

met and came to an agreement on their differences. The remainder of the transcripts were coded individually and we met to resolve our differences and reached complete agreement.

4.3.2 Quantitative. Quantitative data were analyzed to better understand changes in participant knowledge of CS, perceptions of CS, and attitudes towards teaching CS.

Participants’ knowledge of CS was measured using the CS content pre- and post-assessments. The assessment had 41 questions and the questions were mostly multiple choice with a few short answer questions. Questions were graded as either right or wrong, and total assessment scores for each teacher were calculated and compared. We examined not only the group as a whole, but also the two local and national cohorts as separate groups. To determine whether the pre- and post- assessment scores differed between the two cohorts, we conducted a Mann-Whitney U test. For within-subject analyses (e.g. comparing pre and post scores for the same participants), we conducted a two-sided t-test.

The attitudes data was drawn from the pre- and post-surveys. The 2018 PD used the validated Teachers’ Attitudes Toward Computers Questionnaire [6]. Five relevant factors from the survey (enthusiasm, anxiety, semantic perception, absorption, and significance) were included in our pre- and post- survey. The semantic perception questions asked the teachers to rate how they felt about CS ranging from positive to negative adjectives (e.g. pleasant to unpleasant). In addition to these five factors, Enthusiasm for Teaching Computer Science was added specifically pertaining to teaching CS. In total, the final survey consisted of 33 Likert-scale questions.

In 2020, the validated attitude questionnaire was used with the questions being modified to ask about “computer science” rather than “computers” as the original questionnaire was written. To determine whether the pre- and post- survey answers differed between the local and national cohorts, we conducted a Mann-Whitney U test. Then we conducted a Wilcoxon Signed Rank test to compare pre- and post- survey results. We also compared the pre- and post-survey results between the 2018 and 2020 teachers.

5 RESULTS

We begin by comparing the local and national cohorts and presenting results on the overall effectiveness of the PD. We then review our findings about how the teachers perceived the diffuse schedule and virtual modality of our PD.

5.1 RQ1: Within vs. Across District Cohorts

The structure of our virtual PD allowed for two distinct cohorts: a local cohort drawn from a single, large, metropolitan school district and a national cohort. Our hypothesis was that teachers drawn from the same school district, even though they never met in-person and may be physically scattered over a great distance, might have attributes that led to greater learning and attitudinal gains. We have three lines of reasoning that lead to this hypothesis. First, teachers may feel more accountable because district leaders were involved in the PD. Second, teachers might share an identity and sense of community with other teachers in the cohort due to being in the same district and teaching similar students. Third, they might be more engaged because the teachers they meet would be potential local collaborators in the future. To investigate whether

there were differences, we compared the scores of the pre- and post-CS assessments and pre- and post- attitudes surveys by cohort.

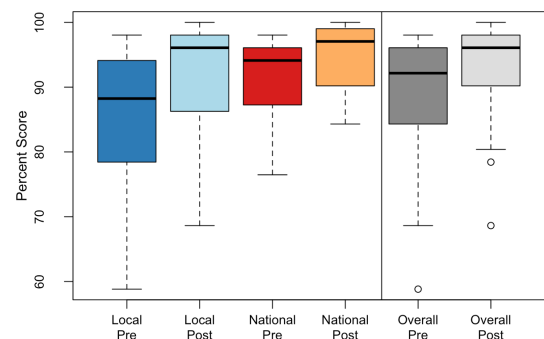


Figure 1: The scores of participants in both cohorts and overall, in knowledge pre- and post- assessments

Finding 1: There were no statistically significant differences in pre- and post- attitudes or knowledge between the local and national cohorts.

Figure 1 displays the pre- and post- CS assessment scores of the participants, both separated by cohort and combined. Despite a visual difference in the graph between the pre- assessment scores of the cohorts, there was **no statistically-significant difference between the groups’ knowledge** for either the pre- ($W=120.5$, $p=0.15$, $r=0.241$) or post-assessment ($W=145$, $p=0.48$, $r=0.117$).

Figure 2 displays the CS attitude scores of the cohorts. We combined Likert scores to form composite attitudinal scores for each factor. Differences in values between the survey factors is partially due to the fact that each survey factor has a different range of values on their Likert scale, shown by the black line. Enthusiasm, Anxiety, Absorption, Significance, and Teaching CS Enthusiasm are measured on a 1 to 5 scale, and Semantic Perception is measured on a 1 to 7 scale. A higher Likert rating indicates a more positive attitude, including the Anxiety factor. There were **no significant differences between the groups’ CS attitude for any factors** in either the pre- or post-survey.

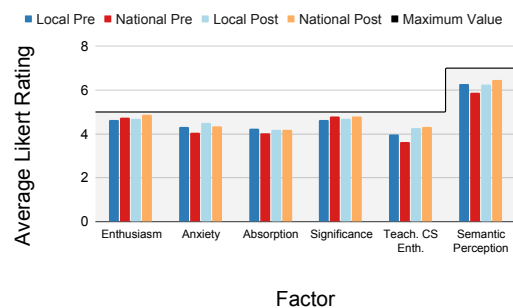


Figure 2: Average Likert rating per survey factor of participants in both cohorts in attitudes pre- and post- survey.

