An Analysis of Virtual Research Experiences for Undergraduates Programs in Light of the COVID-19 Pandemic

Jennifer Collins, Amy Polen, Isabelle Jernigan, Delián Colón-Burgos, Killian McSweeney, and Melyssa Spandri

ABSTRACT: With the continued social distancing requirements of the novel COVID-19 pandemic, many in-person educational programs were halted in 2020, including specialty education and research experiences for undergraduates. However, some Research Experiences for Undergraduates (REUs) progressed in summer 2020 in a fully virtual format. The importance of understanding how these practical STEM skills translated in a virtual REU format, in addition to areas of improvement going forward, are critical to the development of effective online STEM learning through REUs. Two survey instruments were designed to capture data from both the REU mentors (including the PIs) and the students in the programs. Questions included information on the REU they participated in, their perceptions of the best and worst aspects, their overall satisfaction with the experience, and their likelihood to seek out virtual REUs in the future. Overall, both students and faculty involved in virtual REUs were glad to have had the experience and were satisfied with it. The benefits of flexibility, the ease of communication and scheduling, and the increased access to online resources were echoed as the strengths of the virtual format. However, many believe that an in-person REU had benefits that could not be replicated in a virtual environment, including community building and hands-on experiences. Several were bogged down by technical difficulties. With more effort made to include community building to a greater extent, as well as considerations and planning for technical demands, the future of widely accessible online REU experiences is a bright one.

KEYWORDS: Atmosphere; Social Science; Education

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With the continued social distancing requirements of the novel COVID-19 pandemic, many in-person educational programs at all levels were halted in 2020 on a global scale, including specialty education and research experiences for undergraduates that funded undergraduate students to travel to state-of-the-art research universities and laboratories to develop their skills and research prowess. These were especially affected due to the nature of the programs. The traditional and popular National Science Foundation (NSF)-funded summer Research Experience for Undergraduates (REU) format entailed undergraduate students from across the country traveling to a central location and living in dorms together during the summer. As such, the overwhelming majority of REU programs were cancelled during the summer of 2020.

A handful of REUs chose to forge ahead partially or fully virtual in an attempt to give hundreds of undergraduate students a chance to develop new skills and partake in research initiatives (Sloan et al. 2020). This transition also allowed many students who had already been given a contract to keep their REU-provided summer income and housing that they would have otherwise lost (Price et al. 2020). Although this breaks the traditional in-person REU offering, it allowed for faculty to try novel approaches to education.

The execution of a (partially) virtual REU has been attempted previously, such as in 2006 with the Incorporated Research Institutions for Seismology (IRIS) Education and Outreach Program. This program was a blended model of face-to-face and virtual meetings spread out across the nation (Hubenthal et al. 2007). Furthermore, a hybrid-model REU was conducted at the Urban Water Innovation Network (UWNI) at Colorado State University; this consisted of students traveling to separate institutions and meeting virtually with others in the REU during the program’s duration. Elements of REUs prior to COVID-19 were also online. For example, Collins’ and Ersing’s REU hosted at the University of South Florida (2018–20) on Weather, Climate, and Society had a remote summer speaker series. However, the reasons these programs chose to host components remotely were very different than those necessitated by COVID-19. Instead, the reasons included reaching and engaging a broad audience beyond a physical classroom, the ability to invite experts in the field who may not have the time to come to an in-person speaker series, the reduction of cost and travel-related carbon emissions for several speakers, and budget. The remote format allowed for these highly respected scientists to share their research. However, the demands necessitated by the pandemic for fully virtual REU adaptation presented an opportunity for REUs to be entirely innovative in their execution. For example, an REU program at the University of California, San Diego, that chose to continue online in 2020 managed to make the best of the situation and opened access to the course, which drastically increased its class size from 10 U.S.-based students to over 700 students representing a broad international scene (Chin 2020). Many REUs used video conferencing platforms, breakout rooms, and screen sharing.

Despite this push for online learning and research, there are limitations to the format. Kohan et al. (2017) found three identifiable barriers to education in a self-guided virtual learning environment at a postgraduate level: 1) cognitive barriers including information overload and lack of focus, 2) communication barriers, and 3) educational and environmental barriers such as those created by socioeconomic disparities. In addition, according to Chin (2020), practical hands-on laboratory and field skills are next to impossible to convey easily over
the Internet. Other research practices such as qualitative data-gathering and its associated skills, such as those used in interviews, are a fundamentally different experience in an online setting (Deakin and Wakefield 2014). In a survey conducted on college students since the COVID-19 pandemic’s start, it was found that many students did not feel comfortable with an online class format, especially with laboratory and field courses that are difficult experiences to replicate online (Carnegie Dartlet 2020). Integration of hands-on skills development has been shown to be quite effective in retaining students in STEM fields during their higher education and their future careers (Price et al. 2020); as such, students who are missing out on this level of interaction in their online programs may have a lower rate of STEM-driven interest and degree enrollment going forward in their academic pursuits (Day et al. 2021). This is especially true for minority groups in STEM, who are deeply impacted by in-person research experiences such as those provided by an REU and who are recruited by NSF’s program for inclusion (Price et al. 2020).

