Comparison of On-Campus and Virtual Self-Assessment Outcomes for Incoming Appalachian STEM Undergraduates' First Research Experience

Kristin Stover
Department of Biomedical Education & Anatomy, The Ohio State University College of Medicine. 0000-0001-7497-6733

Kimberly Cowley
Youth and Adult Education, ICF

Gillian Gaunt
Department of Biomedical Science, West Virginia School of Osteopathic Medicine

Olivia George
Department of Biomedical Science, West Virginia School of Osteopathic Medicine

Kristy Henson
Department of Natural Sciences, Fairmont State University. 0000-0002-0792-6565

Tuoen Liu
Department of Biomedical Science, West Virginia School of Osteopathic Medicine. 0000-0001-9000-2736

Christopher L. Pankey*
Department of Biomedical Science, West Virginia School of Osteopathic Medicine. 0000-0001-6538-5843
**corresponding author: cpankey@osteo.wvsom.edu.*

Abstract
The First2 Network is an alliance of higher education institutions across the State of West Virginia striving to improve science, technology, engineering, or math (STEM) education by supporting rural, first-generation, and underrepresented college students pursuing STEM majors. Over the summers of 2019 and 2020, the First2 Network delivered two-week summer research immersion experiences at various institutions throughout West Virginia, including our institutions. The 2019 program was delivered on-campus at four universities while the 2020 program was redesigned to be delivered virtually, due to the COVID-19 pandemic, across nine sites. Before and after the immersion experience, students who participated in the program completed a variety of survey questionnaires for the assessment of their interests, expectations, identity, and belonging in STEM. We found that the in-person research experience in 2019 had better outcomes compared to the virtual experience, suggesting that students conducting research directly under their faculty supervisors in-person and on-site will have a more positive impact on their STEM education and career. However, participation in the virtual research format with

structured group activities still resulted in an improvement in belonging and STEM identity, indicating that connecting with students remotely is still worthwhile when it is the most viable option. The student population in West Virginia/Appalachia region faces a number of academic barriers, so there is much to gain by finding new ways to reach as many students as possible with early career development programs. Our virtually delivered program using citizen science projects, group discussions, and team building activities may be a useful template for other STEM programs to search for new ways to connect with a broader population of students off-site.

Keywords: Virtual, in-person, research, network, first-generation, immersive

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The First2 Network is an alliance of public and private higher education institutions throughout West Virginia focused on supporting rural, first generation, and other underrepresented students in the first two years of their college experience. The First2 Network initiative is funded by a 5-year Human Resource Development grant from the National Science Foundation focused on improving science, technology, engineering or math (STEM) participation in underrepresented populations. A major initiative of the First2 Network is summer immersive research experiences for rising freshmen, mentored by undergraduate students and faculty or staff members at the host institution. A goal of the alliance is to double STEM graduation rates in the Appalachian region through immersive experiences, conference attendance, STEM career shadowing, mentoring, and research involvement. Interventions begin the summer prior to freshman year when students are placed at sites throughout the state to gain experience carrying out scientific research. They are also able to continue research after matriculation at their undergraduate institutions by involvement in a campus First2 club and other student leadership activities. These professional development activities not only provide students with resources on their own campus, but also foster a statewide community of STEM engagement.

The student population in rural Appalachia faces several obstacles to their education. These include financial hardship, limited technology and broadband access, deficient career and college attendance information, poor academic preparation, and lower educational expectations. Rural students are less likely to obtain a bachelor’s degree due to their lower socioeconomic background (Byun et al., 2012) with only 15.6% of adults receiving a bachelor’s in rural Appalachia compared to 29.8% of the US overall (Pollard & Jacobsen, 2017). This is compounded by challenges such as a lack of career opportunities other than coal mining and steel production and effective career interventions targeting the cultural and community values of Appalachia (Gibbons et al., 2019). Digital inequalities are also difficult to overcome because of the region’s physical landscape, where hills block wireless signals and make cable instillation difficult (Khan et al., 2020). High school students in Appalachia with aspirations to pursue a STEM career had higher scores in investigating self-efficacy, college outcome expectations, STEMM (additional “M” for medical) college major outcome expectations, math and science self-efficacy, and interest than their peers, making them a high-yield group for potential intervention (Rosecrance et al., 2019). The First2 network targets these students with the goal of incorporating them into the academic and STEM community.

While the 2019 First2 summer immersion experience was in-person on campuses throughout the state of West Virginia, the onset of the coronavirus (COVID-19) pandemic necessitated a transition and redesign for virtual delivery in 2020. Careful consideration was taken during the planning of the online curricula to ensure that the students were still active participants and members of a cohort that got to know each other and their research mentors. The parallel in-person and virtual delivery modes between the two respective years provides us with a unique opportunity to compare learning environments within the same program with the same learning goals. A survey was given to the participants at pre- and post- immersion experience each year, which was used to assess four main aspects of the student’s perspective of their place in STEM before and after the summer immersion program.

