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A Model for Conducting K-12 STEM Summer Outreach Programs During the COVID-19 Pandemic

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Program Overview

Angelo State University and Tom Green County Library have been collaborating in STEM outreach programs for more than three years. The rocketry camp project started with a proof-of-concept one-week camp in August 2018 with enrollment limited to twelve students, from 6 -12th grades. The students learned about the physics of rocketry, built model rocket kits, launched their rockets, analyzed the flight data gathered, and presented a workshop on rocketry for younger students through the San Angelo Museum of Fine Arts (SAMFA) STEM Family Day in August 2018. During the summer of 2019, the camp expanded to include 33 students in a week-long, full-day camp that incorporated the history of rockets and space exploration and arts activities into the physics and engineering design curriculum followed by community presentations at the SAMFA Family Day. With the onset of COVID-19, camp organizers were challenged to deliver a similar outreach program to local families given the new confines of health and wellness restrictions. The goals of the 2020 camp offerings were for 70 percent of participants to come from underrepresented minority groups, and for 65 percent of participants to complete their rocket design and build and attend a launch session.

COVID Program

The planning started with a meeting of camp organizers to discuss alternatives to accommodate the safety restrictions accompanying the global pandemic. The consensus was to redesign the camp as a hybrid learning program where participants worked their way through a daily online curriculum that resulted in the design and build of a model rocket that was then launched as a part of the culminating experience for the camp. The camp was designed so that students logged into Niche Academy, an online learning management system, to complete 4 days of sequenced curriculum that included lessons on the physics of flight, engineering design, and model rocket building skills. Each day included rocket design or building activities. On day 3, participants submitted their design simulations for review and approval. Once the designs were reviewed for stability and approved, participants could complete their rocket builds for launch on day 4. Two separate launch days allowed for launches to be scheduled by family units in order to limit contact between households. Two separate week-long sessions of the rocketry camp were offered during the summer of 2020. The second session was slightly modified, from lessons learned in the first session. This second session included additional support in the form of a welcome orientation and assigned mentors to improve camp outcomes.

Families/households scheduled their launch times as they completed Day 3. The launch schedule included 8, one-hour appointments that were staggered in twenty-minute blocks. When they arrived, families/households navigated through 4 stations where they prepared the rocket for launch, loaded altimeters for collecting data, launched and recovered their rockets. Scheduling the families through the launch in this way allowed us to keep households separate and clean each station prior to the next family. The scheduled launch also provided more one-on-one family time between engineering faculty and families as they discussed and described the flight pattern and

launch details of the rockets. A complete description of the 4-day curriculum is provided in Appendix A.

Key elements of program transition

There were a number of elements which were key to making the transition of this program from a face to face to a hybrid mode successful. Some of these elements were already in the program before the new hybrid model was adopted. Some were carefully planned as part of the transition. And some were learned during the implementation of the hybrid model.

Partnerships

The value of campus-community partnerships has been well documented as an important support in STEM outreach programs [1], [2], [3]. The partnerships formed among Angelo State University (ASU), Tom Green County Library (TGCL), and area community-based organizations provided a wealth of resources which were essential to the program's success. ASU and TGCL provided the cornerstone partnership needed to establish and build the program. While both institutions share goals of acquiring and disseminating knowledge, they have very different characters. Angelo State provides technical expertise within STEM fields and extensive laboratories. However, many of its resources are unavailable to the community beyond campus. While TGCL lacks the STEM expertise of the university, its entire structure is designed for open access to the community. The current summer rocketry camp is the third iteration of this program. The complementary nature of the two organizations and the working relationship built over years of collaboration were key to program success.

The program's ability to reach the target audience of underrepresented minorities (URMs) was augmented by strong ties to community organizations such as the STEM working group of the Tom Green County Workforce Commission, Migrant Student Program of the state regional education service center, Tom Green County 4-H, and the San Angelo Independent School District. These organizations provided critical access to URM students in the region and promoted the program among their constituencies. These partnerships significantly contributed to the diversity of program participants.

