What Makes CS Teachers Change? Factors Influencing CS Teachers' Adoption of Curriculum Innovations

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ABSTRACT
Computer Science (CS) education researchers hope their research has real impact on teaching practices. Developers of innovative curricula and tools for CS education want teachers to adopt their new approaches. What convinces a CS teacher to change and adopt something new—or not? This paper explores factors that influence CS teachers' adoption and change. We studied our workshop participants to determine factors influencing their decision on whether to adopt a new CS curriculum. The results from our study indicate that multiple factors, some surprising, influence CS teachers' adoption. Our findings suggest that teacher excitement in a new approach drives adoption, while more organizational or social issues inhibit adoption.

Categories and Subject Descriptors
K.3.2 [**Computers and Education**]: Computer and Information Science Education–*computer science education.*

General Terms
Design, Experimentation, Theory.

Keywords
Computer Science Education, CS Teacher, Adoption Factors.

1. INTRODUCTION
The past decade has seen significant change in the design and teaching of introductory CS (intro-CS) courses. Innovative approaches, such as Beyond LEGOs[2], Media Computation [10], and TeachScheme! [6], offer options in teaching intro-CS courses. Developers or proponents of these approaches usually provide workshops and other training opportunities to disseminate these innovations. However, offering Professional Development (PD) opportunities does not guarantee that a CS teacher will adopt any new approach into her own classroom. Developers of curriculum innovations often face the problem of the inconsistency, between the positive reactions of teachers towards curriculum innovations, and the fact that the same teachers do not bring those innovations into their own classrooms[13].

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As we know, teachers are the "cornerstone" or "the most influential factor" in implementing educational innovations [5, 8]. Therefore, any change in education requires a change in teachers. More importantly, a change in teachers requires teachers *choosing* to change. Hence, researchers or developers who want their innovations to have real impact on teaching practices need to understand what factors influence teachers *choosing* to change their teaching practices—the adoption, adaptation, and further implementation of computing curriculum innovations.

In this paper, we examine CS teachers' adoption and change in the context of one specific curriculum innovation—contextualized computing curricula. In the workshops we describe, teachers were shown a series of contextualized intro-CS courses offered for undergraduates, which emphasize a particular context or theme that permeates the course. The point of the contextualization is to encourage diversity and to improve the enrollment and retention of students in CS [11]. One major problem of current approaches for teaching intro-CS courses is the lack of relevance [14]. CS is perceived as irrelevant, boring, and difficult [1]. Contextualized courses focus on the learning of computing skills and concepts in terms of motivating domains where computing is useful, such as digital media or robotics [11]. Some past work has found that contextualizing the computing education has had an impact on student retention and motivation [16].

In this study, we investigated those teachers who attended our summer workshops on contextualized computing curricula, around what influences their decision to adopt that innovation. We started to seek answers to this question through collecting self-reported data from teachers on the concerns and challenges they perceived when considering adoption, and how they explained their adoption decisions. The essential goal of this study is to inform the design and implementation of quality PD for CS teachers as well as devising effective strategies for removing barriers that prevent teachers' adoption of curriculum innovations.

2. RELATED WORK
There is still relatively little known about what may affect CS teachers' adoption of educational innovations from the CS education research community. Research on teacher change and educational innovations in other domains offers a start point for us to examine this question in CS subject.

Recent work on teacher change and curriculum innovation has

suggested a bottom-up approach instead of the traditional top-down innovation model [5, 7]. In a traditional top-down innovation model, teachers are assigned a change from a superior (e.g., a school board, principal, or department head), and unfortunately, are usually blamed for the failure of an innovation. Change in this model is viewed as the transmission of ideas from curriculum developers or researchers to teachers [7, 13]. In contrast, the bottom-up or more teacher-oriented approach suggests that the role of teachers in curriculum innovation is not merely executing the innovative ideas of others. Rather, change in teaching practice relies on the change of teachers' knowledge and beliefs [5]. No change can occur without the teacher believing that the change is worth making. From this perspective, teachers' knowledge and beliefs could serve as critical factors that impact teachers' decisions about whether to adopt a new curriculum [12, 15], especially at the post-secondary level where teachers have significant influence (if not the final decision) over adoption.

