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Impacts of the St. Jude STEM Club on STEM Identity, STEM Engagement, and 21st Century Skills: Comparing an In-Person and Virtual Implementation

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ABSTRACT: Afterschool science, technology, engineering and math (STEM) programs are often used as a tool to promote equity in science. The St. Jude STEM Club (SJSC) ran for two years before the COVID-19 pandemic forced schools to shift to virtual instruction. As a result, the STEM Club also shifted to virtual programming. In this study we compare in-person and virtual programming of the same afterschool STEM club on measures of STEM identity, STEM engagement, and 21st Century Skills (i.e., critical thinking, perseverance, and relationships with adults and peers) among students historically excluded from STEM. On the last day of the club, participants in both cohorts completed a retrospective self-change survey. Statistical analysis revealed that participants in the virtual STEM club showed significantly less growth in STEM engagement, and the following the 21st century skills: critical thinking, perseverance, and relationships with adults and peers compared to in-person participants. Changes in STEM identity were not significant when comparing virtual to in-person formats. Yet, analysis showed significantly greater growth for all measures except for relationship with peers and STEM engagement when compared to pre-pandemic national normative data which includes in-person, virtual, and hybrid programs. While virtual programming can increase STEM learning opportunities for youth from racialized groups historically excluded from STEM, there are still drawbacks that should be considered, such as high attrition rates and challenges in STEM engagement and peer relationship development on a virtual platform.

INTRODUCTION

Equity in science and engineering education is still an unmet goal. This is evident in the low percentages of Black and Brown populations participating in science, technology, engineering, and math (STEM) fields in college and beyond (Pew Research Center, 2021). Research has shown that exposure to STEM opportunities early in life is associated with success in STEM careers later in life (Wai et al., 2010). Afterschool STEM programs are important for broadening participation in STEM careers, helping make STEM subjects more inclusive and creating sustained interest and participation in STEM disciplines, especially for youth from racialized groups historically excluded from STEM (i.e., African American/Black, Hispanic/Latinx; National Research Council, 2015). The St. Jude Afterschool STEM club employs a student-driven, case-based approach to cancer education rooted in the constructivist learning theory. The goal of the STEM club is to promote students' science identities and enhance their 21st Century Skills (See Ayers et al., 2020 for a description of club curriculum and structures). We define STEM identity as a student's understanding of themselves as a person who can do and be in STEM and we define STEM engagement as a student's excitement and interest in participating in STEM (Ayers et al., 2020). We define the development of 21st Century Skills as a phrase that includes measures of critical thinking, perseverance, relationships with peers, and relationships with adults (Ayers et al., 20202). Results from a Fall 2019 in-person implementation show that the STEM club is not only successful at increasing STEM engagement, STEM identity, critical thinking, perseverance, and relationships with peers and adults in youth historically excluded from STEM, but also more successful than national averages on these same measures (authors).

During the Spring of 2020, the United States entered a nation-wide lockdown due to the COVID-19 pandemic, disrupting the implementation of the STEM club. As schools shifted to a virtual format during the 2020-2021 school year, the STEM club shifted as well. Though hosting virtual programming through a global pandemic proved challenging, the pandemic gave us a unique opportunity to compare science identity and engagement between students participating in in-person and virtual programming of the same STEM club. While previous research has explored science identity in virtual spaces, these studies focus on virtual learning environments where individuals are fully immersed in a world-based simulative experience (Reilly et al., 2021; Davis and Chansiri, 2019; Reilly and Dede, 2019; Foster and Shah, 2021). In contrast to this previous research, the current study refers to virtual spaces as the space where the STEM club occurred; i.e., an online platform where students synchronously met with a facilitator via video call rather than participating in an immersive virtual world experience. In both cases (online and in-person), our STEM Club curriculum was facilitated by a human and participants saw each other's physical self, either in person or through an online video calling software. We found no prior studies comparing the impact of in-person and virtual programming on STEM identity and engagement among elementary students participating in the same afterschool STEM club curriculum. In this paper we explore the impacts of a virtual STEM club on 5th grade students' science identity and 21st century skill development. This study was guided by the following research question:

1. How does virtual programming compare to in-person programming in terms of STEM Identity and 21st Century Skill development?
2. How does virtual STEM programming impact Identity and 21st Century Skill development?