National organizations such as NASA and the National Association of Rocketry (NAR) provide access to curricular materials, program planning, and safety guidelines. TGCL received significant funding through NASA @My Library (NAML) to develop a robust space science program which supported the summer rocketry camps.

Finally, commercial model rocketry suppliers played a role in the partnerships by providing an affordable source of supplies and materials. One supplier even developed and started marketing a design-your-own rocket kit in response to collaboration with project members.

Online delivery

A quality online content delivery system was essential to the success of the hybrid program model. Online learning modules were developed by ASU faculty members familiar with both the subject matter and online pedagogy. Forty short online instructional videos were developed. Links to the video library are provided in Appendix A. The length of the videos ranged from 30 seconds to 16 minutes long with the vast majority being under 6 minutes long. Each video was focused on a single skill which the student could practice immediately after completing the video. Short quizzes were developed to reinforce student attainment of learning outcomes. Printed materials were developed for most activities to supplement and support the online content.

The choice of learning management system (LMS) platform was critical and illustrates the complementary nature of the ASU-TGCL partnership. The Blackboard LMS used by ASU, while powerful and familiar to faculty members, is a closed campus system. Allowing external users to access this LMS is cumbersome and time consuming. Blackboard also has a significant learning curve for users and very limited support for mobile devices. In contrast, TGCL adopted Niche Academy as their LMS. Niche Academy is designed for easy public access, is simple to use, and provides good support for mobile devices. Using an easily accessible LMS was key to effective online delivery. The content developed for this program is still publicly accessible on the TGCL Niche Academy site. Appendix A contains links to the online material.

The team had to make a choice between using commercial rocket simulation software (RockSim from Apogee Components, https://www.apogeerockets.com) and open source simulation software (OpenRocket, http://openrocket.info/). While RockSim is more powerful and included features not available in OpenRocket, such as animation of rocket flights, OpenRocket was chosen because it was free, and met the requirements for the program.

Hardware used by participants to access the materials included smartphones, Chromebooks, laptops, and desktop computers. OpenRocket is written in Java and runs only under Windows, Linux, and Mac operating systems. The program had a limited number of laptops with OpenRocket installed which were loaned to families without laptop or desktop computers. In a similar fashion, the ASU-TGCL partnership facilitated the camp's ability to provide easy access to laptops and software given their established means of lending materials to the community at-large.

Material kits

Material and supply kits were provided free of cost to participants. These kits included all materials, supplies, and tools needed to complete the rocketry camp. Participants kept all materials and supplies and some of the less expensive tools. Participants returned the more expensive tools at the end of the program. The materials were organized and coded by each day of the program. Printed materials were provided to both supplement the online learning materials and guide participants through the program. A complete list of rocket materials is provided in Appendix B.

Mentors

Having an adequate number of well-trained mentors was critical to the success of the program. The program used 4 mentors to support 26 participants in each week of the program. Initially, mentors worked in a passive response mode, answering participants questions when asked and providing any needed guidance. However, the first offering of the program showed the team that intrusive mentoring was required to keep participants on task to complete the program in the allotted one-week time. During the second offering, mentors followed participants daily as they progressed through the program. Mentors directly contacted those who appeared to be behind or were completing the material out of sequence.

Text sharing

Having a rapid and easy way to communicate directly with participants was essential. The team selected GroupMe (https://groupme.com/en-US/) as a mode of texting among participants and mentors. GroupMe allows participants to join the text group without divulging their cell phone numbers. Participants can leave the text group at any time. It works both with smartphones and with non-smartphones. GroupMe was used not only to communicate with individual participants, but also used for participants to share their progress with the larger group through both text and photos. This turned out to be an important community building tool.