We assessed the following four subsets of student perspective: (1) career, (2) efficacy, (3) identity, and (4) belonging. (1) Career certainty was evaluated in order to gauge student convictions in pursing STEM careers before and after completion of the First2 program. Career questions focused on student commitment to a STEM career path and whether the choice of career path was their own. (2) Efficacy was assessed with respect to self, specifically measuring student confidence in their skills as future scientists. Similarly, we also evaluated (3) identity to predict the strength of the student's scientific identity. Finally, (4) belonging was assessed in conjunction with academic achievement, since students with meaningful connections form a sense of belonging that is believed to help them excel academically. The belonging questions centered on how students anticipate being accepted and respected in the college environment. Overall, the evaluation of these four aspects allowed us to assess the effectiveness of the First2 program and observe how students' perceptions changed over the course of the two-week immersion experiences.

Prior to the virtual immersion program, we attempted to identify potential shortcomings due to the digital environment. A previous study comparing on-site to virtual interactions showed that while effectiveness was not diminished, in-person activities fostered more accountability and support (Cilliers et al., 2021). While we incorporated virtual team-building activities, we thought that it might still be difficult to replicate the in-person support. Many sites incorporated office hours into the schedule, either with student mentors and/or faculty members. Other factors influencing the effectiveness of virtual education include digital division, meaning accessibility and quality, and a lack of social skills among students in the virtual environment (Dung, 2020). The inequality of broadband internet access is especially true in many rural areas of West Virginia (Ferris & Vesely, 2021) where our programs took place. We contacted students prior to the immersion and mailed some combination of laptops, hotspots, and cameras to students based on their specific needs.

The objectives of this study were to (1) compare the pre- and post-immersion student surveys for each learning environment to assess the program as a whole, (2) compare in-person vs. virtual experiences to assess whether delivery mode impacted student STEM perspectives, (3) report outcomes for the first two academic years for prior interns, and (4) consider the benefits and challenges that we encountered during virtual experience in the discussion of this paper, highlighting qualitative faculty and student responses and reactions to the program. We expected less positive change in student STEM perspectives with virtual immersion delivery compared to in-person immersion delivery, partially due to the quick transition to this mode, lack of in-person support (Cilliers et al., 2021), and digital connection inequality among participants. As we addressed objective 2, we considered the type of classroom environment because, as a STEM program, much of the delivery was laboratory and hands-on activity based, and laboratories techniques may be easier to learn in-person where the student participated in troubleshooting during data collection. Based on previously published studies, we expected either 1) no significant difference between online and in-person learning efficacy, or 2) in-person learning would be more effective than online learning (Zhang & He, 2022; Soltanimehr et al., 2019). We expected that identifying some of the challenges encountered would allow us to provide insights for other educators planning similar STEM-related programs.

Methods

Immersion Program Description

The two summer programs (2019 and 2020) that were conducted as part of the First2 Network Summer Immersion Experience focused on helping students understand the commitment required to succeed in the STEM college environment. Students applied to the summer research program for the upcoming summer session before they matriculated at their undergraduate institution. Participation requirements included being either a first-generation college student (neither parent having graduated with a four-year college degree) or belonging to an under-represented group in STEM (including women, people of color/minority, etc.), and with an intention to major in a STEM discipline. Students indicated their preferred immersion sites on their application and were then matched based on STEM interests and majors. Mentors and site leaders collaborated to create a schedule for incoming summer student interns that included research, professional development, and team building. These summer programs are paid internships funded by the First2 Network, and successful completion of the internship resulted in a $600 stipend to each intern.

The inaugural year of summer programming (2019) was an in-person research experience at four sites throughout the state of West Virginia, supporting 31 student interns. These sites included West Virginia University, West Virginia State University, Fairmont State University, and Marshall University. Each of these sites incorporated original research and seminars to connect participants to prospective faculty mentors and undergraduate mentors. There were also industry tours and rotations through participating laboratories. The in-person program was supplemented with a strong focus on community building with the site participants, which included meal preparation, games, and movie nights. The two-week programs culminated in student research presentations to the other site participants, family, and faculty members.

With the onset of the global COVID-19 pandemic, the 2020 program was converted to a 100% virtual experience. Due to the success in the 2019 program, it was expanded to nine sites with the inclusion of government institutions, nonprofit organizations, professional schools, and additional undergraduate institutions. There were 74 student interns, more than double the intern participation of 2019. The additional sites added were Green Bank Observatory, High Rocks Academy, West Virginia School of Osteopathic Medicine, University of Charleston, and West Virginia Institute of Technology. Each day, students took part in research activities that included citizen science projects (https://secure.lamotte.com/wwmday/), data collection, and data processing for ongoing research projects. With the transition to virtual participation, statewide seminars on diversity and inclusion, student resources, and student wellness were added. Students also took part in online games, movie nights, and other programming activities to introduce the participants to one another and build a community before they began their undergraduate careers.

