More Than Just Plain Old Technology Adoption: Understanding Variations in Teachers' Use of an Online Planning Tool

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Abstract: This paper examines variability in teachers' usage patterns as they interacted with an online teacher support tool, the Curriculum Customization Service (CCS), as part of their professional work. The CCS is a web application that supports teachers in planning, adapting, sequencing, and enacting differentiated instruction in Earth science education. By mining the usage log files of over 40 teachers who used the CCS over a yearlong period, we analyzed for variability using a framework developed in marketing research to characterize appropriation of technology. This analysis helped reveal different kinds of teachers' patterns along two dimensions: frequency and variability of use. We then turned to qualitative records of teachers' experiences during the year to better understand why those variations appeared. Focusing on the experiences of several teachers, we distilled "contextual contingencies" that influenced how they chose to appropriate and use the CCS.

Introduction

The complex work that constitutes teaching has and continues to comprise an important area of research in the Learning Sciences (Fishman & Davis, 2006). One function of that body of research (e.g., Horn, 2005; Schneider et al., 2005) has been to inform the design, implementation, and modification of new technologies to support various aspects of work that teachers do inside and outside of a typical school day. For example, technologies have been developed to support teachers as they learn how to use new, inquiry based curricula (Fishman, 2003), reflect on specific moments of their own teaching (Sherin & van Es, 2005), engage in assessment conversations with their colleagues (Shapiro & Wardrip, 2011), participate in online professional development (Dede et al., 2009; Schlager & Fusco, 2003), or seek ideas and suggestions from a distributed network of professional peers for their lesson planning (Renninger & Shumar, 2002; Recker et al., 2013; Sumner & CCS Team, 2010). Beyond the explicit decision to design such tools in a way to support specifically identified work practices associated with teaching, these tools will often capitalize upon emerging technical capabilities and developments that can make the tool more powerful and attractive for teachers to use. As such, technology tools designed for teachers bear similarity to many other technology products in that they tend to accrue a number of new features with each passing design iteration and version release.

This accrual of features means that while we can (and should) continue to be concerned with whether or not teachers will adopt a given technology, we also need to be mindful of *how* those who do adopt the technology will actually use it. To illustrate, consider the example of a smartphone. This ubiquitous device is now built with capabilities such as voice calling, text messaging, video chatting, schedule management, contact management, email, Internet access, and image capture. We would reasonably expect from our own experiences that the patterns of use associated with these varied features will differ across different groups of users. For example, many young adults use smartphones heavily in service of text messaging and image capture, but only occasionally for voice calls. Working professionals may use their smartphones largely for email, schedule management, and contact management in a manner quite different from a senior citizen who may prefer to use his/her smartphone for voice calls and video chats with friends and family. While we could consider all of these individuals to be "adopters" by virtue of owning a smartphone, their actual patterns of use will greatly differ.

In this paper, we hypothesize that similar variability in use patterns will also appear for teachers as they engage with new, feature-rich technology tools intended to support their professional work. Our primary goals with this paper are the acknowledgement and characterization of these use patterns, followed by identification of what we have termed "contextual contingencies" that lead to these use patterns. We argue that the outcome of this work will be profitable and necessary for the Learning Sciences community as it continues to design and improve technology innovations to better support teachers.

In the remainder of this paper, we provide the research context and theoretical framework for this work, followed by a description of the research design, data sources, and analysis. We then present examples of five teachers, through which we explore variability in usage patterns as teachers use an online planning tool, and analyze teachers' experiences to help understand how contingencies influenced variation in these usage patterns.

Research Context

The Curriculum Customization Service (CCS) is a web-based application that supports teachers in planning, adapting, sequencing, and enacting differentiated instruction. Developed through a participatory and iterative design process with several practicing teachers, the tool integrates research-based inquiry-focused curricula (publisher materials, specifically the *EarthComm* curriculum published by *It's About Time*) with open educational resources (OERs) and teacher contributed materials in the context of learning goals and key curricular concepts (Sumner & CCS Team, 2010). The CCS currently includes content for middle and high school Earth science, middle school physical science, and most recently, high school algebra. The focus of the current study is high school Earth science teachers.

In response to teacher feedback and observations of actual CCS use by teachers, a number of features have been added to better support teachers' work practices (see Figure 1). For example, the CCS has features in it now that allow teachers to match online and publisher resources to district learning goals, store a personalized set of preferred resources for later access, and build custom sequences of instructional materials from discovered resources that they can access while teaching. Additionally, features associated with new social media platforms have also been added. In particular, teachers can assign and view star ratings and descriptive tags for resources, see the number of people who have stored a particular online resource, and display a live activity stream indicating recent and current usage of materials by other teachers.