Outcomes

Reusable/Sharable Material

One important outcome was the development of reusable and shareable online materials. In preparing the materials, care was taken to ensure they would be usable in the future. Of the 40+ videos prepared, only 3 or 4 contain material specific to the camps run in 2020. The rest of the material will remain valuable and usable for many years. Care was taken to use open platforms and avoid proprietary materials or materials requiring subscriptions. As discussed earlier, Niche Academy was used as the LMS because of its open nature and OpenRocket was selected as the rocket flight simulation software because it is open source and free of charge. The team also created a complete list of materials needed to support the rocketry camp. This list along with suggested vendors is provided in Appendix B.

Diversity & Family Participation

The virtual rocketry camp brought together a host of students and families at the height of the pandemic. A total of 42 participants were enrolled in the program and 33 completed their rockets and attended launch day for a completion rate of 79 percent. This exceeded the objective of 65 percent completion. Table 1 presents the demographics of participants who completed the camp, as they are normally tracked. These data show a significant increase in diversity by both gender and ethnicity/race compared to previous offerings. The camp met the goal of 70 percent participation by URM participants. In addition to our typical ways of looking at diversity, this

hybrid format created opportunities to engage students and families in unique ways. While the university and library were initially focused on providing STEM outreach activities to the community, the camp resulted in a higher level of family integration than seen in previous outreach efforts. Working alongside students meant working alongside their families. Several of the participants were guided at home not only by parents, but also grandparents and siblings. As camp staff began to notify families of acceptance to the camp, the need for bilingual staff in English and Spanish became apparent. This was not a surprise given our targeted recruitment. Library staff were well equipped to serve families with little or no technical knowledge with software programs and university staff were able to assist Spanish-speaking families. Language and technical skills were not the only elements important to the success of the camp. In fact, the home dynamics played a role in the student outcomes. Families with siblings who could work together tended to finish building their rockets more often than lone-builders who struggled more to complete all of the tasks. Camp organizers recognized that family participation would generate a need to incorporate participants younger than the middle and high school students targeted for the program. To accommodate younger siblings, simple easy-to-assemble rocket kits were provided to families with younger siblings. Incorporating all the age groups in the family catalyzed excitement for launch day. At the scheduled launch, parents recounted the way siblings worked to support one another and grandparents were excited to share the learning experience alongside the students. Younger siblings were excited to launch their rockets alongside their older siblings. We learned that virtual projects pursued at home involved everyone in the household.

One-on-one family-time at launch

While launch day is the culminating experience of the program, in Pre-COVID offerings of the program, it was a hectic event. Managing a large group of participants and family members and conducting a safe launch event left little time for in-depth learning. The need to spread out the launch over two days and to separate family cohorts from one another had the added benefit of providing much more time at the launch site for each participant. This allowed ASU faculty to provide significant one-on-one hands-on instruction before, during, and immediately after each launch. Before the flight, faculty reviewed the flight profile expected and provided guidance on how to observe each segment of the flight. Key phenomena participants needed to observe, and record were discussed. After the flight and recovery of the rockets, faculty had time to discuss the performance of each rocket and tie that performance back to the design decision participants had made. Participants and faculty were then able to brainstorm improvements to future rocket design. This was a significant enhancement in learning over previous versions of the program.

Table 1: Rocketry Program Participation by Gender and Ethnicity/Race, 2018-2020

		Participants Completing by Year (count/percent)			
Demographics		**2018**	**2019**	**2020**	**Totals**
Gender	Male	6/50%	25/76%	21/64%	52/67%
	Female	6/50%	8/24%	12/36%	26/33%
Ethnicity/Race	White	7/58%	23/70%	10/30%	40/51%
	African American	1/8%	3/9%	7/21%	11/14%
	Asian/Pacific Islander	2/17%	3/9%	1/3%	6/8%
	Latinx	2/17%	3/9%	15/46%	20/26%
	Native American	0	1/3%	0	1/1%
Total percent URM Participation		42%	30%	70%	49%
Free/Reduced Lunch		*	*	26/79%	

* First reported in 2020

Future work

Applying model in other outreach programs

As a result of the successful rocket camp, the engineering department planned to pursue similar projects to replace our semi-annual outreach events on campus. Prior to COVID-19, the department sponsored a family lab night, where the community is invited to complete hands-on engineering projects alongside college students and faculty. Given the need to socially distance, lab night was planned to be converted into a hybrid experience with an at-home building kit accompanied by videos followed by scheduled visits to the engineering lab for testing project builds. This model allows us to transition our outreach efforts from a single event, or one-touch opportunity, into a week-long series of activities that allows participants to engage the material over a longer period of time.