Virtual Club Context. The STEM Club was running for two years before the rise of the global COVID-19 pandemic. During the 2020-2021 school year, however, the STEM club shifted to a virtual format in an effort to maintain connection with schools and youth. In working with school principals and educators, we determined that we could keep the day-to-day pacing of the STEM club the same throughout the virtual implementation. That is, the club could continue to meet once a week for one hour after school for a 10-week period. In addition, no changes were made to the club curriculum and structures to promote students' science identities and enhance their 21st Century Skills. Since the school district provided each student with a computer and hotspot (if needed), we did not have to be concerned with access to technology. Other club logistics, however, presented challenges that we needed to find new ways to reach potential participants (student registration), new ways to get participants the necessary STEM club materials (i.e., student workbooks, design challenge materials), and new ways to administer each lesson on an accessible, virtual platform while still maintaining the integrity and consistency of the club, especially in terms of curriculum, student demographic, and materials used. To reach potential participants, an online registration portal was created and shared with parents by school principals. To provide participants with the program materials, STEM Club Kits complete with the student workbook and all materials needed to complete the design challenge were packed and mailed by program staff to each individual student's address. STEM Club meetings were hosted virtually after school and facilitated by a college intern once a week for ten weeks using whichever platform schools/students were most familiar with, often this was Microsoft Teams or Google Classroom. All college interns were majoring in science or science-related area. In addition, while the interns received similar training and participated in weekly meetings to trouble shoot problems that arose during implementation as compared to the in-person format (Ayers et al., 2020), these meetings were also transitioned to a virtual platform. This was all done in contrast to pre-pandemic times where paper registration forms were distributed to schools and sent home with students to be signed and returned on a first-come-first-serve basis, club materials were brought to the students each meeting by the club facilitator where the club took place in-person while the students progressed through the club in groups of 3 to 4. On the final day of the club, students were administered the same retrospective STEM identity survey as the pre-pandemic, in-person students (Ayers et al., 2020). This study was determined to be non-human subjects research by the St. Jude Children's Research Hospital Institutional Review Board.

METHODS

Samples and Attendance Rates. STEM Club demographics across all clubs in both groups reflected that of the overall district's demographics, though White students were over-represented in the virtual cohort compared to the in-person cohort the previous year. The largest racial group in this district is African American (77%), followed by Hispanic (15%), Caucasian (7%), other (1%), and Asian (2%). Table 1 provides the demographic breakdown of participants at each school site for each modality the STEM Clubs were offered.

Design.

Analysis of Attendance Rate. Club attendance rates were calculated by counting daily attendance and averaging across

Table 1. *Demographic breakdown of participants in the in-person cohort and the virtual cohort.*

	School District (N = 106,377)	St. Jude In-Person 2019 (N = 110)	St. Jude Virtual 2020 (N = 76)
Gender Distribution			
Female	49%	59.1%	46.1%
Male	51%	35.5%	28.9%
Prefer not to answer	-	3.6%	7.9%
Racial/Ethnic Distribution			
African American, Black	77%	55%	50%
Latino or Hispanic	15%	10%	7%
White, Caucasian	7%	4%	11%
Other	1%	1%	13%
Prefer not to answer	-	13%	4%
Left Blank	-	17%	15%

the ten weeks for each site. To understand the potential influence of club format (in-person vs. virtual) on attendance rates for racialized categories, the Fisher's Exact Test for Count Data (1962) was used. Analysis was conducted using all four racialized categories (White, Caucasian [non-Hispanic] /African American, Black/ Latino or Hispanic/ Other) while considering missing data and 'Perfer not to answer' as 'Unknown' category. A second analysis was conducted using the categories White, Non-white, and Unknown after exclusion of missing data (Appendix).