Another downfall of online learning comes from a more personal and emotional level when considering the REU students, mentors, and partners. For one, virtual REU learning can lead to a lack of community development. Community development is a critical buffer for emotional stress levels, which positively impacts students’ likelihood of success in an academic setting (Pate et al. 2017). As well, increased levels of familiarity can promote more effective research in an online team setting (Maynard et al. 2018). Traditionally, the small student cohort seen at in-person REUs (often 8–10 students) fosters connection and friendship among the students who participate. However, Chin (2020) notes that this aspect can be lacking from online interactions such as those seen during a virtual REU. Additionally, Day et al. (2021) note that the social connection fostered in a physical classroom is critical. According to Chin (2020) and Hubenthal et al. (2007), this lack of community can be eased, but not replaced, through the use of informal chat rooms, video calls among students, and other digital community promotion activities. Chat rooms and other online communications are not perfect tools either; for instance, although online interactions during a period of isolation (such as chat rooms) replicate many of the aspects of in-person socialization, they are also linked to higher levels of depression despite decreasing a student’s loneliness (Ellis et al. 2020). Furthermore, Chametzky (2016) established that a sense of isolation can prove to be a significant barrier to online learning.

While examining online learning environments in general, it has been seen that students experience increased stress, anxiety, depression, and other mental health tolls (Day et al. 2021; Hillard et al. 2020; Kohan et al. 2017; Moawad 2020). This anxiety tends to stem from concerns about the lack of guidance and large amounts of information traditionally presented in collegiate online courses (Kohan et al. 2017). Hillard et al. (2020) identified college students’ additional anxiety in online collaborative group settings due to factors such as relying on others to finish tasks, not being in complete control, and a general fear of letting their group members down.

The sudden change in format caused by the rapid-onset COVID-19 pandemic resulted in high stress among college students due to the high level of uncertainty, with a greater effect on those who were already vulnerable to stress and other mental health issues (Day et al. 2021; Moawad 2020). This stress persisted past the initial academic shutdowns with other stressors such as Internet problems (Moawad 2020). Information overload experienced by the actual or perceived heavier workloads from online courses and increased demands of time management (that may be on a different level previously expected of a student) has been shown to lead to higher rates of stress among students (Chen et al. 2012; Kohan et al. 2017; Moawad 2020). It has been found that decreasing levels of academic stress among college students leads to increases in self-directed learning readiness, or a student’s ability to independently learn information in a format such as what is seen in online learning experiences (Heo and Han 2018).
Socioeconomic status (SES) and further inequities also have a large role in the success of e-learning programs, skewing them to benefit those who have greater access to technology and resources (Day et al. 2021; Kohan et al. 2017). A lack of Internet accessibility negatively affects those who do not have the funds to continue services or are in rural areas of the United States (Niner et al. 2020). This gap in Internet connection and technology availability disproportionately affects those in racial and SES minorities (Day et al. 2021; Niner et al. 2020). Furthermore, students who do not have much prior experience working with the technology could be negatively impacted and feel less prepared in the e-learning environment (Day et al. 2021); this can be partially attributed to the positive relationship between a student's level of comprehension and learning and their positive attitudes toward computers (Koskela et al. 2005).

However, there are also potential benefits to learning and research experiences in an online environment. Flexibility has been repeatedly shown in prior literature as being a key benefit to online learning and research (Chin 2020; Evans and Mathur 2005; Gilbert 2015; Granello and Wheaton 2004; Kim et al. 2005). As previously stated, the virtual environment allows many students who may have logistical or physical barriers when considering in-person learning and research experiences to now participate in the flexible “anytime, anywhere” format that virtual learning promotes (Chin 2020; Kim et al. 2005). Examples of these nontraditional students would include students who are hospitalized, already working full-time, or are single parents (Chaney 2001; Kim et al. 2005). It also allows students to have additional learning opportunities as they can take courses regardless of their location, providing students with more options for coursework that may not be offered at their home school or institution (Gilbert 2015) and credit for REU programs can often be transferred to their own programs. Additionally, by offering courses online to students at multiple institutions, budget concerns are minimized as less funding is needed for in-person professors or teachers. The “anytime, anywhere” format is especially beneficial to students from rural or lower socioeconomic communities, as online learning can lessen the financial demands of in-person education while still providing a wide range of learning opportunities (Gilbert 2015). These financial demands even include indirect costs to the students such as those associated with having to pay for pet sitting or taking care of a family member when a student participates in an in-person offering.

A computer-based learning environment gives students freedom to absorb information often at their own pace, allowing a better understanding of the key concepts presented (Koskela et al. 2005). Students who thrive with self-regulated learning prefer and do very well in online learning as it allows them the freedom to focus on more difficult topics and less time on easily understood concepts (Gilbert 2015). In a survey given to MBA students conducted by Kim et al. (2005), it was found that over 70% of students had a positive learning experience and 93% found that they were satisfied with their online course’s quality. Wiechowski and Washburn (2014) have also found that college students have a higher course satisfaction in blended or entirely online courses versus their traditional in-person counterparts. Similarly, online research such as that in an REU setting comes with benefits, including convenience, ease of data entry, format flexibility, increased speed, reduced costs, and a wide access to different populations (Evans and Mathur 2005; Granello and Wheaton 2004).