Advantages for diversifying participation

Our goal is to continue to focus our outreach efforts through equitable incorporation of families from underserved and underrepresented communities. An area for future research to consider is how this at-home experience lends itself to engaging underrepresented families in STEM. For us, these types of activities removed the barriers that limit participation from targeted groups. For example, transportation is often a barrier to participating, but the hybrid outreach model limited

the impact of such barriers. Rather than requiring daily transportation to a summer camp, participants were able to complete the projects at home and only needed transportation on a single day at an appointed time. For families with limited transportation means, this meant that families could make necessary arrangements well in advance with the ability to schedule their visit at a time when parents and guardians were available.

Conclusions

The COVID-19 pandemic has brought great tragedy and disruption to our educational systems and broader society. However, within these unwanted disruptions lay opportunities for creative improvements to the way we do business. In the case of STEM outreach programs, it forced ASU and TGCL to rethink our models and adopt a hybrid online socially-distanced/face-to-face format. While this hybrid format was originally conceived as a poor substitute for a fully face-to-face program, it proved to have several advantages over the traditional model. It increased the diversity of the participants and brought a new and positive family dynamic to outreach programs. It reinforced the value of academic and community partnerships—demonstrating their resiliency and flexibility. Ultimately, it has changed the way our institutions will approach STEM outreach from this point forward.

References

[1] R. G. Bringle and J. A. Hatcher, “Campus–Community Partnerships: The Terms of Engagement,” *Journal of Social Issues*, vol. 58, no. 3, pp. 503–516, Jan. 2002, doi: 10.1111/1540-4560.00273.

[2] J. Karia and M. Kramer, “Collective Impact,” *Stanford Social Innovation Review*, no. Winter, pp. 36–41, 2011.

[3] A. Kezar, “Organizational Culture and Its Impact on Partnering Between Community Agencies and Postsecondary Institutions to Help Low-Income Students Attend College,” *Education and Urban Society*, vol. 43, no. 2, pp. 205–243, Sep. 2010, doi: 10.1177/0013124510380041.

Appendix A: Lesson plan outline

Links to online materials

Link to lesson on Niche Academy https://my.nicheacademy.com/tgcls?category=4379

YouTube Video Repository:
https://www.youtube.com/playlist?list=PLZUnyDCJwePoFnluoNEbEpi0l8fTOoz4G

Table A-1: Day one Activities

Task	Topic	Objective	Planned time (min)
1	Program introduction	Identify activities for the day	5
2	Install OpenRocket on home computer	Install software	20
3	OpenRocket Simulation Basics	Open and edit a design file	30
4	Engineering Design process	Identify steps in the process	5
5	Rocket building safety	Use safe techniques	15
6	Dart Design Challenge	Introduction to aerodynamic stability	30
7	Parts of a rocket	Identify and name rocket parts	30
8	Construction: motor mount	Complete motor mount	60
9	Model rocket flight profile Part 1	Find rocket flight videos and sketch flight profile	60
10	Pinwheel Galaxy	Cool down supplement activity	30
11	End of day survey	Gather student feedback	15
		Total estimated task time	5.5 hrs.