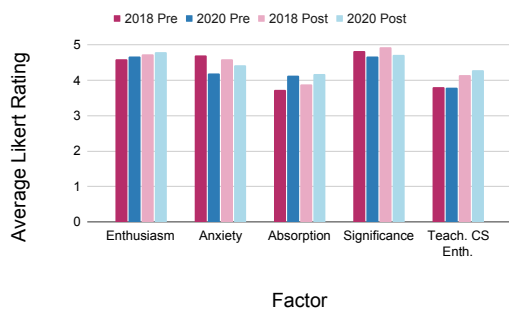


Figure 3: Average Likert rating per survey factor of 2018 and 2020 participants in attitudes pre- and post- survey

5.2 RQ2: Outcomes of a Diffuse, Virtual PD

We next investigate the second research question, which asks if the diffuse PD was successful. To answer this question, we look both at the pre/post differences of the virtual, diffuse PD run in 2020 and also by comparing the 2020 virtual, diffuse PD with the condensed, in-person version of the PD conducted two years prior.

Finding 2: There was a statistically significant improvement in both learning and attitudes in 2020.

The overall results depicted in Figure 1 show a statistically significant improvement in CS content knowledge in teachers who participated in the diffuse PD ($t=2.385, p=0.02, d=0.62$) with the average pre-assessment score being 88.5 and the average post-assessment score being 93.27. The standard deviation for the pre- and post-assessment scores are, 9.56 and 7.5, respectively. Across all participants there was an increase in score between the pre- and post-knowledge assessment. Participants scored on average 4.3% higher on the post-assessment than on the pre-assessment. This increase is despite a possible ceiling effect, since the starting average was already above 88%, indicating that many of our teachers began with a strong set of knowledge about CS and Scratch programming.

Figure 3 displays the average Likert rating for the pre- and post-surveys of the 2018 PD and the combined cohorts of the 2020 PD. Looking just at the 2020 results, we see that there was a significant increase in positive attitudes between the pre- and post- attitudes survey ($V=115, p=0.005, r=0.372$).

Finding 3: The virtual format was as or more effective than the in-person model with respect to attitudinal outcomes.

Figure 3 displays the attitude scores for each factor with each cohort. Table 1 shows that there was a statistically significant difference in the CS anxiety between the 2018 and 2020 groups in the pre-survey ($W = 439.5, p\text{-value} = 0.002166, r=0.427$) but not the post-survey ($W = 356, p\text{-value} = 0.1639, r=0.194$). The 2020 had a larger reduction in CS anxiety; they started at a higher CS anxiety level but ended at a similar point to 2018.

5.3 RQ3: Teacher Perceptions of a Diffuse, Virtual PD

In this subsection, we expand on the quantitative results of the attitudinal Likert questions to present an analysis of teachers’ perceptions of the diffuse, virtual PD design. Our focus group interview

	Pre		Post	
	2018	2020	2018	2020
Enthusiasm	4.60	4.68	4.73	4.79
Anxiety	4.71*	4.19*	4.59	4.42
Absorption	3.73	4.14	3.88	4.18
Significance	4.82	4.67	4.93	4.72
Teach. Enth.	3.80	3.79	4.14	4.29

Table 1: Average rating per factor between the groups. Bolded with a * indicates statistically significant differences when adjusted using the Bonferroni Correction.

protocol asked participants to share their perceptions about the diffuse nature of the PD sessions and the infrequent meetings over a longer period of time than is typical of teacher summer PD.

Finding 4: Teachers had a positive view of the PD length.

An overwhelming majority of the teachers indicated that they had positive views of the PD length (36 out of 42 teachers). Teachers cited the spacing of the sessions, the virtual format, and commuting difficulties as contributing to these views. They felt that the spacing of the introduction and collaborative sessions allowed them time to work on their projects, explore and digest the content, refresh their knowledge and understanding, think about their problems, and ask for help when needed. As one teacher said, the extended length “gave me more time to process and assimilate the information and get a clearer understanding”. As the PD progressed, teachers reported developing routines that fit the diffuse structure: “I was able to work on it Tuesday, Wednesday, so that way Thursday if I had any questions...I was able to kind of come prepared with that.” Five of the above teachers, however, also expressed that the duration of the PD was too long: “I mean this was a long PD.” and “I could even have done like longer sessions ... in between a 2 full days versus the eight weeks.” This indicates that although the teachers found the diffuse schedule to be beneficial, they also found the full 8 weeks to be a large time commitment.

Finding 5: Teachers liked the blend of synchronous and asynchronous work.

Teachers mentioned the blend of synchronous and asynchronous work when we asked about the unique aspects of our PD compared to other virtual PD programs. Nine teachers highlighted positive interactivity and the blend of synchronous and asynchronous components as unique compared to other virtual PD programs. One teacher stated: “I took one other virtual PD this summer and it was asynchronous so it was all just...do it at your own pace and there really wasn’t any real human interaction. So I liked that there’s real human interaction, so that was unique.”

