Faculty Development for Research Inclusion: Virtual Research Experiences for Undergraduates

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Abstract

This paper presents an innovative approach, applicable to all research-based fields, that identifies and broadly engages future computer science researchers. The Computing Alliance of Hispanic Serving Institutions (CAHSI) piloted a national virtual Research Experience for Undergraduates (vREU) during the summer of 2020. Funded by an NSF grant, the goal of the program was to ensure that students, in particular those with financial need, had opportunities to engage in research and gain critical skills while advancing their knowledge and financial resources to complete their undergraduate degrees and possibly move to advanced studies. The vREU pilot provided undergraduate research experiences for 51 students and 21 faculty drawn from 14 colleges and universities. The Affinity Research Group (ARG) model, based on a cooperative learning model, was used to guide faculty mentors throughout the eight-week vREU. ARG is a CAHSI signature practice with a focus on deliberate, structured faculty and student research, technical, communication, and professional skills development. At weekly meetings, faculty were provided resources and discussed a specific skill to support students' research experience and development, which faculty put into immediate practice with their students. Evaluation findings include no statistical difference in student development between the face-to-face and virtual models with faculty and the benefit of training as an opportunity for faculty professional growth and impact. This faculty development model allows for rapid dissemination of the ARG model through practice and application with weekly faculty cohort meetings, coaching, and reflection.

Introduction and Background

The importance of undergraduate research is well understood, as it increases student self-efficacy, introduces new career opportunities, and encourages persistence to degree completion [1, 2]. The merits of multi-year research experiences and the influence of mentors are also well-documented [3, 4]. The benefit of research experiences for undergraduates (REUs) is so significant that the National Science Foundation (NSF) supports multiple annual summer REUs through annual grants. Students have the opportunities to apply to REUs nationwide and, if selected, have the opportunity to travel to another campus, work with a faculty researcher, and learn more about research and the expectations of graduate programs; however, not all students are able to attend summer REUs.

At a national conference, faculty identified a limitation to REUs — many students, such as those who are underrepresented in the profession, are not able to leave their home and travel to another town for an 8- to 10-week immersive, residential research experience [5]. Family or financial obligations prohibit these students from traveling, although they are highly talented, represent future researchers and scientists, and have the potential to impact the diversity of the profession. Involvement of underrepresented students in research is a valuable and underutilized resource that is critically needed to help the U.S. maintain its competitive edge in STEM [6].

The COVID-19 pandemic interrupted the traditional residential REU experience at universities and colleges, halting many plans for summer undergraduate research. Students lost jobs and internship opportunities. With a whole cohort of students and faculty at risk, the Computing Alliance of Hispanic Serving Institutions (CAHSI) researchers realized that the Affinity Research Group model [7] could be migrated to the virtual environment, providing faculty and students with research experiences and opportunities that would otherwise be lost. During the summer of 2020, supported by a NSF grant, 51 students and 21 faculty participated in a virtual REU (vREU) 8-week experience. The results from this work have been analyzed and are shared here.

Prior Work

Undergraduate research experiences and faculty mentoring, which accompanies such an experience, can be transformative; however, this depends in part on faculty experiences and expectations. Faculty mentors report a variety of motivations for undergraduate research mentoring [8] and the outcomes are variable, depending on the faculty mentor's training and experience, the engagement of the undergraduate researcher, and the perception by both the faculty mentor and undergraduate student as to how this experience will contribute to pre-professional preparation.

The Affinity Research Group (ARG) model, a signature practice of the Computing Alliance of Hispanic Serving Institutions (CAHSI), an NSF INCLUDES Alliance[1], offers a deliberate process for the development of faculty mentoring skills in support of undergraduate research development. [7, 9]. The ARG model is a set of activities and practices for engaging students in authentic communities of practice through group apprenticeship [9-11]. ARGs are rich in identity resources and foster meaningful engagement with ideas, concepts, tools, and standards of how to integrate research into problem solving with the guidance and supportive mentorship of experts. In particular, the ARG model emphasizes the deliberate and intentional development of research, technical, professional, communication, and team skills [8, 12-15]. ARG is structured to broaden student participation by giving students opportunities to learn, use, and integrate these skills and knowledge. A study from 2009-2014 [13] revealed that ARG students at CAHSI institutions have attended professional conferences more than three times the rate of a large, diverse national sample of students in Research Experiences for Undergraduates (REU) programs (63% for ARG students versus 18% for a national sample of REU students) and presented a paper or poster at a national conference at three times the national rate (45% for ARG students versus 14% for a national sample of REU students). Note that these differences are statistically significant: (conference attendance: $\chi 2$ (1, N=728) = 0.98, p<.001; conference presentation: $\chi 2$ (1, N=736) = 77.78, p<0.001).

