youtube.com/watch?v=KjnN5-r_NNA	3:19
System design	This video discusses how to engineer a complex system.	https://vimeo.com/749716012/b44641bbdf https://youtube.com/watch?v=j_8Bd-Raxys	2:44
Swarm dynamics	This video illustrates through demonstration how simple rules result in swarm behaviors.	https://vimeo.com/747705678/d5b876016a https://youtube.com/watch?v=PJ3_Cv-F2IU	1:49
Build video	This video provides a step-by-step guide to building a tuna BLIMP.	https://vimeo.com/753027996/0bdc404386 https://youtube.com/watch?v=dbfYhp-0fX4	48:39

Table 1: Summary information on videos released to date (content focus areas shaded sequentially and according to the following: structural engineering – green, aero/hydrodynamics – blue, systems engineering – orange, swarm dynamics – yellow, and construction – grey)

Scripting

While scripting is an obvious and essential step in any video production effort, in this project significant time investment was spent iterating at the pre-production stage as GMU-TV and faculty collaborated to identify how best to effectively communicate scientific principles in a visual manner that is accessible to lay-audiences. First drafts of each script were prepared by faculty, upon which GMU-TV provided advice and posed questions to clarify content for viewers with less depth of technical expertise. From these drafts, shooting scripts were developed, describing in more detail the audio and visual elements of each video. A portion of a sample script is provided in Table 2.

The tuna isn't flying away because we have a string tied to it.	MS Vishva and blimp Vishva showing blimp string	5
There is also a tension force acting downwards. Great – this looks like a pretty good free-body diagram for my tuna BLIMP.	Adrian sketches and labels tension force.	10
But what if Vishva releases the string and turns on its motors – now it is moving forward!	WS Vishva flying tuna blimp.	15
The tuna doesn't have tension anymore since Vishva released the string, but there are a couple more forces I should capture – thrust and drag. Thrust from the propellers is pushing it forward, and drag is opposing that forward motion.	WS MS of Tuna GFX over Video:Thrust ⇐ Drag ⇒	15

Table 2: Snippet of free body diagrams video script where the first column provides the audio script, second column describes visual imagery, and third column indicates estimated duration of segment in seconds.

Recording Sessions

To provide high school students with contemporary, accessible role models, undergraduate and graduate student talent was utilized as the 'faces' of the video program. After discussions between the science and engineering team and the videography professionals, filming locations were selected based on their alignment with the lesson goals of each video and the visually dynamic and engaging nature of the space. Additionally, consideration was given to the feasibility of filming at a location, including lighting, background noise, electrical needs, safety concerns, and the ability to get the necessary permits in a timely manner. Sample spaces are shown in Figures 1-3. For example, an electronics laboratory was used as the venue for the build video (Figure 1, left) and the atrium of the engineering building (Figure 1, right) for demonstrating the impact of helium purity on balloon acceleration. An area park (Figure 2) allowed us to reinforce the biologically inspired theme by showing both natural and manmade structures. And athletic fields on campus (Figure 3) enabled active demonstrations and unique videography via drone.

There was an emphasis on efficiently scheduling production days. Generally, multiple scripts were shot each day. Scripts were often shot out of order, with the shooting schedule dictated by such considerations as location and talent availability, time of day, and equipment requirements (both filming equipment and equipment used in the video lesson). A typical day on-set included 1-2 hours of transportation and setup, 2-5 hours of filming, and 1-2 hours of teardown. Multiple takes and incremental re-shoots were done for each video, with the GMU-TV team coaching the performers on delivery techniques, and faculty/subject matter experts on hand to clarify any content issues that arose.

Figure 1: Venue 1 – Engineering building electronics laboratory during build video with on-screen graduate student talent and GMU-TV team (left); engineering building atrium during video demonstrating impact of helium purity on forces on a balloon with undergraduate student talent and GMU-TV team (right).

Figure 2: Venue 2 – Two settings at area park with various structural elements and lake used for structures in nature video with undergraduate student talent and GMU-TV team pictured.

Figure 3: Venue 3 – Athletic fields on campus with 'swarming' students being filmed by GMU-TV team via drone.

