A Comparative Analysis of Online and Face-to-Face Professional Development Models for CS Education

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ABSTRACT
This paper compares student outcomes from 75 K-12 teachers who participated in either online, blended, or face-to-face professional development design to support teacher implementation of a programming curriculum during the regular school day. The results are based on survey responses collected over two years from 4,832 students. With only one exception, the results showed no negative student outcomes when comparing student survey results from teachers who participated in online professional development compared to students of teachers who participated in face-to-face professional development. Students who had teachers who participated in face-to-face professional development, however, expressed stronger interest in designing their own games at home. These results suggest that online professional development that is designed to support K-12 teacher classroom implementation of CS education curricula is a viable model with respect to student outcomes. Recommendations for the design of online curricula for CS education are discussed.

CCS Concepts
• **Social and professional topics~Computer science education** • *Social and professional topics~Computing education programs* • *Social and professional topics~Student assessment* • *Social and professional topics~K-12 education* • *Social and professional topics~Adolescents* • Social and professional topics~Model curricula • **Applied computing~E-learning** • *Applied computing~Distance learning*

Keywords
teacher learning; student dispositions; game design

1. INTRODUCTION
The need to rapidly scale up professional development opportunities in computer science education has been implied in various initiatives such as CS10K, CS for All, and a number of government and corporate investments in CS Education. The preparation of 10,000 teachers in computer science requires the consideration of a multitude of professional development options, and cannot rely solely on face-to-face models that require teachers to commute hours to a computer programming workshop over several days or weeks. For many teachers, such a commitment to professional learning is an expensive and untenable option that, not surprisingly, leads to further exacerbation of a digital divide for the next generation of students going to schools with teachers who have limited access to such geographically convenient resources.

The promise of distance learning is certainly not new, not by any measure. One of the first documented correspondence courses in the United States, focusing on shorthand lessons, was offered by the Boston Gazette in 1728 [5]. In the 1950s, the rapid spread of television later inspired video-based correspondence courses, which have more recently morphed into short instructional videos that can easily be found on YouTube and Khan Academy. Online learning is happening. The widespread access to computer technology and broadband in many modalities now offers unprecedented immediate access to text, images, video, and a host of interactive technologies. What is less understood is the quality of learning that is occurring, or the relationship between the online experience and the instructional designer's intended outcomes.

Even though opportunities for online learning are present in K-12 schools, to achieve the widespread adoption of computer programming in schools teachers need opportunities to (re)learn computer programming from an instructor's perspective so that they can confidently implement engaging, meaningful instructional units with their students and commit to teach these new course offerings. To support all teachers who are interested in providing these opportunities for their students, the design of effective professional development is critical.

2. RELATED LITERATURE
A well-known set of criteria for effective professional development is that provided by Garet and colleagues [8], developed through a study of outcomes for more than 1000 math and science teachers across the USA. Five essential factors emerged: *duration* (contact hours and timespan), *collective participation* (simultaneous involvement by individuals from the same school), disciplinary *content focus*, *active learning* (performing meaningful activities relating to practice), and *coherence* (alignment with standards and assessments, as well as with teachers' ongoing professional development pathways and learning communities). More recently, other investigators have offered their ideas about additional elements that could be important. Wilson [18] points to promising ideas such as ensuring teachers' comfort with the PD process and familiarizing them with how to teach specific curricula through direct instruction techniques, although further evidence is needed. Other emerging

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PD concepts with implications for student learning include focusing on desired effects for students, the role of teacher coaching, and support from school and district administrators [3, 14, 18].

2.1 Professional development models

In addition to considering recommendations for professional development in general, providers should become aware of the promise and the tradeoffs involved in using and combining different delivery methods. Below we review key findings in the literature regarding face-to-face, online, and blended PD, specifically noting applications with respect to teachers of computer science. One question that past researchers were anxious to address concerned the parity of outcomes from these alternate approaches. In a study comparing matched online and face-to-face PD experiences for high school environmental science teachers, Fishman et al. [7] found equal gains for teachers across conditions, as well as for their students. Similarly, based on a review of published research on these three PD modes conducted by Cordingley and Bell under the auspices of the Centre for the Use of Research and Evidence in Education (CUREE) [3], the effects of other attributes strongly outweigh any influence of mode. It is also important to be aware that PD is a facilitated process, even when resources can be accessed independently, and that mentor qualities, abilities, and actions strongly affect results [12, 13].