In a study [16], adopters (i.e., faculty) reported a strong belief in CAHSI educational practices; a majority of adopters were motivated to improve outcomes for Hispanic students or other underserved student populations. Faculty valued the ways in which ARG practices benefited all underrepresented populations. An adopter at a predominantly white university with many first-generation college students commented [16]:

> *I wanted to create a bridge to build the capacity of Hispanic students in computing to do research and have successful careers. Although in the area there is not a large population of Hispanics, the problems faced by the Hispanics seemed similar to the students at my institution.*

Faculty who used ARG practices in their research groups or courses reported increased student confidence, communication skills, and greater effectiveness in creating a community of learners. One respondent also noted that the culture of her department had changed since her adoption of the ARG model. Her comment on outcomes for students and her department at large [16]:

> *ARG is a powerful model that goes beyond the research towards generating a community of students and faculty who share the same values and interests.*

Most notably, the ARG model is spreading beyond Hispanic-Serving Institutions (HSIs).

The efficacy of online higher education has been under study for decades, and no clear answer has emerged regarding how it compares to face to-face-education. A meta-analysis of online and face-to-face comparative studies on learning environments found that web-based learning was slightly more effective for learning declarative knowledge while web-based and face-to-face learning were equally effective with procedural knowledge [17]. Similarly, a slight advantage for online students in course outcomes was found [18]. Critics note that online courses suffer from retention issues that exacerbate inequities in higher education along socioeconomic differences [19]. Mixed methods studies indicate the benefits of frequent engagement with instructors, frequent communication with peers, and availability of feedback for students [20], all of which are available in the ARG model, used as part of a vREU.

The ARG model has been successfully used for face-to-face, faculty-student mentoring; however, the identification of a large community of potential researchers, unable to participate in traditional residential REUs, caused a re-examination of the ARG model to determine if it could be used for faculty development in support of virtual REU experiences, allowing a large community of faculty and student researchers to be matched for eight weeks of research collaboration.

Virtual REU Implementation Methodology

CAHSI is a national organization established in 2006 to address the low representation of Hispanics in computing in both higher education and the workforce. Composed of a national network of Hispanic-serving colleges and universities, CAHSI higher-education faculty meet regularly to share ideas and discuss best practices and initiatives. The network of communicating departments and faculty was a natural fit for the distribution of the vREU announcement. The goal of the vREU experience using the ARG model was faculty development for outstanding research and mentoring, in addition to the identification, research skills development, and summer funding of undergraduate researchers.

Both faculty and students completed an application to be considered as either a mentor or a mentee for the CAHSI vREU program. Faculty applications asked about prior mentoring experience and proposed research topics, as well as acknowledging the required time commitment. Faculty were expected to meet with their undergraduate researchers at least once a week and also attend a kick-off meeting for faculty and students, followed by weekly faculty cohort meetings.

Student applications asked for GPA, anticipated year of graduation, areas of interest, career plans, and a personal statement. Students were advised that the vREU program required, minimally, weekly meetings with their mentor, student work on research during the week, and collaboration with other students on their research team on a regular basis. The vREU was presented as paid, full-time summer work for the students. Early identification of the expected time commitment to both students and faculty was essential to ensure full participation.