Similar daily schedules were adopted for both the 2019 in-person and 2020 virtual immersion experiences (Table 1). Each site was allowed to create their own specific activities to take advantage of the strengths and resources of that particular institution. A detailed example of one site's events and schedule is outlined in the supplemental information (Stover et al., 2021).

Table 1
General Daily Program, Outcomes, and Example Activities for Both the 2019 In-person and 2020 Virtual Immersion Experiences

Time (M-F, 2 weeks)	**Session Type**	**Outcome**	**Example Activity**
Morning Session 9-12am	**Group Lectures and Discussion**	Describe the steps of the scientific method and design your own research projects	Lecture: "Scientific Method and communication" Discussion: Hypothesis development
Early Afternoon Session 1-3pm	**Independent Research**	Collect, analyze and report data	Collection: Take samples, measure water quality Report: Add data to shared repository
Late Afternoon Session 3:30-5pm	**Professional Development**	Display professionalism and ownership of individual growth and self-reflection	Presentation: "How to find a research mentor"
Evening Session 7-9pm	**Team Building**	Support fellow interns and construct a team dynamic	Game Night: Charades

Survey Protocol

During the 2019 and 2020 research internships, pre/post online survey data were collected as part of the external evaluation of the First2 Network conducted by ICF International. A filter question at the beginning of the survey asked students to confirm that they were at least 18; if not, they were automatically exited from the survey since they were still minors and not allowed to participate without parental consent. This project was approved by the ICF Institutional Review Board (Project# 180739.0.001).

The pre-test version of the survey was administered on the first day and the post-test version was administered on the final day of each immersion. Pre/post surveys were matched based on an identification code that students created in the pre-test and replicated on the post-test. The survey included four STEM subscales identical to those reported previously (Hanna et al., 2021), broadly defined below:

1. The "STEM career" subscale (career) asks students to indicate how certain they are about their decision to pursue STEM education and career (Woodcock et al., 2016).

2. The "STEM efficacy" subscale (efficacy) measures students' expectations about how well they think they will perform in their STEM college courses (Pintrich & De Groot, 1990).

3. The "STEM identity" subscale (identity) gauges students' sense of themselves as people who are engaged with STEM (Chemers et al., 2011).

4. The “school belonging” subscale (belonging) assesses the extent to which students think they will feel connected to their college (Anderson-Butcher & Conroy, 2002).

Students were asked 8 career, 6 efficacy, 5 belonging, and 6 identity questions, which can be found in the Supplementary Information.

Career certainty was evaluated in the pre- and post-surveys to determine how many students were planning to pursue a career in STEM. Our students were either first-generation college students or belonging to an under-represented group in STEM (including, for example, women and people of color/minority). Therefore, many students who participated in the First2 Network summer program faced multiple subsets of stereotype threats, which led to a negative impact on the student's intention to pursue a career in STEM (Woodcock et al., 2016). First2 and other similar programs are designed to help students sustain their academic and scientific interests despite the negative impact that stereotyping may have on their perspective of STEM careers. Specifically, these programs are designed to strengthen academic preparedness, research skills, and professional development skills (Woodcock et al., 2016). Therefore, by evaluating the student’s commitment to a STEM career we can determine whether the program encourages participants to persist in that pursuit.

In line with participants’ career certainty, their perspective on “efficacy” was also evaluated. Self-efficacy was found to be a strong predictor for commitment; specifically, we aimed to evaluate student's commitment to STEM by measuring their expectations on their performance in STEM courses (Hanna et al., 2021). Multiple studies on self-efficacy have found that confidence in one’s abilities to perform a task is more highly and accurately predictive of performance than objective measures of ability alone (Chemers et al., 2011). Other studies have found that engagement in authentic scientific engagement programs such as First2 strengthens students’ confidence in their skills by appreciating the actual work of science (Chemers et al., 2011). Survey questions related to STEM efficacy asked how confident the student was to understand basic and complex material, excel on tests, master skills, and attain good grades in STEM college classes.

Additionally, “identity” as a scientist is also a strong predictor of commitment to a STEM field and was used to evaluate how participants perceive their place in STEM. While the development of identity can be confusing, Arnett (2004) proposed that optimal adolescent development is achieved by forming a sense of coherence that integrates students’ multiple perspectives and identities. Studies have found that identification tethered in a context-relevant element such as student or scientist is more predictive than racial or ethnic identity for persistence and performance (Chemers et al., 2011). Participating in a program like First2 allows students to form a strong connection to science and identify with academic roles, such as being a science or engineering student, which is shown to have a greater persistence to degree completion than students who identify more strongly with their social identity (Chemers et al., 2011). Research experience and belonging to an organization enhances greater involvement in the scientific community, thus strengthening the student's sense of identity in STEM. Survey questions on identity focused on whether students view themselves as future scientists or engineers, and how relevant being in a scientific field is to their self-image.