Table A-2: Day Two Activities

Task	Topic	Objective	Planned time (min)
1	Day 2 Introduction	Identify activities for the day	5
2	Model rocket flight profile Part 2	Identify flight profile segments	30
3	Center of mass	Define CM and locate it on dart	30
4	Center of pressure	Define CP and locate it on dart	30
5	Rocket stability	Describe relationship between CM and CP needed for stable flight	30
6	Rocket Design with OpenRocket	Design a stable rocket	90
7	Rocket Propulsion	Define Newton's 3rd law and explain how it applies to rocket propulsion	30
8	Construction: nose cone	Assemble nose cone	30
9	Constellation cube	Cool down supplement activity	30
10	End of day survey	Gather student feedback	5
		Total estimated task time	5.2 hrs.

Table A-3: Day Three Activities

Task	Topic	Objective	Planned time (min)
1	Construction: body tube	Cut body tube to length	30
2	Propellants and combustion	Define combustion, distinguish between solid and liquid propellants	15
3	Construction: install motor mount	Install motor mount in body tube	15
4	Baking soda rockets	Simulate combustion	60
5	Build: Fins	Cut and attach fins to body tube	90
6	Orbits and orbital velocity	Define orbit and orbital and escape velocity	30
7	Build: Streamer	Attach streamer to rocket	30
8	Build: Final assembly	Complete rocket	30
9	UV detector	Cool down supplement activity	30
10	End of day survey	Gather student feedback	5
		Total estimated task time	5.5 hrs.

Table A-4: Launch Day Activities

Task	Topic	Objective	Planned time (min)
1	Travel to site	Arrive on schedule	45
2	Prep rocket	Install motor and prep for flight	30
3	Launch and recover	A perfect flight & full recovery	30
4	Collect data	Record acceleration, velocity, and altitude reached	15
5	Return home	Safe travel	45
6	Build a planet	Cool down supplement activity	30
7	End of day survey	Gather student feedback	5
		Total estimated task time	2.75 hrs.

Table A-5: Mission to Mars Activities

Used as a filler activity on day students did not have a launch activity.

Task	Topic	Objective	Planned time (min)
1	Mission to Mars: 1	List characteristics of Mars	30
2	Mission to Mars: 2	Describe orbiters, landers, and rovers which have visited Mars. Make a cardboard Mars rover.	60
3	Mission to Mars: 3	Describe plans to humans to live on Mars. Make a model Mars astronaut lander	60
4	Mission to Mars: 4	Describe future colonization plans for Mars and the jobs available in the space industry. Create a Mars critter	60
5	End of day survey	Gather student feedback	5
6	End of camp survey	Gather student feedback	5
		Total estimated task time	3.75 hrs.

Appendix B: Materials and supplies for 40 families with 3 participants per family

Category	Description	Vendor	PN	Qty/ Rocket	Qty/ Family	Unit Price	Line Price
Build kit	Super Glue gel, 2g tubes (or smaller) 12 pack	Amazon	B004YEN37K		0.083	$7.45	$29.80
Build kit	Emery boards medline NON801778 144 pack	Amazon	B00LOL4QXG		0.014	$8.99	$8.99
Build kit	PenBlade #11 Retractable knife 10 pack	Amazon	B010C8DDZI		0.10	$40.00	$80.00
Build kit	Yellow wood glue, 4 oz bottle (or smaller) Elmers, titebond etc	Amazon	B001N7X1UA		0.50	$2.18	$39.24
Build kit	Safety Glasses pgk of 12	Amazon	B01G9J08Q6		0.17	$14.97	$104.79
Build kit	Blue masking tape 3/4" case of 36	Amazon	B0746RPTCY		0.03	$89.00	$89.00
Build kit	150 or 220 grit sand paper sheet 9x11" pkg of 5	HomeDepot			0.20	$6.99	$55.92
Build kit	Plastic model cement (Testors or Duco) 0.5 oz	Michaels	10118149		1.00	$2.69	$107.60
Build kit	Craft stick (popsicle stick) box of 1000	Staples	CKC377401		0.0040	$6.99	$6.99
Build kit	Aluminum or plastic angle marking guide	Local			0.50	$-	$0.00
Build kit	3 fin marking guide	Local			1.00	$-	$0.00
Build kit	4 fin marking guide	Local			1.00	$-	$0.00
Build kit	DLHE template	Local			1.00	$-	$0.00
Construction	9" Bulk Sport 'Chutes - Asst Colors, 25 'Chutes	Aerospace Specialty Products	BSC-25/9	0.04	0.12	$23.99	$119.95
Construction	3" X 48" Sport Streamer Colors: Orange	Aerospace Specialty Products	SST-3/48SS-3/48-O	1.00	3.00	$0.79	$92.43
Construction	T - 50 Body Tube (30" Long)	Aerospace Specialty Products	T-50	1.00	3.00	$2.59	$290.08
Construction	5/20 Centering Rings	Aerospace Specialty Products	CR-520	1.00	3.00	$0.15	$16.50
Construction	20/50 Centering Rings	Aerospace Specialty Products	CR-2050	2.00	6.00	$0.18	$32.40