Once received, faculty applications were reviewed for research areas, expertise, and prior experience mentoring undergraduates. Faculty mentors were selected from numerous states and Puerto Rico. Student applications were reviewed by two faculty initially, with careful attention given to the research area of interest, academic year, GPA, and student statement of need. Further review of the most favorable student applications was done by a second team of faculty, again considering academic, personal, institutional, and geographic factors. Faculty from computer science and computer and electrical engineering were available to be matched with students' research interests in these fields. Attention was paid to the composition of the student team assigned to the faculty researcher keeping in mind the expected research topic and the academic years of the students. Teams of students from dissimilar schools and different academic years were desired, so that each could learn from the others, whether it was new tools, writing skills, software products, or past experiences with research.

After the matching and selection, students and faculty were invited to a virtual orientation, where the schedule for the summer research program was shared with all participants. Faculty and students were introduced to the online notebook that was created to manage all the projects. The expectations for both faculty and students were communicated again, including creation of a research plan and the requirements for the mid-term and final reports, and research poster presentation at a national conference. For faculty, pre- and post- vREU surveys were completed, as part of the overall vREU program evaluation process. In addition, as part of the faculty development activity, attendance at eight weekly faculty mentoring meetings, the orientation and ARG training, and two regional CAHSI meetings was expected.

Communication was accomplished through a CAHSI vREU Faculty Cohort Slack channel and Microsoft OneNote notebook. The notebook and repository were used to manage individual vREU projects, which included student photos and short bios, and the individual web logs of students. Each student's web log served as research journals and received weekly entries from each student with substantial reflective content on the skills developed during the week, research accomplishments, plans for the coming weeks, and challenges. Student expectations included completing pre- and post- vREU surveys and attending regular meetings with faculty mentors (anticipated to be at least weekly), two regional CAHSI meetings, and apply for and attend the Great Minds in STEM (GMiS) conference. All faculty mentors were expected to attend the annual Great Minds in STEM (GMiS) Conference, participate in a GMiS faculty focus group, and provide a brief midterm and concluding project report to CAHSI, in addition to their weekly meetings with the faculty cohort and mentoring their undergraduate students. The purpose of the weekly faculty cohort sessions was to share additional best practices with the faculty in order to use those techniques with their students in the coming week.

As the CAHSI's vREU program distinctively used the Affinity Research Group (ARG) model for mentor-mentee engagement, the vREU faculty mentors became part of a cohort community themselves, meeting weekly to discuss best practices for working with undergraduate researchers and receiving mentoring training and materials for use with their students in the following week (Table 1).

Table 1. ARG Curriculum for vREU Faculty Mentors

Week	Topic	Faculty Homework	Skills Developed
1	Orientation	Introduce self and research	Self-exposition and context. Public speaking & professional presentation
2	Probing Questions	Practice asking probing questions	Critical thinking and listing
3	Abstracts	Draft and discuss abstracts	Collaborative review Scientific writing expertise
4	Elevator or Zoom Pitch	Practice scripted pitch	Public speaking, rehearsal. Strategic thinking
5	Poster Preparation	Layout poster, with hypothesis, proving questions, all.	Research methodology, process. Sequential thinking and presentation
6	Poster Critique	Giving & getting constructive feedback	Critical thinking, understanding dissimilar perspectives, communication
7	Final Report	Draft final report	Writing, crucial thinking
8	Conference registration; Poster Submission	Register for conference with poster	Research communication; presentation

Student participants worked in virtual teams with faculty mentors to develop their research projects. Software tools used included a variety of programming languages, operating systems, and data systems, depending on the team. Early research journal entries often focused on what an individual student was contributing to the team (e.g., web-authoring skills) and what the student was learning (e.g., C programming, Linux, tensorflow, github). The CAHSI vREU methodology supports constructive critique and the deliberate development of research skills, without requiring student re-location, enabling a larger, more representative national group of students and faculty to participate, broadening the community of undergraduates engaged in research, with potential for graduate study. While traditional summer research experiences provide undergraduates with a campus-based research experience, such experiences may exclude many talented students.

Virtual REU Faculty Experience

Weekly faculty development sessions, which included only faculty researchers and the vREU faculty facilitators, were held twice each week due to the availability of the faculty researchers, who were located across all of the US and Puerto Rico time zones. Thursday evenings and Friday mornings were the designated time for faculty cohort meetings. Faculty needed to attend only one weekly meeting.