6 DISCUSSION

Our goal for this work was to understand the experiences of teachers going through a diffuse, virtual PD. In redesigning the PD, we created a longer PD (in terms of calendar days but not in terms of in-person content hours), resulting in a diffuse structure that provided significant flexibility to attendees. The PD also blended synchronous and asynchronous learning opportunities to maximize the benefits of working virtually. In this section, we review our findings and evaluate the effectiveness of the PD and discuss implications of this work and limitations of the study.

6.1 Local vs. National Cohort Similarities

Research has shown evidence of the importance of having a collective community for effective PD [3, 20, 23]. Our hypothesis was that a cohort of teachers from a single school district would see greater benefits compared to a cohort of teachers from different districts. This is because teachers from the same school district may know each other, follow similar norms, and understand the needs of students in the district better. However, no differences appeared in the data. There could be several reasons for the lack of difference.

One explanation is that the school district for the local cohort was too large geographically to produce a cohesive sense of community among the teachers. None of the teachers in the local cohort taught at the same school and might not have known each other. Additionally, with such a large school district, the norms and needs of one school may not be as similar to the norms and needs of other schools as we thought they would be.

A second possible explanation is that this PD was the first opportunity for a national cohort to participate in Scratch Encore PD, but it was the third opportunity for the local cohort, which may place them in different places in Rogers' Diffusion of Innovation theory [27]. The national cohort self-selected based on learning about the curriculum from national forums and then being contacted about the opportunity by our team, which means they might be innovators or early adopters [22]. The teachers from the local cohort, on the other hand, were strongly encouraged by the district, which might have resulted in a group skewed towards early majority. So the personal initiative shown by the national cohort teachers may have balanced out the identity advantages of the local cohort.

6.2 Outcomes of an Effective PD

Virtual PD has shown promising results [5, 28] in the past and allows us to reach more teachers around the country and across the world. Recent work has shown the community that an emergency switch from in-person to virtual PD can still result in positive outcomes for the teachers [1, 15, 31].

Desimone asserts that effective PD should result in the increase of the teachers' knowledge and skills of the subject, changes in their beliefs and attitudes, or both [9]. Our analysis revealed that diffuse structure of the PD for Scratch Encore was effective in increasing teachers' CS knowledge, CS attitude and confidence, and teaching CS attitude and confidence. We also found that the teachers who went through the diffuse, virtual PD in 2020 experienced similar or better positive effects in CS attitude as the teachers in the in-person PD in 2018. We believe that the positive outcomes of our PD can partially be explained by the combination of the diffuse format and teachers increased comfort with virtual instruction.

In offering a diffuse, virtual PD, we found the blend of synchronous and asynchronous time spread across many weeks allowed local and national teachers to participate in the PD due to the flexibility of the schedule. This is attractive to teachers in the summer, especially once the pandemic is resolved. One teacher in this PD even attended a PD session while on vacation.

From our focus group interviews, we also discovered that the virtual aspect removed the barrier of commuting for many teachers, even some teachers in the local cohort who would have only needed to commute within the (large metropolitan) city in which they live.

Five teachers discussed commuting as a barrier to attending in-person PD (*"I would never have come out to [the city] this summer... it just wouldn't have been in the cards for me."*). The virtual and thereby geographically neutral format was important in allowing equal access to CS PD and will lead to more well-trained K-12 CS teachers. While many parts of our lives will return to "normal" once the pandemic is over, the knowledge we gain from learning and teaching online can be harnessed to improve teachers' PD experiences and to continue to reach a larger number and more diverse group of teachers.

6.3 Limitations

The number of teachers who participated in the PD was relatively small (42), and the participants were self-selected because only teachers who had interest in teaching CS would join the PD. Additionally, as a qualitative study, there is always a potential of researcher bias. However, we worked together to resolve our differences through discussion in order to minimize those biases. Finally, we currently do not have data on how teachers implemented CS in their classrooms and whether the PD program helped them boost their students' learning. This is an area of active research and plan on continuing this research to address these limitations.

7 CONCLUSIONS

With the increase in demand for CS in K-12 schools comes the need for knowledgeable teachers to teach CS content. Research on PD for middle grade (5th-8th) teachers has only emerged recently and there is still much to learn about how to design effective and scalable PD for these teachers. Towards this end, this work reports on the effectiveness of a virtual, diffuse schedule PD program for middle grade teachers. We found that the diffuse, virtual PD was equally effective in terms of knowledge and attitude for both local and national cohorts of teachers. Our analysis found that teachers who participated in virtual, diffuse PD for Scratch Encore had increased CS knowledge and improved CS attitudes. Further, they expressed positive sentiments about the extended and virtual PD and its blending of synchronous and asynchronous instruction. Collectively, this work contributes to the growing body of knowledge on how to design effective PD programs for K-12 CS teachers, and in doing so, seeks to help address the need to scale effective CS PD to help prepare teachers to bring CS into classrooms across the country and around the world.

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