E-learning also provides students with the experience to be successful in school and society. It has been shown in prior research that online learning at a collegiate level can better prepare students for integration into the modern “knowledge-based society” (Appana 2008). Furthermore, the development of self-efficacy and scheduling skills needed for collegiate online learning is critical as a strong sense of self-efficacy can be a predictor of continued research interest and career choices (Adedokun et al. 2013). Although students need to learn the skills to manage self-learning and the large amounts of information provided in an online setting, studies have found that many college students have already developed these skills before transitioning to fully online learning for COVID-19 and that students who have had
prior online experience are better equipped for the prolonged e-learning necessitated by the pandemic (Chen et al. 2012; Day et al. 2021). Characteristics of successful e-learning include providing a student with sufficient training on the digital tools, creating a social environment that encourages digital discussion and interaction between students and with the teacher, and providing a consistent course experience throughout (Kim et al. 2005).

The importance of understanding how these practical STEM skills translated in a virtual REU format, in addition to areas of improvement going forward, are critical to the development of effective online STEM learning through REUs. This understanding is important to higher education’s embrace of e-learning, which 65% of universities and colleges are considering within a long-term strategy (Kohan et al. 2017). As such, this study explores the online REU experience from the perspectives of both mentors and students. Topics examined included difficulties and benefits of the online format, overall satisfaction with the experience, the perceived level of worth of the online program, and any future recommendations for program efficiency in an online format. It is important to note that, regardless of the format, undergraduate research experiences are an effective tool at widening a student’s view of what research can look like, potentially increasing interest (Linn et al. 2015).

Methodology

Survey design. Two survey instruments captured data from REU mentors (including the PIs) and the students in the programs. The mentor and student surveys consisted of 31 and 28 questions, respectively (see appendix). Although these survey instruments slightly differed to account for the role of the individual, the surveys consisted of similar questions, including information on the REU they participated in, their perceptions of the best and worst aspects, their overall satisfaction with the experience, and their likelihood to seek out virtual REUs in the future. The questions were either short-answer, ordinal, or categorical in nature, with an additional reliance on Likert-scale questions. The surveys were not based on previous surveys; rather, these surveys were designed by the authors with the intention of capturing as much novel data regarding the emotional experiences of a virtual REU as well as its perceived worth for both students and mentors. Both surveys, once ready in a virtual tool (Qualtrics), went through rigorous testing from volunteers to ensure it functioned properly and that the questions’ wording was easy to understand and resulted in the desired response.

Both of these surveys are organized starting with information on the participant: the REU program a student or mentor was a part of, their supervisor, the field of science the REU fell under, and their role in the REU. This is then followed by a series of Likert-scale and multiple-choice questions aiming to assess various results, perceived learning success, and emotions from their REU experience. Following this, a mixture of multiple-choice response and short answer questions were asked to determine the best and worst aspects of an REU, especially regarding their satisfaction with various aspects of the program and the resources made available to them. Finally, demographics of the survey respondent were collected. For further information on the content of the surveys, please see the appendix, which includes both survey instruments.

Data distribution and collection procedures. The online survey, accessible via Qualtrics, was live for approximately 6 weeks from 3 August to 15 September 2020, and it was distributed through the REU-GEO listserv hosted by the University Corporation of Atmospheric Research (UCAR). This listserv has provided a forum primarily for Principal Investigators of REU grants to have fruitful discussions and a support network. The survey was further distributed from this listserv through these individuals’ academic networks to a host of universities and laboratories conducting virtual REUs during 2020, and to their own mentors and students of their programs. The sampling method was therefore a combination of convenience sampling and
snowball sampling. With a total of 237 respondents within 6 weeks of data collection, the survey was sent out to this group just one time.

**Data analysis techniques.** After data were cleaned from their original Qualtrics output, which involved categorization of short-answer responses into overall themes, consolidation of questions for analysis, and verification of answer’s accuracy, analysis was conducted using SPSS Statistics v26. Any short-answer questions were grouped by the research team into thematic categories based on their original responses for analytical purposes. Nonparametric testing and simple frequencies were relied on as the primary data processing techniques due to the nature of the questions asked on this survey.

**Results**

**Sample size and characteristics.** Of the 237 respondents to the surveys, 146 consisted of students and 91 consisted of mentor responses. Individuals who responded represented 44 universities or laboratories and 43 distinct REU programs from a diverse geographical region spanning the length of the United States (it is important to note that a university can be host to many different REUs and that some REU programs exist across multiple universities). These students and mentors also represented over 60 STEM subfields including geosciences, physics, and mathematics; 87.0% of students and 82.2% of mentors stated that their REUs were funded by NSF.

**Student results.** As shown in Table 1, 14.2% of students identified as a first-generation student, and 2.2% of students identified as a U.S. veteran or active-duty service member. Regarding STEM representation, 51.4% of individuals identified as a woman and approximately half (47.4%) of participants identified as belonging to at least one underrepresented ethnicity (including Native American/Alaskan Native, Asian American/South Asian American, Black/African American, Middle Eastern/North African, or of Hispanic, Latino, or Spanish origin). Approximately half (51.5%) of the students had prior in-person research experience (Table 1). In total, 90.9% of students either agreed or strongly agreed with the statement “I am glad the REU program went ahead in a virtual format this year,” with 75.5% of students strongly agreeing with this statement. 89.5% of students strongly agreed or agreed that the REU covered all their essential expenses during the program’s course, with 86.7% of students not needing a job during the REU.