2.1.1 Face-to-face professional development

Thought of as the original professional development model and the standard by which other PD models are judged, the benefits and limitations of face-to-face PD only come to light when other models are considered. Training conducted in person is advantageous with respect to personal interaction, even though some exchanges can be replicated online. In particular, facial expressions and body language are more visible, leading to richer communication [3]. Also, while in-person PD instructors and peers cannot always reply instantly, the time needed for learners to receive responses to their questions is much shorter than it would be using asynchronous technologies such as discussion boards. Through the workshops accompanying their CS Principles MOOC, Gray, Corley, and Eddy [10] expected that this level of interactivity would lead to stronger community and greater teacher confidence. Another advantage of meeting face-to-face is that teachers are more likely to complete the training [6]. The social obligation to participate in face-to-face PD through active or passive engagement scheduled class activities requires greater personal commitment for a sustained period of time. The peer influence on completing in-person training is also more compelling than what is found in online options. Although there are clear benefits, PD providers must also consider associated difficulties, such as lack of scalability [4] and higher cost of attendance [1, 6]. One initiative that successfully worked at scale is England's Network of Teaching Excellence in Computer Science program, which deployed master teachers at hubs throughout the country to conduct group activities and work with individual CS instructors on pedagogical and programming skills [15]. An entirely different approach to professional development is used by Exploring Computer Science, which actively engages teachers in using that curriculum in a paced series of summer institutes and quarterly gatherings [9].

2.1.2 Online professional development

Online professional development comes in many forms. In addition to the basic synchronous / asynchronous distinction, delivery approaches can include the use of written materials, live or pre-recorded webinars, and even high-fidelity simulated environments [4, 6]. Such resources are typically meant to be used within a supportive community environment rather than independently. According to a study led by the Harvard Graduate School of Education, which examined the research landscape for online professional development in 2009, this common approach is used both to foster collegial collaboration and for its ability to encourage teachers to reflect on their learning and professional practice [4]. Asynchronous PD can support extended discussion and contemplation particularly well due to its lack of real-time constraints. However, individuals who are isolated from others who teach similar classes, either due to geographic location or because they teach in low enrollment disciplines—as is often the case for K–12 computer science instructors—may prefer synchronous events that allow direct interaction, although any access to professional learning communities is desirable [1, 3, 14].

Another strong benefit offered by online PD is time flexibility for teachers. They can choose when to learn on both short- and long-term scales, accessing "online resource repositories, which are brimming with lesson plans, assessments, videos of lessons in action, and other tools to meet immediate needs" [1] as well as scheduling training that is relevant to their continuing professional growth [4]. Even teachers from large, well-funded districts can appreciate the wide range of options available online, allowing them to obtain training outside of locally-arranged opportunities and receive mentoring from people possessing specialized expertise [1, 4]. In spite of its many strengths, online learning for teachers is not a panacea, as disadvantages also exist. In the absence of course credit, obligatory reporting to administrators, or other extrinsic factors, they may not feel sufficient motivation to fully engage in or complete online coursework [3]. In addition, PD providers may be unable to keep online course content up to date or offer continued access due to funding constraints for facilitators or online instructional technologies [1].

2.1.3 Blended professional development

In blended (also called hybrid) PD offerings, face-to-face and online components are combined, and the resulting structures vary broadly from program to program. For example, Georgia Tech's Institute for Computing Education focuses primarily on in-person workshops (full weeks in the summer, and brief, ongoing events during the school year), with supplemental materials such as webinars available online [6]. In contrast, the structure of training for the Beauty and Joy of Computing, an implementation of the AP Computer Science Principles course, is quite different. The PD wraps beginning and ending weeks of face-to-face professional development, culminating in a focus on pedagogical content knowledge and classroom integration, around four weeks of online activities [14]. If opportunities to meet in person are limited, focusing on issues of practice and tool use while instructors are present is considered to be an effective use of the time [1]. Improvements in practice and corresponding effects on student outcomes are more likely when programs support classroom implementation by offering highly relevant and timely information and by allowing teachers to adapt activities to their specific needs [11].