Educational researchers who study teachers have identified a variety of teachers' knowledge and attitudes that might influence curriculum adoption decisions [15]. One central category is *pedagogical content knowledge and beliefs*—knowledge and beliefs that are specially related to teaching a particular subject (e.g. "CS" here). Specifically for CS domain, we have seen some related research on CS teachers' knowledge and beliefs, such as university lecturers' conceptions of successful and unsuccessful teaching of CS [3], and teachers' opinions about what should be taught in intro-CS courses[4]. However, we do not know if and how these perceptions or other aspects of teachers' knowledge and beliefs might impact their adoption of curriculum innovations.

In next section, we introduce our pilot study, which used CS teachers' self-reports as a starting place for an exploration of adoption factors.

3. PILOT STUDY

We conducted a pilot study through three summer workshops to explore what kinds of factors facilitated or prevented CS teachers' adoption of curriculum innovations. Through surveys at two different time points, we sought to understand what teachers thought their adoption factors *might be* and what they found them *to be* when they had to make the decision.

3.1 CS Teacher Workshops

We studied teachers in workshops on several contextualized intro-CS courses for undergraduates, including Introduction to Media Computation in Java or Python (both CS1), Media Computation Data Structures in Java (CS2), Engineering in MATLAB (CS1), and Robotics in Python (CS1). These approaches were presented as potential solutions for problems that the teachers might be facing. The teachers were shown research results providing evidence that contextualized computing education had a dramatic impact on student retention and motivation [9, 16].

Three teacher workshops on these contextualized courses were offered during summer 2007. The Media Computation Workshop was open to all CS teachers from the U. S. and described the three Media Computation courses (CS1 Java, CS1 Python and CS2 Java). The other two workshops called First Courses Workshop were limited to the University System of Georgia (USG) faculty and presented content from all the above five courses. In total, 36 CS faculties attended the workshops.

The workshops were designed to engage teachers in completing learning tasks proposed in each approach (e.g. creating a collage of images computationally, or getting a robot to follow a light), in order to give the teachers confidence about using the approach. The workshops were divided into 4-5 sections each day, organized around example lectures, follow-up exercises, and discussions.

3.2 Data Collection and Analysis

At the end of the workshops, we gathered information about teachers' attitudes towards making change, attitudes about the new courses, as well as their adoption concerns, through use of post-workshop surveys and discussions. We also asked teachers to evaluate the workshop quality. In Fall 2007, we surveyed them again to get actual adoption decisions with their own explanations.

In the post-workshop survey, we asked twelve general questions about teachers' attitudes and beliefs in terms of their interest and confidence in making change, perceived need to change, and their attitudes to the innovations. Teachers' attitudes to the new courses included their interest in using a specific course context, beliefs in the role of context in attracting students, the need to attract students, and students' ability to learn CS. These questions were selected as an initial subset of teachers' attitudes based on our prior experiences and literature review. In addition, we asked what challenges they perceived when considering adoption, and what unique needs of students or school situation didn't get addressed in the workshop. Meanwhile, during the workshops, participants had a 45-minute discussion about the adoption concerns they had.

A second survey was distributed in the fall semester after the summer workshops, so that the teacher participants would have made an adoption decision. In the adoption decision survey, participants were asked what the decisions were and their reasons for those decisions. Overall, 30 of 36 workshop participants filled out post- workshop surveys. 24 of the them also filled out the adoption decision surveys at the beginning of Fall 2007 semester.

Both qualitative and quantitative analysis techniques were applied to identify potential variables as well as the correlations between teachers' adoption and different variables. First, based on data from post-workshop surveys and in-workshop discussions, we identified common themes of adoption concerns. Since our sample is pretty small, we included all the variables reported by participants. We used regression analysis to examine the correlation between adoption decisions (as the dependant variable, 0-No, 1-Yes) and teachers' general beliefs and attitudes (as independent variables, using their responses to the twelve questions, from 1-Strongly Disagree to 5-Strongly Agree). Furthermore, motivation and barriers for actual adoption were generated from teachers' explanations for their adoption decisions.