Comparison of CIS Scores Between the In-Person and Virtual Cohorts. To understand difference between youth scores on the CIS survey between the in-person and virtual cohorts, a retrospective post-then-pre design was chosen to avoid pretest sensitivity and response shift bias that results from pretest overestimation or underestimation (Howard, 1980; Pratt et al., 2000; Lam and Bengo, 2003). This type of design asks participants to assess their own change from two viewpoints—in this case before and after participating in a STEM club—around a specific topic (i.e., STEM identity and engagement). On the final day of the program, student participants completed the Common Instrument Suite (CIS), a retrospective, self-change survey (Allen et al., 2017; Allen et al., 2019; Martinez et al. 2014). During the survey, participants were asked to intentionally consider how their answers to each prompt have changed as a result of participation in the program, on a five-point scale of "Much Less Now", "Less", "About the Same", "More". And "Much More Now." The survey was used to determine the program's impact on students': STEM engagement (14 items; α = 0.91); STEM Identity (5 items; α = 0.88); and development of 21st century skills, including critical thinking (5 items; α = 0.79), perseverance (4 items; α = 0.85), relationships with peers (4 items; α = 0.74), and relationships with adults (4 items; α = 0.74). During the last club session of the in-person format, students were asked to complete a paper version of the survey. During the last club session of the virtual format, students were provided with a link via the chat function of the virtual platform and asked to complete the survey online. In both formats, survey completion was limited to those who were present for the final session.

Each item is scored on a scale of 1 to 5 with 1 representing students who responded "Much Less Now" and 5 representing students who responded "Much More Now." The mean score across each domain was calculated by The PEAR Institute at Harvard Medical School and McLean Hospital and provided through a Qualtrics data portal along with national normative data. National normative data represents students across the nation who participated in various OST STEM activities and are assumed to self-selected into the programs, making them an ideal comparison group as students in the STEM club select to participate (Allen, 2019). All national normative data provided to us was collected pre-pandemic for in-person programming and presented to us in aggregates, therefore we are unable to determine or stratify national normative data by club format.

Statistical Analyses. We used a modified two-sample t-test to compare our data to national normative data using the mean and standard deviation from our cohort for which we had subject-level data, the published mean for national normative data, and the mathematically largest possible standard deviation for the national normative data. This modified t-test is statistically conservative in the sense that its actual type I error control is greater than its nominal Type I error control. We used the Welch two-sample t-test to perform unadjusted comparisons of our data for the in-person and virtual modalities. We also used mixed linear regression models to perform comparisons of the two modalities in our data that adjusted for race, sex, and primary language as fixed effects, and school site as a random effect. We have looked into three modelings: 1) adjusting race in three categories (Non-white/Unknown/White, Appendix), gender (Female/Male/Unknown), primary language (English/Non-English/Unknown) and random effect of 18 school sites; 2) adjusting race in five categories (African-American, Black/Other/Unknown/Latino or Hispanic/White, Caucasian (non-Hispanic)), gender, primary language and random effect of 18 school sites; 3) adjusting race in three categories, gender, primary language and random effect of three school sites (Appendix).

RESULTS

Attendance Rates. In total, 151 fifth-grade students participated in the in-person STEM clubs with an average weekly attendance rate of 67% across all sites with available attendance records. Individually, the school sites showed variation in participation and attendance, ranging from schools

Table 2. *Comparison of Virtual Programming to In-Person and to National Norms.*

CIS Scale	St. Jude Virtual 2020		St. Jude In-Person 2019			National Pre-Pandemic Norms	
	N	Mean Score	N	Mean Score	p-value	Mean Score	p-value
STEM Engagement	76	3.954	110	4.271	<0.001	3.841	0.249
STEM Identity	67	3.743	105	3.767	0.843	3.301	<0.001
Critical Thinking	71	4.014	109	4.336	0.006	3.659	0.001
Perseverance	71	3.989	109	4.329	0.005	3.66	0.002
Relationship with Adults	71	3.736	106	4.095	0.01	3.429	0.01
Relationship with Peers	71	3.641	108	4.077	0.001	3.592	0.658

with 3 to 21 participants and 38% to 83% attendance rates. In total, 229 fifth-grade students participated in the virtual STEM clubs with an average weekly attendance rate of 54% across all sites with available attendance records. Individually, the school sites showed variation in participation and attendance, ranging from schools with three to 20 participants and 23.3% to 81% attendance rates.