By doing the activities listed in Table 1 with faculty during the weekly faculty cohort meetings, faculty reported that they were refreshed and reminded of the needs of undergraduates. Many faculty had not received any formal mentoring training, and the ARG skills development was clear and useful immediately. The vREU faculty cohort focused solely on research. Unlike campus based residential REUs, the faculty in the vREU experience were not responsible for the students outside the mentoring and research activities. Virtual REUs are less costly than residential REUs, but offer comparable, if not greater, impact, given the number of students who are afforded this important experience.

Effectively, the CAHSI vREU summer 2020 program supported multiple REUs simultaneously, as the faculty and students involved represented many different research areas, including artificial intelligence, networking, high performance computing, and machine learning, to name a few. Students investigated data analysis to reduce software maintenance, deep learning for sign recognition, neural networks, brain-controlled drones, scalable security, foraging algorithms for swarm robots, virtual patient simulations, early detection of brain disease, and a variety of other topics. Through remote access, shared screens, research papers, and tutorials, the student cohorts asked probing questions, provided constructive critique, and worked as a team with their faculty mentors on their research.

Through the use of Microsoft's OneNote, faculty and student teams could see the notebook entries of other groups. Students would enter their weekly logs, and faculty could respond directly in the notebook, replying back to the student and commenting on what had been written. This transparency helped encourage best practices, which faculty would share with each other during the cohort meeting. Students who may not have updated their notebooks or attended meetings were also discussed. Based on feedback from other faculty, information about regional power outages, illness, or work schedules, which may have impacted students during the week, was shared; and faculty mentors were able to use this empathetic perspective the following week to follow up with their students, resolving any missing entries or absences. The vREU environment ensured that faculty were not isolated in their work with students, and always had a supportive community of peers to consult for ideas and insight, as did the students participating in the vREU. The vREU effort leveraged the work of the faculty cohort to mentor the participating faculty in much the same way the faculty were themselves mentoring the participating students. The inclusion of reflection for faculty during the cohort sessions, reflecting on the past week and plans for the future, as well as for the student in their research journal entries, identified the importance and utility of the ARG model for the vREU process. Finally, all participants, faculty and students, had a shared, authentic task, in the research project each team had selected, and all were focused on the same goal — preparing a poster presentation for the GMiS conference in fall. Leveraged efforts, reflection, shared tasks, and goals — all supported the positive faculty development environment. The burden that faculty experienced with in-person, on-campus REU mentoring, such as logistics, housing, student cohort activities, was removed and replaced with faculty student mentoring focused on research and tasks to be accomplished.

Evaluation Results

Results from the analysis of the vREU experience were gathered. Of the 21 faculty participating in the vREU, 16 responded to a survey administered by an external evaluator. Overall, faculty reported that student interest in graduate school and research careers had increased after students participated in the CAHSI vREU program.

Faculty and students who participated in the vREU experience were asked to participate in surveys adapted from previous evaluation studies of the ARG model. The faculty survey results are highlighted in this paper, particularly the results that relate to the experience of the preparation

and the implementation of ARG in the virtual setting.

Faculty reported that they had a "good understanding" of the ARG model following the vREU experience (71%), with one respondent (7%) indicating "a lot of understanding" and about 1 in 5 (21%) stating that they had "some understanding of the model," as shown in Figure 1.