Finally, “belonging” to school or an academic entity—specifically, college—was assessed due to its association with academic achievement. School belonging was found to be the most important indicator for placing increased value on learning difficult scientific topics (Smith et al., 2022). The belongingness hypothesis developed in 1995 by Baumeister and Leary postulated that students must maintain significant interpersonal relationships that are both lasting and positive. Developing these relationships helps to form a sense of belonging in an academic community which can also positively affect students’ achievement, motivation, and well-being (Smith et al., 2022). Thus, when evaluating students’ perspective on STEM, it is important to assess their sense of belonging to STEM. The survey questions in this area asked about students’ sense of being accepted, expressed as feeling comfortable, respected, and fitting in at college.

To secure outcome data for students, First2 Network staff contacted the 2019 and 2020 interns via email and text messages to confirm retention status and whether they persisted with a STEM major two years after participation in the immersion experience.

Statistical Approach

Questions within the same subscale were pooled, resulting in averages for career, efficacy, identity, and belonging, both before and after the immersion experience. Averages were derived from Likert scores, which are non-parametric data. Therefore, differences were determined by Wilcoxon tests in JMP (Version 15. SAS Institute Inc., Cary, NC, 1989-2021) and reported in Table 2 and Table 3, addressing our first objective. To compare changes in students’ perspective of their place in STEM between in-person and virtual environments, paired data were used to find delta values by subtracting the pre-survey score from the corresponding post-survey score for each question within each immersion year. Responses without both pre- and post-immersion responses were omitted from the analysis.

For our second objective, we compared in-person and virtual experiences to assess whether delivery mode impacted student STEM perspectives. To identify differences between the two learning environments (in-person, 2019; virtual, 2020), only data from the original four institutions that were involved both years were included (Figure 1). Student outcome data (persistence rates in STEM) were analyzed using Chi-Square tests. For all statistics, alpha was set at 0.05.

Results

In 2019, of 31 students who finished the First2 program, 27 completed a pre-test and 25 completed a post-test. Of those 27, more than half were female (56%) and about two-thirds described themselves as white (67%). About a third (35%) indicated they qualified for a federal Pell grant, nearly all (96%) identified themselves as first-generation students, and more than three-fourths indicated they grew up in a town (48%) or rural area (35%) (Howley et al., 2022). Pell grant status is noteworthy because receipts have been shown to be a good proxy to estimate income bracket, as students who receive these grants come from families with a lower than average income in the United States (Carnevale & Van Der Werf, 2017; Heller, 2004).

In 2020, 69 students (out of 74) completed a pre-test and 59 completed a post-test. Of those 69, about two-thirds (67%) were female and 81% described themselves as white. Sixty percent qualified for a federal Pell grant, and more than half (58%) considered themselves as first-generation students. Nearly three-fourths indicated they grew up in a town (26%) or rural area (48%) (Howley et al., 2020). This summary data can be found in Table 1 of the Supplementary information.

The first objective focused on how STEM perspectives changed due to the immersion program within each learning environment (Tables 2 and 3). During the in-person experience in 2019, there was an increase in STEM efficacy (6.2%, p=0.0016), belonging (14.9%, p<0.0001) and identity (11.1%, p<0.0001). No significant difference was observed in students' perspectives on STEM career (2.6%, p=0.239). The virtual experience increased students' perspectives on belonging (7.4%, p<0.0001) and STEM identity (6.1%, p=0.0004) but STEM career (-1.3%, p=0.5687) and STEM efficacy (2.3%, p=0.2066) showed no difference between the pre- and post-surveys.

Table 2

Comparison of Pre- and Post-immersion Survey Results from the In-Person Experience

	N	Questions	Average Pre-results	Average Post-results	Delta	Percent change	P value
STEM Career	25	8	3.84	3.94	0.102	2.6%	0.239
STEM Efficacy	25	6	4.01	4.26	0.254	6.2%	0.0016
STEM Identity	25	6	3.77	4.19	0.414	11.1%	<0.0001
Belonging	25	5	3.95	4.54	0.596	14.9%	<0.0001

Note. Survey data outcomes from before and after the in-person research experience delivered in 2019. All questions within a given subscale were pooled to give an average rating for STEM career, STEM efficacy, belonging, and STEM identity. Significant differences were determined with p<0.05.

Table 3
Comparison of Pre- and Post-immersion Survey Results from the Virtual Experience

	N	Questions	Average Pre-results	Average Post-results	Delta	Percent change	P value
STEM Career	58	8	3.78	3.73	-0.048	-1.3%	0.5687
STEM Efficacy	58	6	3.99	4.08	0.09	2.3%	0.2066
STEM Identity	58	6	3.78	4.01	0.214	6.1%	0.0004
Belonging	58	5	3.94	4.23	0.29	7.4%	<0.0001