In-Person Versus Virtual Modalities Locally. In unadjusted analyses, virtual participants in our program showed significantly less growth in STEM engagement, critical thinking, perseverance, relationships with adults, and relationships with peers in comparison to in-person participants from the previous year (all $p < 0.01$; Table 2). STEM identity did not differ significantly between these two cohorts ($p = 0.843$; Table 2). These trends remained in analyses adjusted for race (white/non-white/unknown), sex(male, female, unknown), primary language (English, non-English, unknown), and school site. In these adjusted analyses, growth in critical thinking, perseverance, relationships with adults, and relationships with peers was significantly less among virtual participants relative to in-person participants (all $p < 0.014$; Table 3). Virtual participants also had notably less growth in STEM engagement ($p = 0.066$; Table 3) than in-person participants. In these adjusted analyses, there was essentially no difference between in-person and virtual participants (Table 3).

To further evaluate the potential impact of confounding factors on these results, we performed an analysis limited to data collected from three schools that participated in both modalities (Appendix) and obtained similar estimates for effect sizes (Appendix), reducing some concerns regarding confounding. However, these results were not statistically significant; potentially due to reduced sample size. Supplementary Table 3 in the Appendix provides results of an analysis of all schools that categorizes race into five groups (White, Caucasian (non-Hispanic) /African American, Black/ Latino or Hispanic/ Other/ Unknown); these results are similar to those of Table 2, indicating the results are robust against different schemes to categorize race.

Local Virtual Modality versus National In-Person Modality. Scores in STEM identity, critical thinking, perseverance, and relationships with adults for pandemic-era virtual participants in our program were significantly better than those for national norms for in-person pre-pandemic participation (all $p < 0.01$; Table 2). Also, participation in our virtual program had a non-significant association with better scores for STEM engagement and relationship with peers than national norms for in-person participation. Adjusted analyses for these comparisons are not possible due to lack of access to subject-level national normative data.

DISCUSSION

This study expanded on previous research in after school STEM programming and virtual learning by comparing in-person and virtual formats of the same STEM Club curriculum. The club was initially designed as an in-person club hosted at schools that primarily serve communities from racialized backgrounds historically excluded from STEM. During the COVID-19 pandemic, the clubs shifted to a virtual format in an effort to maintain connection with schools and students. Unsurprisingly, average weekly attendance was down to 54% during the virtual year compared to 67% during in-person programing. Yet, it is unclear from our data why some students inconsistently attended the club and others did not. We speculate that there are several, complex reasons for this lack of consistency during the virtual year, many of which are likely outside of the students' control, such as family obligations, access to technology, or lack of

Table 3. *Estimated effect of format (virtual vs. in-person) on score adjusting for race (3-category), gender, primary language and school site.*

CIS Scale	Est. Coefficient of Format	95% CI of Est. Coefficient	p-value
STEM Engagement	-0.2	[-0.41, 0.01]	0.066
STEM Identity	0	[-0.27, 0.26]	0.989
Critical Thinking	-0.31	[-0.51, -0.1]	0.005
Perseverance	-0.28	[-0.5, -0.06]	0.014
Relationship with Adults	-0.34	[-0.6, -0.09]	0.011
Relationship with Peers	-0.4	[-0.67, -0.13]	0.005

engagement and peer relationship development in the virtual format of the club. These are important questions to consider when thinking about the ability of virtual programs to promote equity in STEM education and broaden participation. More research is needed to understand these different subgroups of students and how virtual programming during a time of crisis might be modified to provide better support for students who did not consistently attend the club.

For students who persisted to the end of the club, results suggest that while STEM engagement and 21st Century skill scores were significantly lower than in-person programming, Our virtual version of the club was still able to provide significantly better increases in STEM Identity than the national in-person normative data through developing critical thinking, perseverance, and relationships with adults. This may have been due to the club occurring in real time facilitated by a college intern as opposed to asynchronously. Students were also provided with their own individual STEM Club kit that had the necessary materials for the engineering design challenge. Being able to be hands on and manipulate materials during the build during a time when all their instruction was happening in the virtual world may have contributed to these results. We found no significant difference in STEM identity between the in-person and the virtual programming. STEM identity is quite similar between both in-person and virtual groups (Tables 2 and 3), suggesting that STEM Identity is challenging to foster and understand regardless of the club format. The low score may also be related to high attrition rates (only three clubs had an average attendance rate above 70% when programming was virtual) during virtual programming where students already possessing a high STEM identity were likely to be the ones persisting through the program; however, we don't have STEM identity score data for the students that left the club. It is important to note that students were attending their daily instruction completely online as well and may have been experiencing online fatigue (Zuo et al., 2021) thus potentially leading to them skipping some STEM club meetings as well as some youth not having a parent/guardian reminding and encouraging them to attend STEM Club (Haderlein et al., 2021). Further, there was no significant differences in STEM identity between in-person and virtual youth, this is likely due to the complex nature of Identity, something difficult to capture from a Likert scale survey. Interviews with students will help elucidate the nuances of STEM identity especially within racialized students in the club.