A number of desirable outcomes occur in response to strategic use of face-to-face interaction opportunities. Both early and frequent use of such meetings have been found to contribute to teacher community development [10, 11]. Additionally, in comparison to fully online PD, blended experiences can significantly increase instructional unit completion rates for individuals. In the case of the PD MOOC mentioned earlier, the number of completed activities grew more than fourfold, from 21% to 88% [10]. For greatest success, professional development providers must also ensure that an intentional and complementary relationship exists between the online and face-to-face components of their offerings. Berger, Eylon, and Bagno [2] investigated how teacher growth can be promoted though the flow of ideas between the two learning environments, and also examined effects on patterns of reasoning.

2.2 The need for PD options

This review of the pros and cons of various professional development models suggests that advances in information and communication technology have led to greater leveraging of tech-based instructional resources. Even in the context of face-to-face PD, technological resources are used to share curricula, document teacher reflections, and sustain communication between teachers beyond the duration of a summer workshop. In some sense, an increasing integration of technology into all forms of teacher professional development has occurred, resulting in challenges in making strict comparisons between face-to-face, online and blended models. For the purposes of this paper, face-to-face PD is defined as an initial training facilitated through in person interaction between facilitators and colleagues. Online and blended models involve facilitation and interaction that primarily occurs through online communication tools and activities.

3. METHOD

The Scalable Game Design project has been offering face-to-face professional development to K-12 teachers since 2008, resulting in the participation of over 500 educators in professional development activities. Three years ago we partnered with eMINTS National Center, an organization that specializes in the design and facilitation of online and blended professional development, catering specifically to teachers who often are not able to travel to professional development in the summer months due to time, travel and/or expense.

3.1 Face-to-face and online PD models

The *project* instructional materials designed for students support their programming of more progressively sophisticated games. The materials are also designed to support explicit classroom discussion of computational thinking patterns (CTPs) across the instructional sequence. Our approach to professional development has been to engage teachers in programming of the same sequence of games their students will complete so that they can more easily discern and appreciate the challenges their students might encounter when they attempt to troubleshoot typical programming errors that might occur.

The instructional sequence for teachers is facilitated at a more accelerated pace than what is expected for students for an average duration of approximately 32 hours of professional development (i.e., four eight-hour days). By the end of the first day, teachers have completed their first game, Frogger, and learned four CTPs, equivalent to what students would cover in one to two weeks of classroom instruction. As the training proceeds, teachers create additional projects including another game in the curriculum, a self-designed game, and a simulation. Additional topics include software features, debugging, pedagogy, and assessment.

The online professional development activities designed for this project model an instructional sequence that is similar to the face-to-face model. Nearly all of the activities in the online PD were adapted from resources provided to the design team when they attended face-to-face PD. Various widgets for online discussions and facilitator support are built into the online instructional delivery system. To satisfy the requirements of the online course teachers are expected to implement one game design unit with their students within a few months of completing the online PD activities. The duration of the online PD sequence is approximately 32 hours.

3.2 Data source

The primary research objective of the first phase of Scalable Game Design was to monitor the impact of the computer programming activities on students' dispositions towards computer science education and future pursuits [17]. To support this research objective a Student Motivation Survey was developed, validated and used [16]. Student data were collected before student experiences with the programming unit and after completion of the unit.

3.3 Population

For the purpose of this paper, we completed statistical analyses on student responses to the post-unit survey for teachers who participated in face-to-face PD and compared those results to responses from students who had teachers who completed the online PD. The survey was administered to students who were enrolled in classrooms of 75 participating teachers ($n_{\text{online}} = 28$ and $n_{\text{f2f}} = 47$) from August 2014 to June 2016.