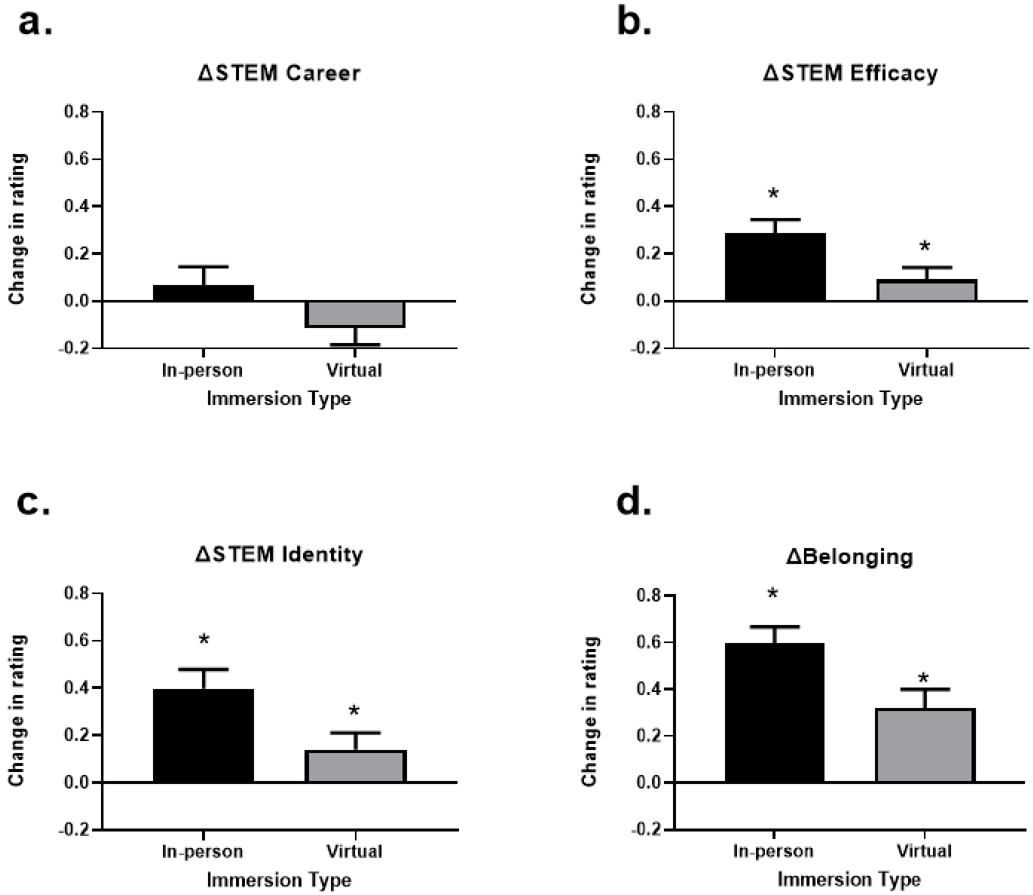
Note. Survey data outcomes from before and after the virtual research experience delivered in 2020. All questions within a given subscale were pooled to give an average rating for STEM career, STEM efficacy, belonging, and STEM identity. Significant differences were determined with p<0.05.

For objective two, we compared the two learning environments (in-person and virtual) in the four institutions that were involved both years to determine whether the delivery mode impacted student STEM perspectives during the immersion program (Figure 1). The data suggested that there was no difference between pre-and post-experience results in STEM career (p= 0.0904). However, the in-person learning environment had a greater increase in rating for STEM efficacy (p=0.0327), STEM identity (p=0.0218), and belonging (p=<0.0015) (Figure 1).

For objective three, of the 31 students experiencing the in-person research internships in 2019, retention status could not be secured for four students. Of the remaining 27, 18 persisted in a STEM major between the fall 2019 and fall 2020 semesters, for an early STEM persistence rate of 67%. Eight did not re-enroll in a STEM major in the fall of 2020 (30%) and one student (4%) dropped out of college (Hanna et al., 2021). Of the 31, 8 (26%) served as mentors for the 2020 internships and 4 served as mentors during the 2021 internships. For the 74 students experiencing the virtual research internships in 2020, status updates were obtained on 27 of them. Of these, 21 persisted in a STEM major between the fall 2020 and spring 2021 semesters (78%). Five students did not re-enroll in a STEM major in the spring of 2021 (19%), and one student dropped out (4%). Of the 74, 8 (11%) will be serving as mentors for the 2021 internships. STEM persistence rates did not differ by experience type.

Figure 1

Changes in Immersion Survey Results for the In-Person and Virtual Immersive Research Experiences



Note. Survey results for A. STEM career, B. STEM Efficacy, C. STEM Identity, and D. Belonging. Change values were determined by subtracting the pre-immersion survey results from the corresponding post-immersion survey results for each student. Twenty-five in-person students (2019) and 31 virtual students (2020) answered 8 career, 6 efficacy, 6 identity, and 5 belonging questions. Means with an asterisk symbol differ significantly ($p<0.05$).