A total of 95.1% of students found their virtual REU experience to be rewarding, with 62.0% of respondents replying “strongly agree” and 33.1% responding “agree” to the statement “I found my virtual REU experience to be rewarding.” There was an association between a participant’s response to this question and their prior research experience [$X^2(3) = 7.547$, $p = 0.056$], with those individuals who had prior research experience more likely to “strongly agree” (72.5% compared to 55.4% among those without prior in-person research experiences). Interestingly, only those students who did not have prior research experience disagreed with this statement.

However, only 38.8% of students thought the program was as rewarding as they would have expected it to be if the REU was conducted in-person (Fig. 1). When presented with the statement “If I were to do an REU again, I would consider a virtual REU,” 20.3% answered definitely true, 52.6% answered probably true, 23.3% answered probably false, and 3.8% answered definitely false (Fig. 2).

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<th>Question</th>
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<tr>
<td>First-generation student</td>
<td>14.2</td>
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<td>U.S. veteran or active-duty service member</td>
<td>2.2</td>
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<tr>
<td>Identified as a woman</td>
<td>51.4</td>
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<tr>
<td>Belongs to at least one underrepresented ethnicity</td>
<td>47.3</td>
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<tr>
<td>Had prior in-person research experience</td>
<td>51.5</td>
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Table 1. Student responses to questions regarding their demographics, presented in percentages. $N = 134, 134, 133, 133$, and 134, respectively.
When presented with the statement “My experience with the REU reinforced my desire to either stay in, or change my major to, a STEM field,” 62.0% strongly agreed, 25.4% agreed, 10.6% neither agreed nor disagreed, 2.1% disagreed, with none strongly disagreeing.

There was a strong association between a student’s desire to change or remain in a STEM field and their prior research experiences \(X^2(3) = 10.067, p = 0.018\), with students who had prior research experience more likely to agree with the statement (97.1% compared to 80% among those without prior research experiences). Those without prior research experience were far more likely to say that the REU did not influence their desire to pursue a STEM career (16.9% compared to 2.9% among those with prior research experience) and represented all those who disagreed with the statement presented.

A total of 91.6% of students were still able to have a mentored research experience as part of their REU, with only 6.2% stating that they had a mentored experience to some extent, and 2.1% stating they did not have a mentored research experience. This may be a reflection that more PIs participated and shared the survey if they were providing a full mentored research experience. Although not all REUs adopt a research team approach, when asked if they got experience working within a research team, 63.4% believed the statement to be definitely true and 24.6% believed it to be probably true. When presented with the statement “I had individual responsibilities with my research,” 88.7% of students found this to be definitely true and an additional 8.5% found this to be probably true. In total, 95.2% of students identified the research project as doable within the virtual format. This could be attributed to many student respondents identifying a coding-based project, which lends itself to review and collaboration readily in a virtual format. The student–mentor relationship was found to be beneficial, with 90.8% of students agreeing that they worked effectively in a virtual format with their mentor; 90.9% of students also agreed that their mentors were available when they needed to touch base with them.

Most students (82.1%) found that the amount of time working independently to be about right. Many students (52.6%) found that there was too little time spent with student members of their program, with none considering it was too much time; 66.2% and 82.7% of students identified the time they spent in research teams and talking to their mentors as about right, respectively (Table 2).

When asked about technical difficulties, 10.4% of students identified “a lot” of these experiences while an additional 61.2% identified they had technical difficulties “a few” times. Most students (92.5%) had access to library and other academic resources.
When asked about the best aspects of being virtual for their REU, many students identified the added flexibility (26.0%), ease of communication and collaboration (26.9%), and tools offered by online learning (13.2%) to be of top importance. When asked to identify their least favorite aspects of a virtual REU, the overwhelming majority of students identified the lack of social interactions with other students and other face-to-face interactions to be the worst aspect (40.0%). Other areas of note include technical difficulties (5.5%) and a lack of hands-on and laboratory experiences (20.8%) (Fig. 3).

Mentor results. Of the respondents, 24.4% identified themselves as PIs or co-PIs, 58.9% identified as mentors, and 16.7% identified as both. Further, 8.2% identified as assistant professors, 10.6% identified as associate professors, 22.4% identified as full professors, and 58.8% identified in the “other” category (such as lecturers, instructors, research associates, and graduate students). A total of 72.9% of the respondents also identified that they served as a mentor or a PI for an REU in the past. As shown in Table 3, when asked if they were glad that the REU went ahead in a virtual format this year, 65.6% strongly agreed, 32.3% agreed, and 2.2% neither agreed nor disagreed; no mentor indicated that they disagreed and were unhappy that the REU progressed virtually. Almost all (96.5%) mentors agreed that they found their virtual REU experience rewarding.