4. OUTCOMES

4.1 Workshop Evaluation Results

After each workshop, we asked teachers to rate how informative, engaging, and helpful each workshop was in terms of each section in the workshop. One question on the post-survey was "How informative was the workshop?" where "1" is "not informative" and "4" is "informative." Similarly, we asked how engaging and helpful each section was, where "1" is "not engaging" (or "not helpful") and "4" is "informative" (or "helpful"). Overall, the participants considered the workshop to be satisfactory. Table 1 summarizes the responses.

Table 1: Survey responses to overall quality of workshop

Workshop	N	Overall Average	Overall Percentage Choosing "4"
Total	35	3.81	83.53%
May "First Courses"	5	3.83	87.50%
"Media Computation"	23	3.79	80.28%
July "First Courses"	7	3.87	87.30%

Teachers told us explicitly that the workshops did influence their perceptions on teaching CS. 16 teachers said that their attitudes and opinions about teaching intro-CS courses changed through the workshops. Half of the 16 mentioned they became more convinced in the importance and benefits of using a context teaching CS after the workshops. 5 of them reported they felt themselves more excited in or committed to implementing some aspects of the new courses. 3 teachers felt the need to change the current teaching approaches. 2 teachers reported feeling more confident in teaching these courses.

4.2 Workshop Attendees' Adoption Concerns

Although all participants expressed their interest in those contextualized courses with the majority of them (26 out of 30) considering adopting at least some ideas or materials of one course, they reported all kinds of concerns about adopting these courses in post-workshop surveys. We included all the concerns reported by participants to get a general idea of the relevant variables from teachers' eyes. During the workshops, a large group discussion also addressed the challenges of adopting a contextualized computing approach. The discussion points indicated similar results as reported in the surveys.

Results of teachers' adoption concerns can be summarized into four kinds of themes: teachers' attitudes and beliefs about CS curriculum, students and themselves, and organizational factors.

- **About CS Curriculum**

Teachers reported concerns related to their attitudes and beliefs about CS curriculum in terms of course transition from CS1 to CS2, content coverage and learning objectives. One challenge perceived was making a new course fit into existing curricula. For example, how teachers could integrate an introduction to media computation course into a current CS1 course, so that it could still match up a follow-up (CS2) course that might not change. Some teachers had concerns about whether these contextualized courses covered all the required content of intro-CS courses, and whether the approaches were fit for both CS majors and non-CS majors. A few teachers explicitly said that they didn't believe that students would learn the same concepts in these new approaches as with existing courses.

- **About Students**

Teachers were concerned about the fit between their students and these new courses related to students' interest in the course context, their background/preparation for learning the new course. One big challenge perceived was to get students prepared to learn a new course since students might lack background knowledge in math, media, or other areas related to the course context. Some of them explicitly worried about the low quality of students in their schools. A number of teachers wondered whether their students would be interested in the course context, e.g. media manipulation.

- **About Themselves as Teachers**

When considering adopting a new approach, teachers also experienced challenges from themselves. The most common concern reported was about their confidence in making change. Preparation time was among the most often-repeated concerns. When adopting a new course, teachers needed to spend time learning the materials, working on lectures, and developing lab assignments. While all the approaches provided lecture and assignment materials available, teachers would likely expend extra efforts to adapt the course materials to fit their own needs. The course context was a two-edged sword. While it might motivate students, it was also a challenge for teachers to become proficient in the context where they might have limited background knowledge. Meanwhile, some participants said their personal interest in a context (e.g. manipulating pictures or composing music) could facilitate adopting a contextualized course.

- **Organizational or Social Factors**

The above challenges were mainly related to what teachers believed about how the new course would be able to fit with curriculum, students and teachers themselves. Beyond these personal concerns, our participants also reported external, organizational, social factors that influenced their adoption.