Discussion

With the sudden emergence of COVID-19 related restrictions, we had the opportunity to assess differences between in-person and virtual formats for delivering summer immersion programs. Overall, both the in-person and virtual experience improved select aspects of STEM self-assessment. However, the in-person program led to more post-program improvement. After one year of college, 67% of in-person students and 78% of virtual students remained in a STEM discipline, although these numbers were likely affected by the low response rate as reported in the results. Prior work analyzing the 2019 program reported that persistence in STEM after one year was lower than the state rates for non-First2 students (74% in 2018 for rural Pell-grant recipients), but the virtual student STEM retention percentage was higher in the 2020 virtual cohort (Hanna et al., 2021). The intention of the First2 program is to increase STEM persistence for participants by providing a community, support and special programs like the one described here. We hope that by continuing to monitor and receive feedback from the students who both stay in STEM majors and those who leave, we can continue to improve the program to increase STEM persistence in this important student population.

We found that the in-person format increased STEM efficacy, identity, and belonging when comparing the pre- and post-immersion scores, whereas the virtual format showed an increase only in STEM identity and belonging. The virtual format was not able to increase the student's confidence in math and sciences. This could be due to the different amount of participation possible, such as simple citizen science projects versus live bench science, or watching the groups' statistics be analyzed rather than doing them on their own. There was also less one-on-one time virtually with mentors to help build that confidence. We did not expect to see a difference in career perspectives with either group, as these questions focus on a career path. First2 students have already selected a STEM major and dedicated part of their last pre-college summer to a STEM program, so it is not surprising that no change was observed over the two-week period.

Our results confirmed the hypothesis that virtual delivery would change student STEM perspectives less than the in-person immersion experience. This program was shifted quickly to the virtual environment, and while care was taken to maintain similar structure and objectives, there were certainly differences in teaching approaches and group activities. However, we still observed that the virtual format led to some significant increases in STEM perspectives, specifically STEM identity and belonging, indicating that a virtual experience is still much better than no participation at all. The difference observed between in-person and virtual outcomes may be due to a lack of in-person support (Cilliers et al., 2021), digital connection inequality among participants (Ferris & Vesely, 2021), and forming friendships among peers without face-to-face interactions (Bikowski, 2007). Indeed, due to poor internet connectivity, even with hotspots, some students had to turn off their cameras at various times to circumvent lagging issues.

The surveys also included free responses that allow us to assess some of the qualitative student feedback. In addition, each site leader completed a follow-up report within two weeks of the end of the immersion program, and we have summarized the results in the following two sections to address our fourth objective.

Benefits of the Virtual Experience

There were many benefits to the virtual immersion program, including flexibility in schedule, interacting with the broader First2 network, tailoring research projects, and engaging with students in new and different ways. Virtual experiences can also eliminate significant costs such as those associated with room and board. A greater number of students may have the opportunity to participate remotely and without the need for transportation.

Some flexibility was built into the online platform schedule since it did not require a particular physical space. The sites requested daily feedback and were able to adapt as needed if students required more time to accomplish a goal or finish a discussion, as activities were synchronous. If a demonstration was required, for example showing students how to use a microscope to analyze a sample, a camera could be set up in a lab and every student had access to the video livestream. Students could also share their screens to show everyone data or present their work, and small group work could be accomplished by opening multiple breakout rooms. Students were able to adapt quickly, as many of them had finished the school year using similar platforms. "Zoom Fatigue" (Wolf, 2020) was avoided as much as possible by offering activities on and off-line, such as going outside to collect samples and breaks for mealtimes.

The virtual immersion also allowed students to have additional experiences that would not have been possible on-site. Rather than just interacting with small on-campus groups, students participated in state-wide meetings and took tours of industry, educational, and laboratory facilities they would not be able to visit at their assigned campus. Guest speakers did not need to be physically present, so the students had an opportunity to hear from more diverse presenters, with one site even including international speakers. These interactions can potentially help broaden the students sense of STEM community even in the virtual environment. Indeed, this approach has transformed the scientific community over the past year, making conferences and seminars more accessible to people around the world (Price, 2020), and this practice is likely to be carried over, likely taking the form of a hybrid format in future years.

One unexpected outcome highlighted in the site reports noted that it tended to be easier to get to know shy students. When a student's camera is on you can comment about something unique or meaningful in their space such as a poster, stuffed animal, or pet, allowing that student to open up. Undergraduate mentors were also utilized to engage the rising freshman and create an inclusive environment. They organized the evening socialization and various sites provided activities such as scavenger hunts, book clubs, movies, and games. Everyone went into the virtual program with an open mind, making it easier to have fun and team build. The undergraduate mentors, who had been through the program previously, helped get students to speak openly and freely during the team-building time, noticeably increasing student engagement in the other activities as the week went on.

Students still received meaningful research and mentor experience through the virtual immersion. Lab-based projects were still carried out with the students collecting samples such as water, soil, or insects which were tested either by the student or sent to the lab. Many sites used citizen science projects which allowed students to get outside to collect meaningful data and be part of a bigger project such as tracking fireflies (West Virginia Division of Natural Resources (WVDNR), Light Up West Virginia), box turtle identification (WVDNR, Box Turtle Citizen Science Survey, 2020), or water quality testing in the region (EarthEcho International, monitorwater.org). Students then worked together to analyze the data and interpret the results. Though this was online, these research experiences tended to allow students to focus on a topic of interest to answer a specific research question, often as a subset of the whole group's data. By the end of the two-week program, students had advanced their project through the scientific method and presented their work to the site group. The faculty were very pleased with how far this class of virtual students had progressed in such a short time period.