Only 40.0% of mentors stated that they agreed that their research experience was as rewarding as it would have been in an in-person REU setting (Fig. 1). Equally stark, only 37.2% of mentors agreed that the research experience for the student was as rewarding as it would have been in-person. Despite this, 92.1% of mentors either strongly agreed or agreed that they were able to develop a project that fit the virtual setting (Table 3). There was a significant association between the respondent’s designation as a mentor, (co)-PI, or both in regards to their feelings of project development \( X^2(6) = 15.463, p = 0.017 \). Those who solely served the role of PI or co-PIs

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<td>0.7</td>
<td>82.1</td>
<td>14.9</td>
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<tr>
<td>Time with all student members of your REU program</td>
<td>52.6</td>
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<td>Time spent in research teams</td>
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<td>66.2</td>
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were more likely than any group to strongly disagree that they were able to develop an appropriate project, making up all dissenting responses to this question. Additionally, those who served as mentors only agreed with the statement, with no individuals showing indifference or disagreement. A total of 57.6% of mentors stated that they used online tools with their students and 72.9% stated that their students needed to download specialized software for the REU, with 39.4% of mentors finding difficulties, at least to some extent, downloading and operating this software. Overall, 41.9% of mentors indicated that they felt more burdened in a virtual format.

When presented with the statement that they would consider a virtual REU again in their role as a mentor or PI, 47.6% found it to be definitely true, 35.7% found it to be probably true, 10.7% found it to be probably false, and 6.0% found it to be definitely false (Fig. 2). There was no significant difference between (co-)PIs, mentors, or those who served both roles when answering this question. When asking those who were mentors or PIs previously if this virtual experience was comparable to in-person, 3.2% stated it was better than in-person, 41.9% found it to be about the same, and 54.8% found it to be not as good as an in-person option (Fig. 4).

Almost all mentors (97.6%) agreed that they found their students were engaged with the virtual REU. When asked if the mentees in their program worked effectively in a virtual format, 38.8% strongly agreed, 50.6% agreed, 9.4% neither agreed nor disagreed, and 1.2% disagreed (Table 3). Mentors indicated that 72.6% of them met at least two times a week; 31.3% of PIs indicated that they themselves met with the students at least twice a week.

A total of 83.3% of mentors believed that the REU provided a mentored research experience, with an additional 11.1% supporting this to some extent. When presented with the statement “The REU students got experience working within a research team,” 62.4% found this to be definitely true and 29.4% found it to be probably true. When presented with the statement “The REU students had individual responsibilities with their research,” 84.9% found this to be definitely true and 10.5% found it to be probably true (Table 4).

When asked the best aspects of transitioning to an online REU, many mentors answered that the fact that it allowed students to still have an REU (11.0%), that it provided flexibility (19.1%), and ease with meeting scheduling were the best parts (23.1%). The least favorite aspects of the virtual format for mentors included the lack of community building and in-person collaboration (27.9%), not being able to do field work (15.0%), and a higher difficulty level of teaching (14.3%) (Fig. 3).

<table>
<thead>
<tr>
<th>Table 3. Mentor responses regarding their experience with the virtual REU, presented in percentages. N = 90, 88, 85, and 85, respectively.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly agree</td>
</tr>
<tr>
<td>&quot;I am glad the REU program went ahead in a virtual format this year.&quot;</td>
</tr>
<tr>
<td>&quot;I was able to develop a research project for the REU which worked well in a virtual setting.&quot;</td>
</tr>
<tr>
<td>“I found my students were engaged with the virtual REU.”</td>
</tr>
<tr>
<td>“My mentee(s) and I worked effectively in the virtual format.”</td>
</tr>
<tr>
<td>How would you rate this virtual experience comparatively?</td>
</tr>
<tr>
<td><img src="image" alt="Fig. 4. Responses from mentors who had been involved in a previous REU to “How would you rate the virtual experience comparatively?” N = 62." /></td>
</tr>
</tbody>
</table>
Discussion

Students. Most students (90%) indicated they were happy that the REU was able to forge ahead in a virtual format. It should be noted that it is possible that students who did not participate in this study were offered an REU position but declined as they knew this virtual option was not for them. Additionally, 72.9% of students indicated they would consider participating in a virtual REU again in the future, although 61.2% believed that an in-person REU experience would be more rewarding.

Many students also found some unexpected benefits seen to the online program format. For instance, one student discussed in her extended responses her increased comfort at navigating teamwork as the only woman on a team; this is contrary to Hillard et al.’s (2020) results, which found collaborative group work in online settings can cause additional anxiety. Students who had prior research experience were more likely to be able to gain a better research experience that was rewarding and impacted their future desires to pursue a STEM degree than their counterparts who did not have a prior in-person research experience. Other benefits that the students identified included the increased flexibility, ease of communications, and large availability of online resources for them to use, which are all consistent with the benefits of online research noted by Evens and Mathur (2005) and Granello and Wheaton (2004).

Mentors. Nearly all mentors (97.9%) indicated they were happy the REU continued in a virtual format. Furthermore, 83.3% of mentors indicated that they would consider participating in a virtual REU in the future even though 62.8% agreed that an in-person REU would be more rewarding.