Post-production

The first step in the video post-production process was editing together the best of the multiple takes of each shoot. Once the "string out" edit was completed, additional visual footage (b-roll) was added. Some of this b-roll was filmed on location while other assets were licensed stock footage. Graphics and animations were included to further illustrate more complex concepts and to add visual interest. For example, various equations or scientific principles were explained with graphic layovers. The graphics package was designed to match the look and feel of the online lessons' branding. Then, a video open was created for each lesson, along with the corresponding "lower thirds" (graphic identifiers) for on camera talent as well as other on-screen graphic elements like key terms. The next step was to take this "rough cut" and finalize it by "color grading" and "audio sweetening" (adjusting the colors and brightness of each shot to achieve a desired look, and adjusting audio levels and adding additional audio elements as needed, *i.e.* music, sound effects). These efforts were dependent upon the professional skillset of GMU-TV. Post-production for any given video in this series took approximately 50-80 hours for a 10-minute segment.

Launch

As stated previously, at the time of this writing, eight of ten videos are published via YouTube, Vimeo, and the project website, with two more videos pending. The tri-launch approach of YouTube, Vimeo, and website leverages the searchability of YouTube, professional delivery of Vimeo, and allows interweaving videos with written lesson plans and build instructions in the web-based delivery. Examples of how the videos are integrated into the web-based curriculum are provided in Figure 4. A resources section of the project website[4] also provides Vimeo links to project produced videos as well as a curated selection of additional videos and content by other researchers, educators, and news sources. A sampling of those resources includes content on biologically inspired robots[5-10] and biologically inspired design[11]; for the most current list, the interested reader is referred to the project website[4].