Challenges of the Virtual Experience

Many challenges arose during the virtual immersion program. Both students and faculty members were hesitant about the virtual environment. Internet accessibility and equality were problematic. Digital fatigue was unavoidable while managing the expectations and interaction of students.

Despite a monetary incentive, nine students withdrew from the virtual immersion experience before it even began. One possible explanation may be that some students had a negative view of digital experiences due to the rapid closure of schools and transition to online teaching that occurred in the spring of 2020 (Hebebci et al., 2020). However, some self-selection may have also occurred, as a previous study found that students who chose to enroll in an online class felt they possessed greater self-regulation and effort strategies that could help them succeed in this setting (Quesada-Pallarès et al., 2019). In addition to students, many faculty members were slightly apprehensive about hosting the virtual experience, facing struggles with learning, and working with new technology. Perhaps not surprisingly, all sites indicated they would prefer in-person immersions. Students may have felt disconnected if faculty members did not feel comfortable in an online setting. The site surveys state that all sites struggled with organizing and technology. Even though all sites expressed caution and hesitancy towards the virtual experience, they articulated the importance of having a virtual experience and felt it was worth the time and effort.

Another challenge of the virtual experience was the ability of rural students to access broadband internet. Connectivity is an issue facing many rural areas, with West Virginia ranked as the 44th worst state for high-speed internet (Ferris & Vesely, 2021). Some students were issued hotspots and computers, while others logged on from parents' phones. Poor internet may have caused students to miss a portion of the presentation or not be able to see a demonstration, decreasing self-confidence with the online format, which could certainly influence STEM efficacy and identity. Virtual teachers and mentors should have increased awareness of a student's ability to access broadband and adapt accordingly, for example sending temporary hotspots or checking in after a session to see what the student might have missed.

Some amount of digital fatigue is unavoidable over the course of an extended online program (Bailenson, 2021). There was certainly some degree of digital fatigue over the course of the two-week immersion felt by students, mentors, and site leaders. Lectures could not be avoided and most sites were online for 5-6 hours a day, broken up by breaks for eating and collecting data. Because groups were relatively small, everyone was visible on camera for extended periods of time, which could lead to long periods of direct eye-gazing, reduced mobility, and visualizing oneself (Bailenson, 2021). Statewide seminars were the lowest-rated event because they were not actively engaging, tending to be long lectures around dinner time. We suggest thinking very carefully about scheduling when developing an online camp-like experience. While there may be many interesting topics to cover, the effectiveness is easily diminished if the audience spends too long in front of the screen without enough breaks (Fauville *et al.*, 2021).

A few other issues emerged based on expectations and interactions associated with the virtual format. Some students felt that because the immersion experience was virtual they would be able to take on additional courses or responsibilities. At the outset of a program, clear terms of agreement and expectations should be explained to students to ensure students are present. Additionally, managing students' interactions can prove challenging as mentors walk others through sharing screens on different devices, keep everyone engaged, and monitor discussions, especially considering the impact behavior has on meeting satisfaction and effectiveness in online formats (Odermatt et al., 2018). Tailoring the schedule to include activities such as brainstorming, peer review, and think-pair-share is crucial for active student engagement (Brent et al., 2021). Finally, additional financial costs should be considered as homes will not likely be stocked with research related materials, and mailing equipment can become limiting and expensive.

Benefits and Challenges of In-Person Learning

While in-person learning is the more traditional method of teaching, we did want to highlight a few observations of the modality within the context of this study. Our in-person learning environment had a greater increase in rating for STEM efficacy, STEM identity, and belonging than the virtual experience (Figure 1). The in-person students were able to spend time on campus in a faculty member's lab and had more one-to-one face time with mentors. In the online format, it was often a few students working with one mentor at a time, with the potential for dominant personalities to receive more attention. Students were also able to form connections to peers in-person and spent more time with their peers overall, for example at meal times. Both of these factors likely increased their confidence and sense of community within the STEM fields. However, the STEM retention after one year did not reflect an increase in benefit, as the retention was similar, if not lower, than state-wide rates, although it should be noted that the sample set was only 27 students.

There were a few challenges to highlight with the in-person format, including cost, logistics and the potential to limit participation. It was more expensive to run the in-person program due to the cost of room and board, and some sites did not have dorms to house students. Transportation was also an issue for some sites, which required daily transport to campus, or at least a way to get to the site to begin camp which might be hours away from their home location. Many students did not have access to a car, which limited the participation of some students. Additionally, some students were still minors, which led to more logistical issues, with some sites unable to accommodate students under 18 years of age. Indeed, this led some sites to continue using the virtual format for the 2021 immersion camp.