For their own personal experiences, 41.9% of mentors felt more burdened with research and teaching within the online format, and 40% of mentors indicated their research experience was not as rewarding in the virtual setting. Mentors did identify that the ease of scheduling meetings, the flexibility, and the ability of students to still participate in an REU were benefits, indicating that there were positive aspects despite the drawbacks of a virtual environment such as the lack of community-building and higher difficulty of teaching that they experienced.

Students and mentors. When examining the results, many similarities appear between the perceptions of a virtual REU for students and mentors alike. Both parties were incredibly happy the REU was able to forge ahead in a virtual format, and a significant majority of both groups indicated that they would consider participating in a virtual REU in the future. Despite this high support, both groups were also overwhelmingly likely to agree that an in-person REU experience would be more rewarding.

Both parties felt that the experience provided a mentored research experience that, although potentially lacking on the research and skills benefits of in-person fieldwork, laboratory work, and collaborative teamwork (consistent with the findings of Chin 2020), appropriately gave students the chance to independently contribute meaningful research to the overall project. However, mentors faced a particular burden with research and teaching within the online format that was not experienced by students. Approximately half of mentors reported feeling more burdened in a virtual setting, and almost half indicated that their research experience was not as rewarding as it would have been in an in-person setting. Mentors indicated that

<table>
<thead>
<tr>
<th></th>
<th>Definitely true</th>
<th>Probably true</th>
<th>Probably false</th>
<th>Definitely false</th>
</tr>
</thead>
<tbody>
<tr>
<td>“The REU students got experience working within a research team.”</td>
<td>62.4</td>
<td>29.4</td>
<td>5.9</td>
<td>2.4</td>
</tr>
<tr>
<td>“The REU students had individual responsibilities with their research.”</td>
<td>84.9</td>
<td>10.5</td>
<td>1.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>
this additional burden in an online format resulted from the teaching being more challenging and more time consuming due to its planning necessities, general nature, and the fact that mentors could not rely on other faculty and graduate students in their department as heavily. Mentors also felt that it was more burdensome due to a lack of social bonds and natural interactions, resulting in students who were less engaged during the program.

Sentiments of the lack of community building were echoed in both the student and mentor results, similar to Chin (2020) and Hubenthal et al. (2007), with this facet of the virtual program being a number-one complaint among both groups. Other drawbacks of the virtual program that were disagreeable to both were the burden of technical difficulties and the lack of hands-on laboratory or field research opportunities.

Limitations. Due to the nature of this study’s distribution, there are potential limitations regarding generalizability of results. First, it is hard to gain a sense of the response rate to this survey in comparison to the population of all students and mentors involved with REU programs in 2020. Additionally, the results presented herein could be underrepresentative of opinions of those outside of geoscience disciplines as it was distributed through a geosciencesspecific listserv. Those students who are the most engaged in the program may also have been more likely to respond, thus creating a potential bias in the results. Additionally, since selection for REUs is an intensive process and limited by the number of available student positions, students who participated may have been more prepared to overcome the challenges of an online environment. In future virtual REUs, the students may be more broadly distributed resulting in barriers to participation not seen during the highly unique 2020 REU season. As noted previously, some students may have been offered a position and declined, so the survey may be skewed toward students who may have felt more comfortable with a virtual format. The number of students who declined an offer was not offered as a question in the survey.

Conclusions
This research demonstrates that both mentors and students were largely happy with the opportunity to participate in an REU against all odds. With the rapidly assembled online nature of the REUs, many mentors and students still felt a sense of success in engaging students in meaningful independent research while developing skills that were possible without a hands-on face-to-face experience. Mentors and students demonstrated an effective working relationship over a virtual platform. This survey has also demonstrated an interest in future virtual REU experiences from both students and teachers. However, both students and mentors stated that, despite the online format still allowing the students to contribute meaningful research, virtual REUs were not as rewarding as in-person equivalents. It is important to keep in mind that not all students and mentors had a previous REU experience to really compare it to.

As seen in the results and other testimonials on virtual REU formats (Chin 2020), the incorporation of IT departments into early planning is critical to success. Without this key support, technical difficulties can lead to frustrating situations for all involved in the experience. Mentors and (especially) students found technical difficulties to be a huge burden and one of their least favorite aspects to the virtual REU experience. Mentors stated that, although they would strongly consider doing a virtual REU in the future, the experience created additional burden on them. One REU held an IT Office Hours day prior to the REU where software could be downloaded and problems addressed so the technology was on the students’ computers and ready for the start of the REU.

Other key drawbacks of the virtual experience lie in the lack of face-to-face interaction and community building—this was shown to be the top detractor for the online format for both mentors and students. Of note is that no students indicated that too much time was spent on social bonding, leading to the conclusion that more could be conducted to promote a sense of
friendship among virtual REU students. Several REUs did provide ice-breaker activities and other social events such as Games Nights as a method of developing a sense of community, which could be implemented in future virtual REU experiences.

Despite any drawbacks to a virtual REU, the benefits of flexibility, ease of communication, and large availability of online resources does pose its own unique benefits to the virtual format. With more effort made to include community building to a greater extent as well as considerations and planning for technical demands, the future of widely accessible online REU experiences is a bright one. Future work could consider how in-person REUs are incorporating components and materials which people found successful during their virtual experiences. Furthermore, a study comparing virtual and in-person REUs for inclusivity to all students could be considered.