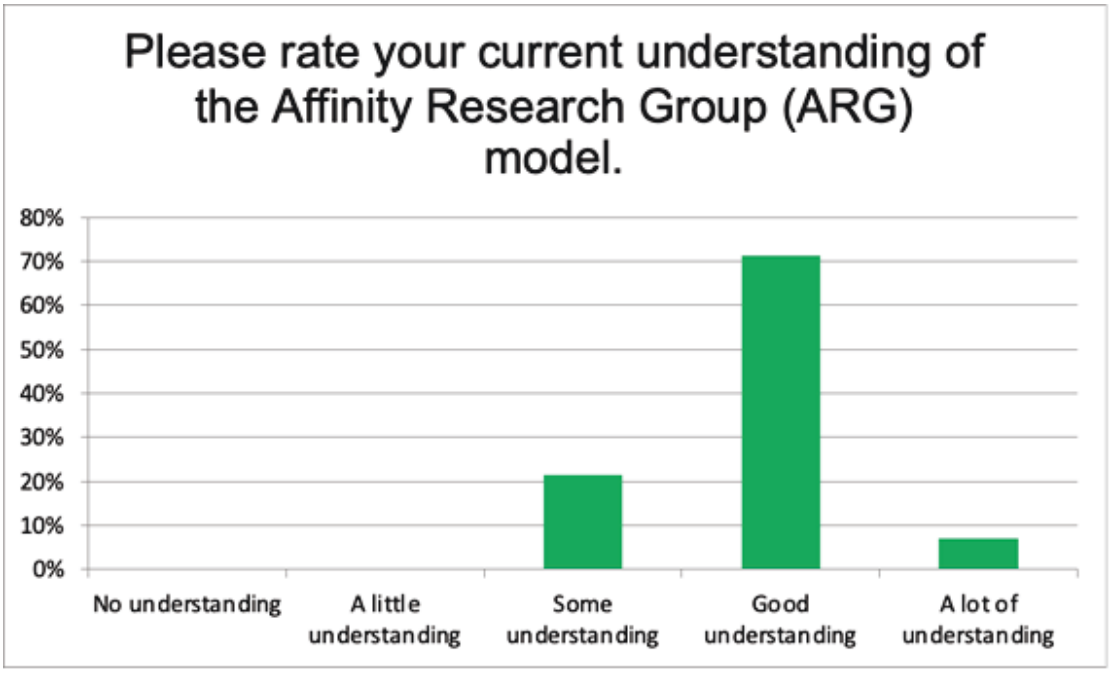

Figure 1. Faculty rating their understanding of the ARG model at the conclusion of the vREU.

Faculty found the model "highly effective" for developing undergraduate researchers (50%) with remaining faculty noting it was "mostly effective" (29%), somewhat effective (14%) and "a little effective" (7%), as shown in Figure 2.

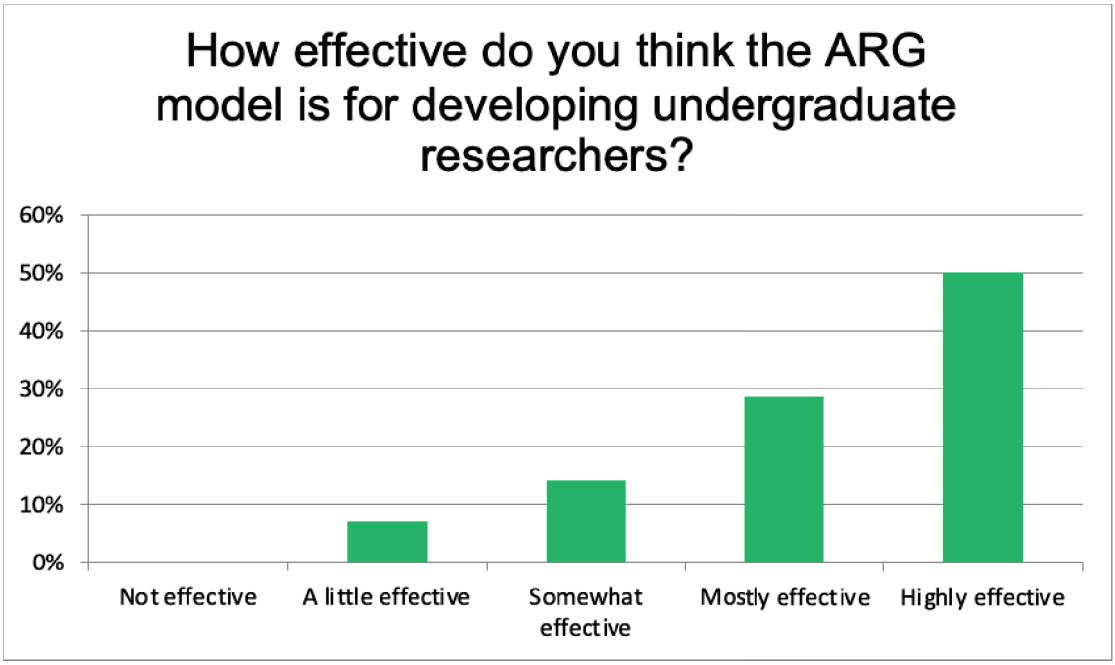

Figure 2. Faculty rating the online version of ARG for developing undergraduate researchers.