First, participants reported a major problem was getting colleagues to embrace a new approach. A new approach could only succeed if it meshed with the other courses in local curriculum sequence, and with the colleagues who taught those courses. Second, some teachers did not have a wholly free hand in making curricular choices such as textbooks and programming languages. Funding for specialized resources (e.g. robots for Robotics in Python course) was a financial constraint. Third, teachers were worried about successfully installing all the software tools used in a new course such as a new IDE or other specialized tools. Teachers were insistent about the need for a sufficient package of course resources. Their confidence in their ability to adopt would be tightly tied to the existing of resource package.

4.3 Workshop Attendees' Adoption Decisions

4.3.1 Adoption Results

As Fall 2007 semester began, we were able to contact 24 teachers who reported their adoption decisions. 15 (62.5%) of them adopted/adapted some of the workshop content into their own classrooms. The adoptions varied. 8 teachers modified an existing course to use some of the content. 3 other teachers used one of the approaches to replace completely an existing CS1 course. 4 teachers created a brand new course in their schools.

4.3.2 Motivation for Adoption

Teachers explained their adoption decisions in terms of what motivated their adoption. First, the adopters were motivated by their beliefs about the *underlying philosophies* of the approaches, such as the role of context in motivating students and promoting learning. One adopter had told us that she had a big barrier from required programming language. She had to teach C++ in her classes, and none of our approaches worked with C++. She still decided to adapt our media computation ideas into her current C++ courses, because she became convinced that teaching CS in a context would help students to grasp CS concepts better. About half of the adopters said they adopted because they believed the adopted approach would help to motivate their students. Quoting from teachers' responses in adoption decision survey:

> "I feel that it's very important to motivate students to learn and this approach seems to satisfy that concern."
>
> "My motivation is motivation--I think our students will be motivated to work harder when their programs give them cool results."

Secondly, participants' prior experiences also played a role in facilitating adoption. Some of them found the ideas conveyed in the workshops were connected to their prior teaching experiences, which convinced them to adopt. As one teacher said:

> "I have always struggled with how best to motivate students to learn programming. For the past year, I have experimented with teaching Objects-First with a heavy emphasis on graphics and GUIs. I had some success with this approach last spring. After seeing [the workshop leader] is doing, media computation seems to be a natural migration for the way I teach CS1."

In addition, the features of the software used in these approaches might facilitate adoption. One teacher mentioned he was willing to adopt the new IDE—Dr. Java since it was easy enough.

4.3.3 Concerns Preventing Adoption

Teachers' explanations for their non-adoption decisions went beyond the factors that we originally considered. As reported in the post-workshop survey, some teachers did not adopt due to their personal concerns about the course content and about the preparation time demands. Non-adopters also described a lack of confidence in being able to utilize new course materials. However, the *main* barriers (more than half of the non-adopters reported) to adoption came from *organizational or social issues*. Non-adopters told us that they were unable to convince their colleagues to use a new approach or to integrate it into current courses. Otherwise, they were stymied by department curriculum restrictions (e.g. required programming language or materials to use). Below are quotes from teachers' responses to the adoption decision survey:

> "The other two people teaching the class wanted to unify the material taught to students and neither of them is informed of the Media Computation approach."
>
> "Actually, I personally would like to adopt both the Media Computation Course as well as the sequel Media Computation Data Structures Course. However, I am still working on convincing other members of my CS Discipline Committee."

4.3.4 Regression Results

Given the large number of factors reported by teachers, we wanted to know what were most important in teachers' actual decisions. We used regression analysis to look at proposed factors as possible predictors for actual adoption decisions. These factors included teachers' interest and confidence in change, the need to change, and their attitudes to the new approaches, including their interest in using the course context, beliefs in the value of teaching contextualized CS courses (attracting students), the role of context in attracting students, the need to attract students, and students' ability to learning CS. We only used these original survey variables (presented in twelve statements) in this analysis, not the new factors that emerged during the course of our pilot study.

Using binary logistic regression analysis at entry-level of $P < .05$, we were unable to build a significant regression model for our small-sized data. After running the regression analysis (forward stepwise method) at enter rate of $P < 0.1$, we got a final regression model including six variables with a *perfect* (100%) correct percentage of predicting adoption.