Acknowledgments. We thank those on the REU-GEO listserv for their fruitful discussions and the assistance in distributing surveys to their students and mentors. We would also like to thank Alan Berkowitz for assistance with information on the Urban Water Innovation Network (UWIN) based at Colorado State University. We appreciate the time of mentors and students in completing the survey. We appreciate the feedback on the survey questions from Dr. Valerie Sloan (Director of the GEO REU Network, NCAR Education and Outreach). Finally, we would like to acknowledge students of the NSF Research Experience for Undergraduate program in “Weather, Climate and Society” for input on this project (NSF Award 1659754; PIs: Collins and Ersing).
Appendix: Surveys
Please note the actual survey was on Qualtrics and therefore formatted differently.

Dear REU student,
Please help us to learn about the impact of your virtual learning experience within your REU by filling out this survey. Your participation in this survey is voluntary. You may decline to answer any question and you have the right to withdraw from participation at any time. You do not have to answer all of the questions, and anything you tell us is confidential. Any formal reporting of the survey results will be aggregated with survey responses from other REU programs. The survey tool does not reveal your identity. The survey will take approximately five–ten minutes to complete. If you have any questions about this survey or survey participants’ rights, you may contact me Jennifer Collins directly at collinsjm@usf.edu.
Thank you so much.

Please state
The name of the REU__________
University or laboratory where REU was based ______________
Principle director(s) of REU (if known)___________________________
Say to the extent you agree with these statements:
1. I am glad the REU program went ahead in a virtual format this year.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree______
2. The REU covered all of my essential expenses over the course of the program.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree______
3. I did not have to have another job during the REU program.
   True______ False______
4. Did you have a mentored research experience during your REU?
   Yes______ No______ To some extent______
4b. If you answered “to some extent”, explain…_______________________________
5. I got experience working within a research team.
   Definitely True______ Probably True______ Probably False______ Definitely False______
6. I had individual responsibilities with my research.
   Definitely True______ Probably True______ Probably False______ Definitely False______
7. I found my virtual REU experience rewarding.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree______
   Disagree______ Strongly Disagree______
8. I found my research experience in this REU program to be as rewarding to what I expect I would have received if I had done an in person REU.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree______
   Disagree______ Strongly Disagree______
9. I found my mentors were available when I needed to touch base with them.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree______
Disagree______ Strongly Disagree ______

10. My mentor and I worked effectively in the virtual format.
   Strongly Agree______ Agree_______
   Neither Agree nor Disagree______
   Disagree______ Strongly Disagree______

11. Please indicate the frequency that you connected with at your mentor or at least one of your mentors if you had more than one.
   Less than 1× a week______ 1× a week______
   at least 2× a week______

12. My experience with the REU reinforced for me to either stay in, or change my major to, a STEM field.
   Strongly Agree______ Agree_______
   Neither Agree nor Disagree______
   Disagree______ Strongly Disagree______

13. In order, list the three things you liked best about the virtual format of the REU.
   1.
   2.
   3.

14. In order, list three things you least liked about a virtual REU
   1.
   2.
   3.

15. If I were to do an REU again, I would consider a virtual REU.
   Definitely True______ Probably True______ Probably False______
   Definitely False______

16. What suggestions do you have to your REU leaders to make the virtual experience better if they offer it virtually again?
   1.
   2.
   3.

17. Please comment on the scope of your project in terms of it being both doable and challenging in a virtual environment, including whether you were involved in interpreting and synthesizing results.

18. Please rate your satisfaction with the following:

<table>
<thead>
<tr>
<th></th>
<th>Too Little</th>
<th>About Right</th>
<th>Too Much</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time working independently</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time with all student members of your REU program</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time spent in research teams if applicable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time talking with your mentors</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18b. If you checked “Too little” or “Too much” in any of the above categories, please elaborate for each.

19. Did you have technical difficulties?
   Yes (a lot)______ Yes (a few) _______ No______

19b. If you answered Yes, please describe what these were and if they got resolved within an adequate amount of time.

20. Did you have access online to library resources or other academic resources?
   Yes______ No______
21. Have you previously had an in person research experience.
   Yes______ No______
21b. If yes, please describe.
22. Please indicate your academic standing in this upcoming fall 2020:
   a. High school student
   b. Community college student
   c. Undergraduate student at a 4-yr university
   d. Other explain
23. Do you identify as having a disability as defined under the Americans with Disabilities Act (e.g., physical, mental health, or other disability):
   a. Yes
   b. No
   c. I prefer not to answer
24. Are you a first generation student (meaning that you are the first generation in your family to attend college/university):
   a. Yes
   b. No
   c. I prefer not to answer
25. Are you a U.S. Veteran or active duty service member?
   a. Yes
   b. No
   c. I prefer not to answer
   d. Other (please specify)
26. How would you describe yourself? Please check all that apply.
   a. Man
   b. Woman
   c. Transgender
   d. I identify in a different way
   e. I prefer not to answer
27. How would you describe yourself? Please check all that apply.
   a. American Indian or Alaska Native
   b. Asian American or South Asian American
   c. Black or African American
   d. Hispanic, Latino, or Spanish origin
   e. Middle Eastern or North African origin
   f. Native Hawaiian or Pacific Islander
   g. White or Caucasian
   h. I prefer not to answer
28. Anything else you would like to tell us about your virtual experience __________

Thank you so much for your time in completing this survey!