Category	Description	Vendor	PN	Qty/ Rocket	Qty/ Family	Unit Price	Line Price
Construction	1/8" Launch Lugs	Aerospace Specialty Products	LL1/8	1.00	3.00	$0.10	$10.60
Construction	Estes NC-50 Nose Cone Assortment	Aerospace Specialty Products	PNCEA50	0.10	0.30	$7.99	$87.89
Construction	Estes NC-20 Nose Cone Assortment	Aerospace Specialty Products	PNCEA20	0.00	0.00	$4.99	$0.00
Construction	Tube Coupler - Size 50	Aerospace Specialty Products	TC50	1.00	3.00	$0.39	$46.80
Construction	Engine Hook - Standard Size	Aerospace Specialty Products	EH-STD	1.00	3.00	$0.59	$53.10
Construction	Snap Swivel, Size 5 or 7 pgk of 100	Amazon	B00AEGE9C0	0.02	0.06	$0.25	$0.50
Construction	1/8" X 3" X 36" Balsa Sheet pkg of 20	Amazon	B002YHDYTG	0.01	0.04	$40.78	$81.56
Construction	18mm x 2.75" Motor Tube (BT-20) (50/pk) - 50 Per Pack	Apogee Components	#10064	0.02	0.06	$11.69	$23.38
Construction	24mm Plastic Nose Cone Assortment - 6 Per Pack	Apogee Components	#09533	0.083333	0.25	$11.79	$94.32
Construction	18mm x 18" Body Tube (BT-20) - 6 Per Pack	Apogee Components	#10086	0.00	0.00	$9.12	$0.00
Construction	24mm x 18" Body Tube (BT-50) - 6 Per Pack	Apogee Components	#10100	0.166667	0.50	$9.41	$178.79
Construction	18mm Plastic Nose Cone Assortment - 8 Per Pack	Apogee Components	#09532	0.125	0.00	$13.22	$39.66
Construction	Estes Tube Cutting Guides Set - 1 Per Pack	Apogee Components	#35516	0.125	0.00	$13.34	$39.66
Construction	Estes Gnome Model Rocket Bulk Pack (12 pack)	Belleville Hobby	1749			$41.29	$82.58
Construction	Shockcord, Kevlar, 100 lb test	Amazon	B07X5VQ4WC			$20.69	$20.69
Launch	B6-4 Model Rocket Engine Bulk Pack	Aerospace Specialty Products	B6-4EB	0.04	0.13	$65.99	$263.96
Launch	Estes 1/2A3-4T Bulk pack 24	Aerospace Specialty Products	1/2A3-4TEB			$51.99	$51.99
Launch	Jolly Logic AltimeterTwo - 1 Per Pack	Apogee Components	#09135			$69.99	$209.97

Vendor websites

Aerospace Specialty Products: https://www.asp-rocketry.com

Apogee Components: https://www.apogeerockets.com

Belleville Hobby: https://bellevillehobby.com/product/estes-gnome-model-rocket-bulk-pack-12-pack/