Faculty were most likely to state they implemented ARG "to a moderate extent" (57%) than they were to state implementation was "to a great extent" (21%), as shown in Figure 3.

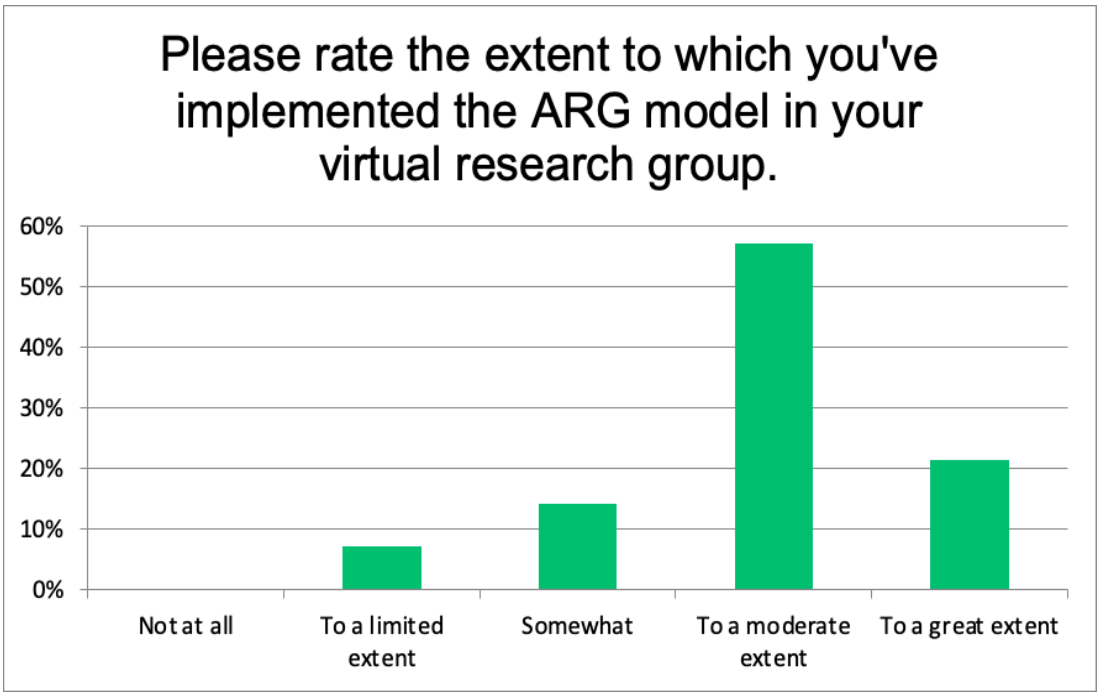

Figure 3. Faculty rating the extent to which they implemented the ARG model.

Faculty were asked to describe how the weekly preparation influenced their work in the vREU. Faculty reported that they appreciated the initial workshop and the weekly meetings with peers, as well as the use of the Slack channel. Those who had already worked in an ARG model saw the initial workshop as a good refresher; and, for those new to ARG, the weekly meetings were important information sources.

Faculty engagement with ARG. Faculty found the most useful concepts to introduce to students were: a) the ways to provide constructive feedback, and b) the skill of asking probing questions. Others were appreciative of the resources (e.g., materials to learn about elevator speeches) and the technical structure (e.g., use of notebooks and journals structured for student use). Multiple faculty noted the integration of what they already do with students with the ideas of the ARG model — an example was the introduction of a storyboard as a tool for communication within the research experience.