It is unsurprising that virtual students reported lower rates of Relationships with Peers compared to in-person students. During in-person programming students' progress through the curriculum and complete the design challenge in groups of 3-4 while students participating in the virtual programming progressed through the curriculum individually while logged onto a video call led by a college facilitator with the rest of the club participants. Cameras were encouraged to be on so that the entire group could see each other, but some students opted to have their cameras remain turned off. Previous research has found that availability and quality of peer relationships influences an individual's STEM identity (Allen, 2019) and likely plays a role in students' interest in persisting through a STEM club, especially during the pandemic, a time during which students were reporting a lack of social interaction in their daily lives (Zuo et al., 2021). This points towards the need for further research exploring why some students persist through the club and others don't.

Our results show that our programming was able to maintain successful increased STEM engagement and 21st Century skill development compared to pre-pandemic national norms, but not as high as our St. Jude 2019 in-person cohort for most measures, begging the question of whether to continue virtual instruction as pandemic restrictions ease and society returns to "normal." It is particularly important to consider the results of this study in the context of a global pandemic, a time when nothing was the status quo for anyone. We must be careful not to conflate increased science identity engagement scores, content knowledge gains, and/or motivation to learn science during virtual instruction with increased desire for virtual afterschool programming. While virtual instruction has the potential to increase accessibility to STEM learning opportunities for individuals from racialized groups historically excluded from STEM, more research is needed to determine if virtual afterschool programming is desirable to students and educators especially when daily instruction occurs in person. Studies have shown that while virtual instruction during a global pandemic brings about its own challenges, such as struggling to communicate with parents/teachers/students, lack of teacher preparation/tech-savvy skills, and potential exacerbation of inequalities related technology and Wi-Fi access (Huck and Zhang, 2021; Williams et al., 2021), educators do not want the skills they've learned through shifting to remote teaching to be in vain. Future research is needed to explore if similar trends to science identity and engagement found in this study exist outside of the context of a pandemic.

Conclusions. This study contributes to the STEM education literature by comparing in-person to virtual afterschool STEM programming of a STEM club designed to increase access to STEM learning opportunities in youth historically excluded from STEM. In this study we present data that shows our afterschool STEM club, despite underperforming relative to our in-person programming, is still outperforming national normative data related to STEM identity and engagement regardless of having to shift programming to the virtual space due to the pandemic. This suggests that virtual STEM programming may play an important role in addressing issues of equity in STEM education. While virtual programming can have significant impact on youth STEM development, there are still drawbacks that should be considered, such as high attrition rates in online spaces as we saw in our study as well as online fatigue. This highlights the need for future research exploring how virtual programming compares to in-person programming in terms of accessibility, desirability, and value, especially as pandemic restrictions begin to ease allowing students to return to the classroom for daily instruction. This is critical as COVID-19 and other viruses continue to pose a threat to society. Our study was limited by the fact that we cannot statistically adjust for the multiple confounding factors that were present during the time of the pandemic; however, this is a limitation of all studies conducted during this time. Our study was also limited by the fact that we did not conduct in depth interviews with participants. Future research should conduct interviews with students that complete the club and with students that do not complete the club to more comprehensively understand STEM identity and engagement in the club as well as to understand the unique factors that play a role in attrition out of the club.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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ABBREVIATIONS

ALSAC: American Lebanese and Syrian Associated Charities; CIS: Common Instrument Suite; SJSC: St. Jude STEM Club; STEM: science, technology, engineering and math

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