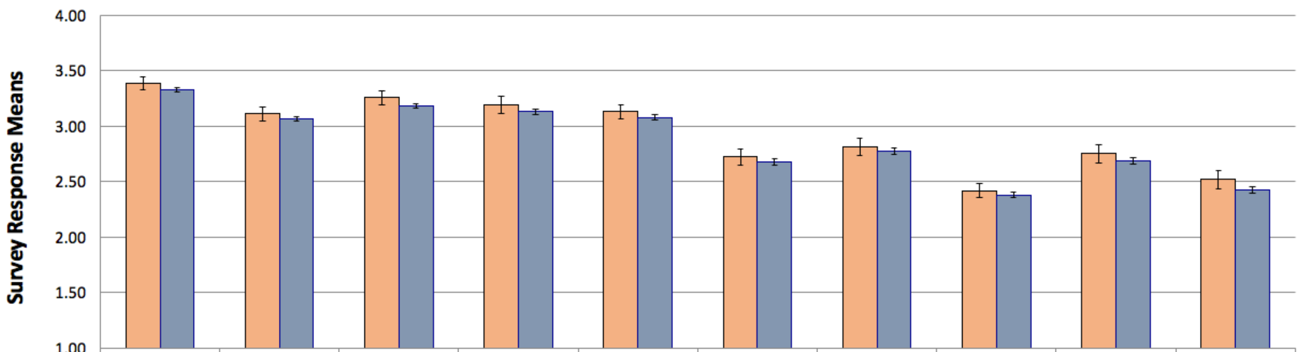
After removing student responses that did not include student assent or specific teacher information that could be used to identify their professional development mode, the data set resulted in a total of 4,832 student responses. Of that group, 479 students had teachers who participated in either online or blended PD; 4,353 students had teachers who participated in face-to-face PD. We chose to aggregate online and blended into one group given that approximately 70% of the blended model PD time was online content. The demographic distribution of each student sub group is outlined below, in Table 1. The race and ethnicity categories used in the survey were similar to those used in the most recent US Census.

	White	*Black/ AfAm*	*Hisp Latin*	*Nat Amer*	*Asian PacIs*	*Mult Ethn*
Online PD n = 479	58%	15%	9%	2%	2%	7%
F2F PD n = 4,353	48%	4%	19%	1%	4%	15%

Table 1: Surveyed student ethnicity (excludes no response)

While the groups are more similar than different, the online PD group had a much higher proportion of black students and the face-to-face PD group had a higher proportion of Hispanic, Latin@ students. These differences in student demographics for each group are consistent with differences in the demographics of student populations in the regions served by these PD models.

With respect to student gender, the online PD group was 45% female and the face-to-face PD group was 41% female. Regarding primary language, English was not the primary language spoken in the home for 7% of students who had teachers who completed online PD, compared to 11% for students who had teachers who completed face-to-face PD.



	Using computers is easy for me	I helped my friends do things during this class	I am confident in my ability to use computers.	I usually understand what is being talked about in class	Time goes fast when I am solving problems on the computer	In high school, I would like to take a computer programming class.	I want to take a class where I design games.	I would like to study computers in college.	Computer scientists have fun jobs.	I enjoy talking to other people about computers.
Online/Blended	3.38	3.11	3.26	3.19	3.13	2.72	2.81	2.42	2.75	2.52
F2F	3.33	3.06	3.18	3.13	3.08	2.68	2.78	2.38	2.69	2.42

Figure 1: Student responses to post-unit survey prompts by teacher training type

3.4 Data Analysis

To compare the student outcomes for each group we proposed hypotheses based on our observations and experiences with the F2F model and out review of the online activities. From these comparisons we hypothesized that students who had teachers who participated in online PD might struggle more often with the expected troubleshooting that would be required with most any programming activities. This might be due to one of the known trade-offs with online PD, due to the limited opportunities for online participants to interact and offer real-time peer feedback. With respect to student outcomes, more challenges with troubleshooting and how teachers might be able to support those situations might result in lower confidence and persistence in problem solving.

We computed descriptive statistical summaries for each of the Likert-scale items on the student motivation survey, using values of 4 for Strongly Agree, 3 for Agree, 2 for Disagree, and 1 for Strongly Disagree. We ran statistical tests of means (i.e., two-tailed *t*-tests) to ascertain any differences between the online PD and face-to-face PD groups.

4. RESULTS

Our summary of the results is organized as a chronological account of the findings that emerged from the analysis and our approach to pursue additional analyses to inform arguments that could be made against probable counterfactuals related to what we know about the professional development context and other possible factors.