Research formats differed by faculty, who were serving as mentors, with some meeting daily with all students and others sharing the meeting responsibilities with graduate students to a greater degree. Most faculty met 2-3 times per week for an extended time, often with other peers with whom the vREU students were engaged. Many faculty described structured set-ups, such as the first meeting of the week with student presentations of progress incorporating group feedback and the second meeting allowing for skill building. Faculty specified tools the students should use to keep on task and to keep the group informed. Faculty appeared to differ regarding the extent to which communication was encouraged across group members and with the individual faculty member beyond the meeting times — some indicated regular email and text communications while others did not. Some faculty mentioned forming personal relationships while others did not. An example of a vREU structure is explained by one of the faculty mentors:

> *I had a group of two students. We had two weekly meetings of 2 hours each. The first meeting each week started with a research paper presentation done by one of the students, over a paper related to the research project assigned by me a week in advance. The second*

student would have to ask probing questions and provide constructive feedback at the end of the presentation. After this part, we would go over a professional development session based on the CAHSI provided materials. This presentation/workshop would be led by me. The final part of the meeting would be a brief chat to determine if the weekly assignments were clear and see if there were any issues to be addressed by me.

The second meeting of the week would be split evenly with each student having one hour to work on his project, while the other student would be part of the conversation for feedback and suggestions. We would go over the assigned work for the week and go over questions and potential issues. As the research progressed, we used this meeting also for the students to review their abstracts, elevator pitch, poster and presentation with the other students contributing with questions and feedback.

Shifting Online. Faculty described how the online REU model compared to the face-to-face model. For most it was the first time they facilitated research groups fully on a remote platform, and there were adjustments made to support student development at a distance. This section summarizes main points from faculty open-ended responses.

Benefits of the online format included the creation of access for more students to learn from faculty members and peers from other computing departments; the online format could be run from any location, cutting down on commute time and making time and place flexible for faculty and students alike; and, finally, the formality of meetings online made for more polished products by students and faculty — time together was more structured than in a more fluid in-person lab setting.

Drawbacks of the online format included lack of hardware, requiring shipment to a student's home; onboarding students with software was slower and more difficult; troubleshooting was more difficult at a distance; non-verbal communication cues were lacking; internet connectivity for some students and faculty mentors was problematic; and, finally, the ability of students to anonymize self or avoid face-to-face connection with video-influenced, relationship-building with faculty and peers.

Summary

Many of the suggestions for further refinement of the vREU program using ARG may be naturally addressed as the program evolves in subsequent years. Specifically, the initial vREU program using ARG was developed for online use as the program progressed, just in time for use. Future iterations will provide faculty with the ARG materials in the beginning which will support their use and further re-development of materials, as needed.

Faculty feedback identified an interest in contributing to the ARG materials, modified as needed, for the next set of vREU mentors. They expressed interest in building the resource base for future participants. Timelines for vREU expected metrics and outcomes provided early in the program would help alleviate the stress of preparing for the GMiS virtual poster session in late September — faculty were not always sure about what was expected from their undergraduates and when it was expected.

Faculty encouraged multimedia resource development and hoped to use it to supplement skill-building workshops. A faculty member noted that adding in opportunities to measure growth quantitatively or qualitatively in a structured way would be beneficial. For example, the faculty member mentioned asking students to complete an elevator pitch in early, mid, and later weeks of the program as a potential model for all to adopt.

Overall, students and faculty were positive about the vREU program, particularly the structure, sense of collective action, and sense of support for the majority of faculty and students. The student self-reported outcomes indicate the vREU is a viable option for student growth and research advancement. Students reported the most growth in research skills (89%), technical knowledge (64%) and communication skills, both oral and written (66%). Personal growth, defined as confidence and patience with setbacks also grew (57%).

The vREU using the ARG model successfully provided 51 students with undergraduate research experiences they would not otherwise have had. This approach also provided an ongoing faculty workshop for the 21 faculty participating from 14 universities and built a cohort faculty community. In addition to the poster presentations at GMiS during fall, ongoing interactions with the faculty have been sustained. Having first been introduced during the vREU experience, many of the faculty continue to collaborate and use ARG methods, and are developing grant proposals for submission to NSF on topics that were first explored with their undergraduate researchers during the summer. Future vREU experiences are being considered, and the ARG model has been successfully shared with the 72 students and faculty that participated in this experience.

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