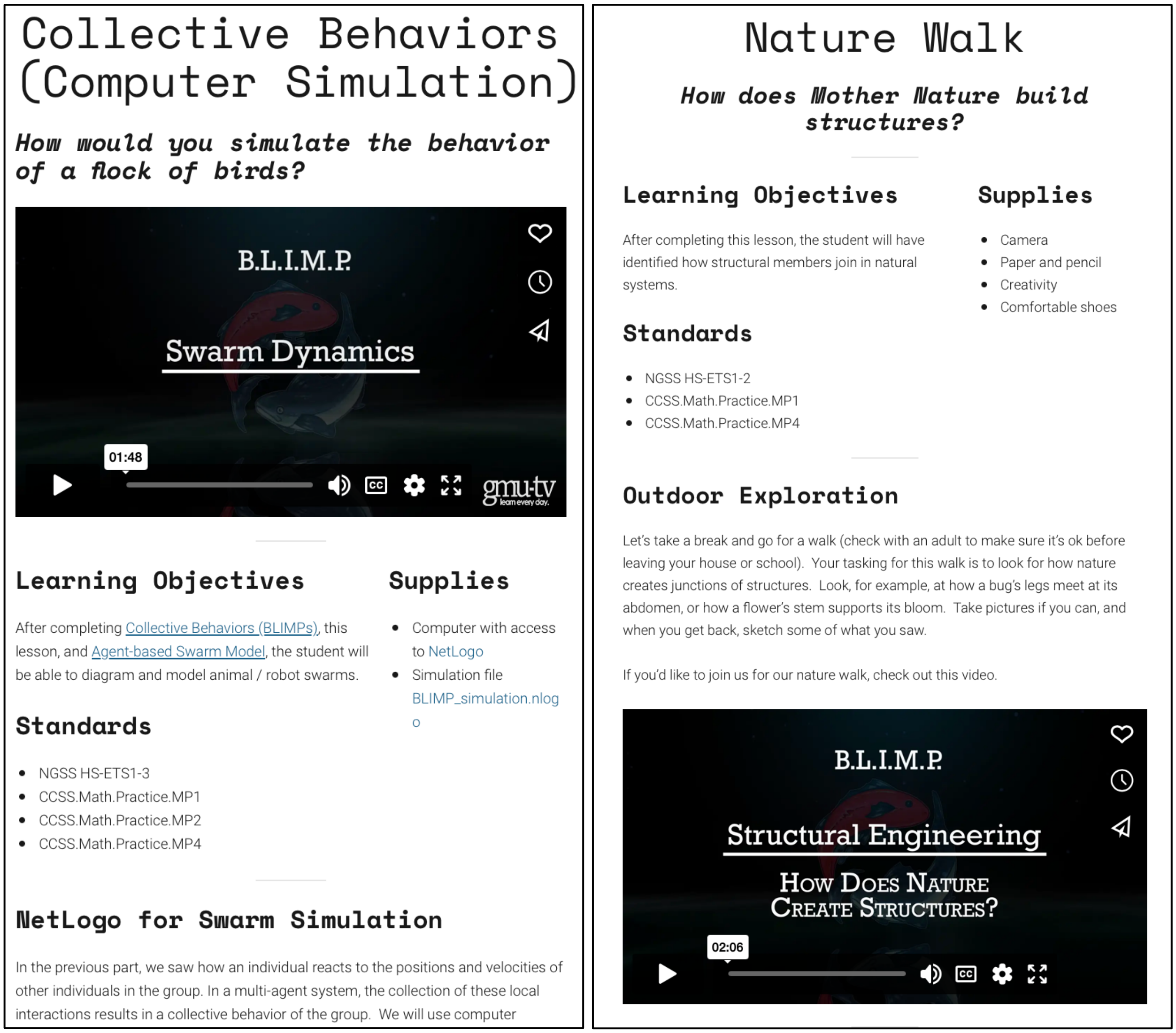

Figure 4: Example integration of videos into curriculum on swarming (left) and structural engineering (right).

We intend to track view and engagement rates as performance metrics for the videos. For the eight videos posted to date, views are provided in Table 3. Notably, these videos have only been posted for a short period, and have not yet been marketed widely. The videos embedded in the website are the Vimeo links. Moving forward with this project we will continue to monitor view rates on both YouTube and Vimeo platforms to help identify any trends which might indicate topics that warrant additional video coverage. For example, we immediately note that the build video has the highest rate of engagement, and as such, more content focused on construction may add further value.

Topic	Combined YouTube and Vimeo views
Free body diagrams	20
Structures in nature	16
Centers	5
Helium and buoyancy	18
Introduction to coding with hydrostatic pressure	8
System design	9
Swarm dynamics	13
Build video	38

Table 3: View metrics for released BLIMP videos as of 1/4/23

Conclusions

This paper provides an introduction to how professional video was used to supplement content for a STEM robotics program. The mechanics of the effort are described, including scripting, recording, post-production, and launch, with initial metrics provided. Going forward, it will be worthwhile to track viewer engagement metrics across the different release platforms in order to identify which video(s) are providing the most value to learners. The curricular components of this project are designed for use in classroom or afterschool club-type environments[1]. Some videos were scripted in direct response to focus group feedback. For example, one focus group participant advocated for a coding tie-in with the curriculum, which resulted in the video that introduces students to MATLAB as a tool to calculate and plot hydrostatic pressure. Multiple focus group participants indicated struggling at some point in the build, which inspired development of a complete build video to supplement written instructions. Further feedback from educators, parents, and students on the video components of this project specifically would help identify how best to develop future content to serve constituent needs and assess if the video content is serving the aim of enhancing knowledge attainment.

Acknowledgements

The authors gratefully acknowledge support for this effort under ONR grant N00014-21-1-2968. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Office of Naval Research.

References

1 McCue, L., Hagarty, A., Nowzari, C., Raz, A., Riggi, M., Rosenberg, J., Shishika, D., Smith, C., Nelson, J., "Work-in-Progress: Development of a new hands-on STEM program for biologically inspired maritime robotics," Ocean and Marine Engineering Division, American Society of Engineering Education Annual Conference, Minneapolis, MN, June, 2022.

2 Knott, Ryan, "Video Length: How Long Should Instructional Videos Be? (New Data)," https://www.techsmith.com/blog/video-length/, last accessed December, 2022.

3 Fishman, Ezra, "How Long Should Your Next Video Be?" https://wistia.com/learn/marketing/optimal-video-length, July 5, 2016.

4 BLIMP, "Resources," https://blimp-robotics.org/resources/, last accessed December, 2022.

5 Virginia Tech, "Virginia Tech: Autonomous Robotic Jellyfish," https://vimeo.com/62880818, March 28, 2013.

6 WXYZ-TV Detroit, “U.S. Navy testing underwater fish robot called GhostSwimmer,” https://www.youtube.com/watch?v=A9f9G5CO4Lk, December 15, 2014.
7 NUS, “MantaDroid – A NUS-Developed Robotic Manta Ray,” https://www.youtube.com/watch?v=XzO_XAQ2_xw, November 7, 2017.
8 The UVA Center for Bio-Inspired Engineering Research, “Meet the Mantabot,” https://www.youtube.com/watch?v=UEIfVA8tLqU, October 18, 2017.
9 The Economist, “Nature does not use propellers. So why do people?,” https://www.economist.com/science-and-technology/nature-does-not-use-propellers-so-why-do-people/21806832, December 16, 2021.
10 Institute of Physics, “Bioinspired Robojelly fuelled by hydrogen,” https://www.youtube.com/watch?v=U2OSJQhHQp8, March 20, 2012.
11 Vox, “The world is poorly designed. But copying nature helps.” https://www.youtube.com/watch?v=iMtXqTmfta0, November 9, 2017.