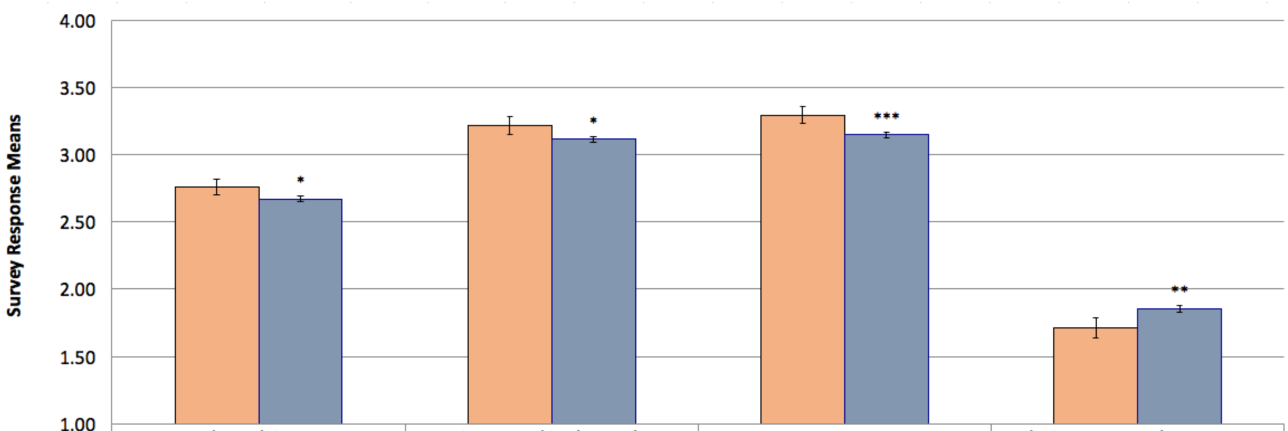
4.1 Summary of the post-unit survey

On the Student Motivation Survey (SMS) there are 35 items in which students self-report their use of technology, confidence towards computer use, future interests in computer science education, and their opinions regarding what they design in the Scalable Game Design unit. Fourteen of these items are Likert scale items. For the purposes of this paper, we begin with the items in which no statistically significant differences were found.

The survey items are summarized in Figure 1 using Likert scale means, with lower scores associated with disagreement and high scores with agreement to the prompt. Since the purpose of this analysis was to identify similarities and differences between students who had teachers who completed online and face-to-face professional development, we disaggregated the data by just those two groups. As there was no option for students to select “neutral” as a response, an item mean of 2.5 would be comparable to an overall neutral affinity toward that prompt. Standard error bars are also included for each mean to support the evaluation of statistically significant comparisons between means.

Figure 1 focuses on statistical similarities between these two groups. For item *a*, both groups found computers equally easy resulting in the group means for this prompt to be the highest for any survey item. With respect to our troubleshooting challenge hypothesis, in item *b* both groups of students self-reported that they helped their peers in class to the same degree. Both groups appear to include opportunities for peer feedback. The classroom environment for peer feedback as reported by students was surprisingly similar, suggesting that teachers created (or maintained) opportunities for peer feedback when they implemented computer programming activities with their students, regardless of the type of professional development. The similarity in these means may also be due to the explicit discussion of pedagogy in both PD options and the use of prior research data to communicate the importance of more student-centered pedagogical approaches like guided discovery and the inclusion of opportunities for peer feedback [16]. This appears to have been communicated through PD and incorporated into teachers’ practices in such a way that students helping peers with classwork was perceived similarly by both groups. The similarities in classroom environments may explain why the implementation of game design units also resulted in equally positive reports of students understanding what happens in class.

Four items on the survey relate to students’ future pursuits: taking a computer programming class in high school, taking a game design class, studying computers in college, and their perception of computer programming jobs. In each case, the results for each group showed no statistically significant differences between the means. In fact, it is remarkable how close the means for these two groups are for each of these prompts. These items are important for addressing the computer science education pipeline where students, particularly females and underrepresented groups, drop out of computer science more frequently as they move through school.



	I am good at solving computer problems.	I am interested in the work I get to do in this computer class.	I enjoy the work I do in class.	I design games at home on my own computer.
Online/Blended	2.76	3.22	3.29	1.71
F2F	2.67	3.12	3.15	1.85

Figure 2: Student responses to prompts by teacher training type (statistical significance levels: *p < 0.05; **p < 0.01, ***p < 0.001)

The similarity of the online and face-to-face responses is encouraging as it suggests that an online PD model does not contribute to differences in practices that might discourage students from pursuing computer science pathways. The data also show room for improvement for both types of professional development, suggesting further analysis and exploration into what might be causing lower interest in students continuing computer science education.