Effectiveness of Virtual versus In-Person STEM-Based Learning

While virtual programs increase accessibility to STEM education, the effectiveness of virtual learning must parallel in-person learning for students to obtain a quality education regardless of the learning platform. Studies within higher education programs report either in-person or virtual learning to be more effective depending on the population of students being evaluated and the educational goals of the program, with some studies reporting confounding results. For example, when post-graduate students were evaluated on their clinical performance, which can be compared to laboratory activities, test scores were positively correlated with either (i) in-person class attendance or (ii) there was no significant difference between virtual and traditional style learning platforms (Soltanimehr et al., 2019; Zhang & He, 2022). These opposing results show the variability based on the particular program or curriculum. However, when the goal of learning is knowledge development and retention, a virtual learning format is correlated with higher test scores (Moazami et al., 2014; Soltanimehr et al., 2019). These mixed experimental results support the idea that a hybrid learning format may optimize learning

(Bowers et al., 2022). However, additional experimental studies are necessary to determine which methods of learning are more effective depending on the learning goals, the specific population of students, and the students' level of education.

Many experimental studies show that virtual learning is as effective as in-person learning when general knowledge and retention are the measurements of learning efficacy. However, there are conflicting results of virtual versus in-person learning efficacy among STEM programs with a laboratory-based learning objective. Studies conducted during the COVID-19 pandemic that compared in-person to virtual learning courses with laboratory activities found that students cannot master biological experiments and practice technical skills within an online learning platform. Both skills are necessary for students to conduct research within an academic setting or pursue a career within research. While there are some distinct advantages to online teaching, hands-on experience in labs using scientific equipment is also needed. These findings further support the optimization of learning through a hybrid format (Zhou, 2020). Our immersion program was an introduction to the scientific method with some simple synchronous laboratory activities. Each site sent supplies to their participating students, including scientific equipment such as microscopes or experimental kits, which likely provided a somewhat similar experience to the in-person program. In some cases, training was done synchronously, such as how to use a microscope, while in other cases the student had to troubleshoot on their own in the field while collecting data. Higher level courses with a complex laboratory component would be much more challenging to carry out virtually and likely not as effective. Laboratories are also a good opportunity for peer learning (Choi et al., 2021), which is more challenging to do in separate locations.

Only a limited number of studies compared in-person to online learning among underrepresented student populations studying STEM majors. An analysis of data from over 10,000 course enrollments conducted in 2020 found that first-generation college students pursuing an online STEM degree had lower grades compared to their in-person attending peers (Mead et al., 2020). Based on limited experimental studies, the current literature inconclusively evaluates the effectiveness of online versus in-person learning formats among underrepresented college students pursuing STEM majors. The focus of our study directly compared underrepresented first-generation college students' online versus in-person research immersion experience and the program's effect on improving students' STEM education. Student populations such as those in rural Appalachia have much to gain from programs that increase STEM access and build an academic community. Both the in-person and virtual immersion platforms were effective in increasing both STEM identity and belonging, making this type early career intervention a viable option for increasing STEM retention among these underrepresented student groups. Care needs to be taken in the planning stages to have activities that build community within the cohort, as well as building confidence through close mentorship and professional results, such as presentations.

Conclusions

While the in-person summer research immersion program had higher overall improvement in STEM self-assessment, the virtual program still showed improvement in the areas of STEM identity and belonging. The virtual learning environment are more flexible and reach more students at a lower overall cost, but certain steps need to be taken to ensure digital equality and student engagement through carousel scheduling and planning of interactive activities. The in-person program was especially helpful to foster STEM identity and belonging, while also increasing student's confidence in their math and science abilities. We felt that the use of group research such as Citizen Science projects can be very useful for these types of programs. Scheduling time for fun group activities as well as off-screen time to prevent burnout should also be considered in planning a virtual extended program for students. Ideally, the goals of a particular program should be assessed before selecting the mode of delivery if a choice is possible.

The virtual format during the pandemic has largely changed the pattern of our life and work. As the pandemic is better controlled and life returns to normal, we expect that the First2 Network program will mainly be delivered as the in-person format, as before the pandemic. Indeed, for the 2021 program, a majority of the participating institutes allowed the students conduct research and perform other activates on-site. However, based on our study, the virtual format is still a beneficial consideration to enhance STEM education especially for certain hard-to-reach student populations and in certain circumstances such as a lack of funding, space, equipment, ability to travel, or other resources.

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Availability of data: The datasets generated and analyzed during the current study are not publicly available since participants did not agree for their data to be shared publicly but are available from the corresponding author on reasonable request.

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Authors' Contributions: CP, TL, KS conceptualized this project, CP analyzed the data, KS, KC, and KH drafted the work, CP, MF, and TL revised the work.

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Consent to Participate: Informed consent was obtained from all individual participants included in the study.

Consent for publication: Participants signed informed consent regarding publishing their data.

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