Dear REU PIs and mentors,
Please help us to learn about the impact of your virtual REU experience by filling out this survey. Your participation in this survey is voluntary. You may decline to answer any question and you have the right to withdraw from participation at any time. You do not have to answer all of the questions, and anything you tell us is confidential. Any formal reporting of the survey results will be aggregated with survey responses from other REU programs. The results will not reveal your identity. The survey will take approximately five–ten minutes to complete. If you have any questions about this survey or survey participants’ rights, you may contact me Jennifer Collins directly at collinsjm@usf.edu.
Thank you so much.

Please state
The name of the REU __________
University or laboratory where REU was based ______________
Principle director(s) of REU ___________________________
Say to the extent you agree with these statements:

1. I am glad the REU program went ahead in a virtual format this year.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree______

2. I was able to develop a research project for the REU which worked in a virtual setting.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree______ N/A______

3. I was aware that at least one of the students in the REU had a job during the REU not related to the REU.
   True______ False______

4. The REU provided a mentored RESEARCH experience for the students.
   Yes______ No______ To some extent______
4b. If you answered “to some extent”, explain... ________________________________

5. The REU students got experience working within a research team.
   Definitely True______ Probably True______ Probably False______
   Definitely False______

6. The REU students had individual responsibilities with their research.
   Definitely True______ Probably True______ Probably False______ Definitely False______

7. I found my virtual REU experience as a PI and/or mentor rewarding.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree ______ N/A______

8. I found MY research experience in this REU program to be as rewarding as if I had done an in person REU.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree ______ N/A______

9. I found the research experience of the REU students in this REU program to be as rewarding as if they had done an in person REU.
   Strongly Agree______ Agree______
   Neither Agree nor Disagree ______
   Disagree______ Strongly Disagree ______ N/A______

10. I found my students were engaged with the virtual REU.
    Strongly Agree______ Agree______
    Neither Agree nor Disagree ______
    Disagree______ Strongly Disagree ______

11. My mentee(s) and I worked effectively in the virtual format.
    Strongly Agree______ Agree______
    Neither Agree nor Disagree ______
    Disagree______ Strongly Disagree ______
12. If you were a mentor, please indicate the frequency that you connected with your mentees
   - Less than 1× a week
   - 1× a week
   - at least 2× a week

13. If you were a PI, please indicate the frequency that you or a Co-PI connected with your mentees
   - Less than 1× a week
   - 1× a week
   - at least 2× a week

14. In order, list the three things you liked best about the virtual format of the REU.
   1. 
   2. 
   3. 

15. In order, list three things you least liked about a virtual REU.
   1. 
   2. 
   3. 

16. If I were to do an REU again as a mentor or PI, I would consider a virtual REU.
   - Definitely True
   - Probably True
   - Probably False
   - Definitely False

17. What suggestions do you have to make the virtual experience of your REU program better if offered virtually again?
   1. 
   2. 
   3. 

18. Please comment on the scope of your project in terms of it being both doable and challenging in a virtual environment, including whether you were involved in interpreting and synthesizing results.

19. Please comment as to any limitations you had in being able to complete the mentored research with your mentees virtually and whether you were able to overcome them.

20. Did students need to download specialized software during the REU? If so, what?
   - Yes
   - No
   - Do not know

21. If Yes, were there difficulties with downloading and opening the specialized software?
   - Yes
   - No
   - To some extent

22. If yes, or to some extent, please elaborate on what these were and how quickly you were able to resolve them.

23. What platform did you use for live sessions? Click all that apply.
   - a. Zoom
   - b. Google Meet
   - c. Go to Meeting
   - d. Other. Please specify.

24. Are there any other online tools you used with your students?
   - Yes
   - No
   - Do not know

24b. If YES, please state

25. Have you mentored or served as a PI for an in-person REU in the past?
   - Yes
   - No

26. If yes, how would you rate this experience comparatively?
   - Better than in-person
   - About the same
   - Worse than in-person
27. If yes (to Q25), Do you feel more burdened in a virtual format (compared to in-person)?
   Yes______ No______
27b. If Yes, why?
28. How would you describe yourself?
   a. Man
   b. Woman
   c. Transgender
   d. I identify in a different way
   e. I prefer not to answer
29. How would you describe your ethnicity?
   a. American Indian or Alaska Native
   b. Asian American or South Asian American
   c. Black or African American
   d. Hispanic, Latino, or Spanish origin
   e. Middle Eastern or North African origin
   f. Native Hawaiian or Pacific Islander
   g. White or Caucasian
   h. I prefer not to answer
30. What stage of career are you?
   a. Faculty: Assistant Professor
   b. Faculty: Associate Professor
   c. Faculty: Full Professor
   d. Other, please specify __________
31. Anything else you would like to tell us about your virtual experience as a mentor or PI? __________

Thank you so much for your time in completing this survey!
References