The first valid variable entered the model was teachers' excitement in using context to teach intro-CS courses ($P=.07$). The correct percentage of this variable was 70.8%, meaning that teachers' excitement in using course context could predict 70.8% of actual adoption. This variable also stayed in the final regression model with the biggest and positive impact on actual adoption. The other two positive predictors were teachers' confidence and their interest in new educational approaches, which were not surprising.

Surprisingly, teachers' *negative* feelings when thinking of trying new approaches had a *positive* impact on adoption. In other words, teachers who were worried about trying new approaches were more likely to adopt. One conjecture could be those teachers might pay more attention to research results and other results presented in the workshops and thereby became more prepared for adoption. Moreover, both teachers' belief that CS was relevant to students' lives and belief that non-CS majors have a harder time understanding CS concepts had *negative* effects on adoption. These results suggested the need of further examination of at least some of those factors in the regression model.

Most importantly, the findings highlighted the significant role of teachers' excitement/interest, which was also clued in both the perceived adoption concerns and reported adoption reasons, as stated by CS teachers:

> "Can faculty with no interest in Media Computation be dragged (successfully) into teaching using the Media Computation approach?"
>
> "[It's] fun, interactive approach. It was fun for me, so I'm sure the students will enjoy it too."

5. DISCUSSION & FUTURE WORK

5.1 Adoption Factors and Implications

As a first step, this pilot study helps us to uncover a variety of factors that influenced CS teachers' adoption of curriculum innovations. We found, similarly to what researchers have found in the other domains, CS teachers' attitudes and beliefs about curriculum, students and teachers themselves influenced their decision on adoption of curriculum innovations. Most of teachers' concerns were related to adopting innovative curriculum in general, such as the issues of teachers' preparation time, students' general level of knowledge sophistication, and availability of course materials. A few other issues were specific to the contextualized computing courses. For example, teachers were concerned about students' and their own background knowledge related to the course context. Moreover, both teachers and students' interest in the course context influenced teachers' adoption. Teachers wondered whether these courses could fit with general learning goals of a specific intro-CS course and students could ideally transfer from CS1 to CS2, despite any potential advantages in enhancing student motivation and engagement.

Meanwhile, for CS instructors, organizational or social factors such as local curriculum restrictions could influence and even critically prevent them from adopting a new CS curriculum. These factors are usually not determined by adopters, but do affect how teachers perceive the feasibility of adoption. Therefore, teachers may face multiple obstacles or concerns to adoption. Their adoption decisions are influenced not only by their individual beliefs and attitudes about curriculum, students, and themselves, but also by those external variables such as resources, faculty interactions, and organizational restrictions.

On the other hand, the pilot study results suggest teachers' interest/excitement plays a positive role in facilitating them to adopt curriculum innovations. Teachers might become interested in *the specific course content or learning activities in the new curriculum*, e.g. manipulating media in an intro-CS course. Teachers' excitement in a new curriculum probably have the magic to drive teachers to try it out, to help them make sense of it, and finally to convince them to adopt it. Broadly speaking, exciting teachers could be a powerful strategy for facilitating teachers' adopting of curriculum innovations.

It is also useful to reflect on the factors that were not significant in our regression analysis. The existence of research results showing the value of an approach is *not* a significant factor in predicting adoption. Teachers' belief that a new approach is good for student learning was also *not* a significant factor. To be clear, we are not claiming that research on learning is useless, nor do teachers not care about student learning. Rather, we are saying that the decision to adopt was *most significantly* driven by teacher excitement.

5.2 Future work

In this paper, we are at our first step—identifying adoption factors emerging from the pilot study. Our results are provocative but by no means conclusive. Future studies will have more convincing results if we have a larger *n* and consider the wider range of variables that we are now considering. Moreover, we found teachers' excitement in the new approach played the biggest role in driving adoption. Further study is needed to better understand what makes teachers become excited in a new approach. As we continue to refine the adoption factors and identify their relation to adoption, related findings might offer a basis for PD developers and facilitators to devise effective strategies for removing barriers that prevent CS teachers' adoption of curriculum innovations.

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