Of the fourteen Likert scale prompts, the four items summarized in Figure 2 were found to have mean differences that were statistically significant. Three of the four prompts had means that favored students who had teachers who participated in online PD. Given the previously discussed favorable aspects of face-to-face PD, these results were unexpected. The only prompt that favored face-to-face PD was item *p*.

Item *k* focuses on students' confidence in computer based problem solving. This prompt is somewhat open to student interpretation, and could include hardware or software related troubleshooting. Both means suggest general agreement, with the online PD even more so than the face-to-face group.

Items *m* and *n* are closely related. They focus on interest and enjoyment in classroom activities and the means for each item are nearly identical, with the means for both prompts favoring the online PD group. The consistent statistically significant difference in means for prompts *k*, *m* and *n* suggest a generally more positive student disposition towards class activities for teachers who completed online PD when compared to students who had teachers who completed face-to-face PD.

We included item *p* to document the extent to which classroom activities influenced student initiated activities. This prompt asks students about designing games on their own computer. As the item with the lowest means for both groups, one could argue that students might design games at home if they had access to a computer. From the analyses of a different set of student data from the same survey, we found that 85% of middle grades students reported having access to a computer at home. While not universal or perhaps as prevalent as access to television, student access to computers at home is significant. This is the only item that favors students who had teachers who completed face-to-face PD, with less general disagreement than the online PD group.

4.2 Possible intervening effects

Several possible intervening effects are possible that could explain the differences observed in survey responses between students of teachers who received different types of PD.

4.2.1 Sample size

There were significantly fewer students of teachers trained online who submitted post surveys as compared to teachers who were trained face-to-face. This smaller sample size could be influencing the results. That is, the lower numbers of online and blended PD teachers who have contributed to the research component of this project, and consequent small sample of students, could be responsible for the findings. Perhaps fewer personal connections between the research team from another state and the online/blended PD teachers could be contributing to reduced teacher buy in. To date we have observed lower yield rates from PD to research implementation, and more rapid attrition in research participation, but we are incorporating strategies to improve these rates.

4.2.2 Lack of comparable professional development

Teachers in the online group primarily came from a partnership between the Scalable Game Design project team and eMINTS. The eMINTS National Center offers online and face-to-face professional development and trainings for teachers and has one training with an inquiry based learning and growth mindset focus. About half of the online and blended teachers who were identified for this study also participated in the eMINTS' growth mindset training. With the much smaller sample of teachers (and students) for the online/blended student group, there is greater potential for the teacher sample to be influenced by training other than the programming and game design PD.

5. DISCUSSION

The student dispositions that resulted from the implementation of equivalent game design curricula, from teachers who participated in online, blended, and face-to-face professional development, demonstrated that there exist more similarities than differences. With only one exception, the results showed no negative student outcomes when comparing student survey results from teachers who participated in online PD compared to students of teachers who participated in face-to-face PD.

These results suggest that online PD designed to support K-12 teacher classroom implementation of CS education curricula can serve as a viable model to improve the leaky CS education pipeline. It is worth noting, however, that the design of the online PD instructional sequence and related activities was an adaptation of a face-to-face PD model that was iteratively improved over a period of five years. In the face-to-face PD we explicitly addressed the importance of pedagogy and the extent to which classroom practices can influence students' future pursuits in CS education. The activities were also designed to explicitly address computational thinking concepts so that students could apply concepts used to program one game in subsequent games, including ones that they design and program. Face-to-face models and their related instructional activities may serve as a design sandbox to promote the development of a robust, research-based online adaptation that can produce similar student outcomes.

These results should not suggest, however, that there are no differences in *teacher outcomes* when comparing online and face-to-face professional development. Findings from a number of MOOCs point to a severe attrition rate, although our online PD had completion rates of closer to 60%, far exceeding almost any MOOC. On the other hand, our online PD is not massive nor is it open to anyone. It is a managed online PD so that smaller groups of teachers can develop a sense of community and assigned facilitators can check in frequently with teachers to offer feedback and guidance in technical matters and completion of assignments.

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