To date, there have been a number of noteworthy successes with the use of the CCS in several schools (Butcher, Ferrara, & Devaul, 2013; Sumner & CCS Team, 2010; Ye et al., 2013). Teachers report that the CCS and its various features (that many of them had suggested) has helped them to approach their daily teaching in new ways, to become aware of the colleagues' work practices, and to customize their instruction for their students' specific needs. Student exam scores indicate that students, especially English language learners, are increasing in their knowledge and understanding of science concepts. Yet even with these successes, the increase in the number of features in the CCS led us to suspect that the ways in which teachers use the tool may vary in consequential ways.

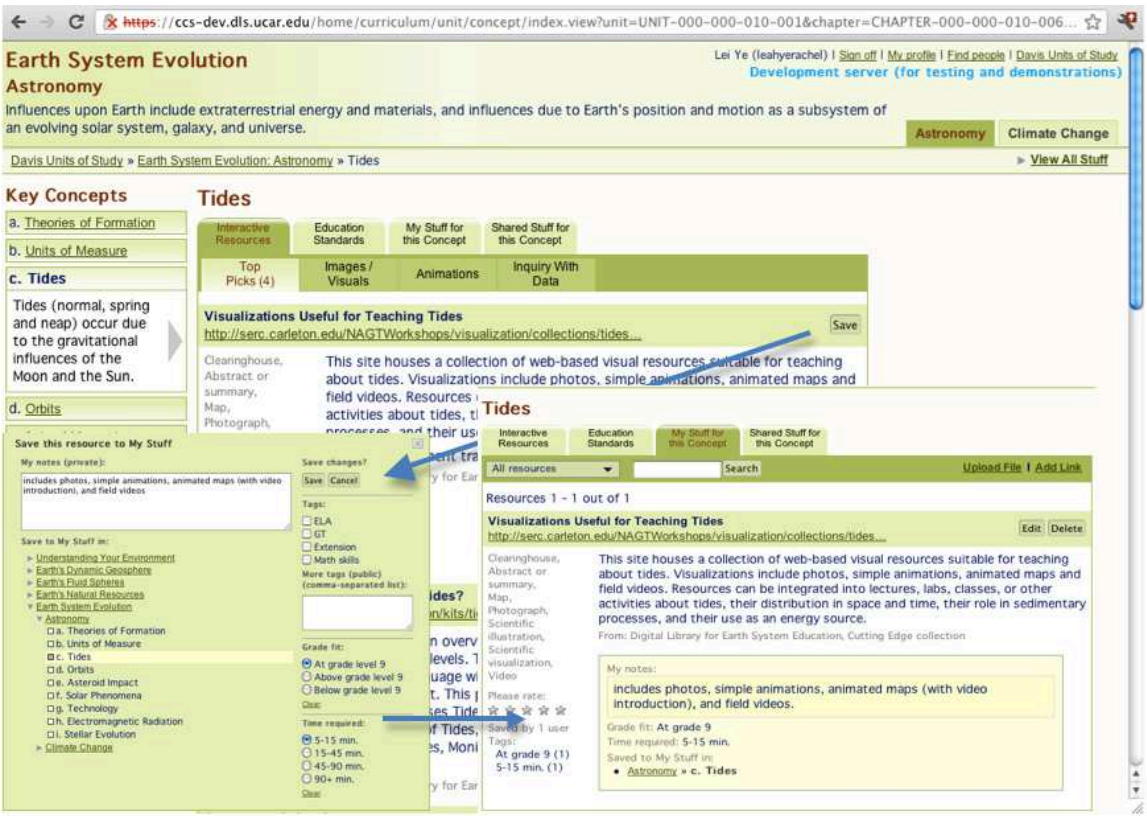

Figure 1. A screen capture of the CCS as a user selects an online resource and saves it as a private resource.

Theoretical Perspectives and Related Prior Work

This study of variation in teachers' use of the CCS is informed by two theoretical perspectives related to appropriation of new information technologies "in the wild." The first is a perspective on technology appropriation called "use diffusion" that originated from the marketing research literature (Shih & Venkatesh, 2004). Similar to the example of smartphones presented above, the use diffusion perspective also begins with the assumption that different groups of people will preferentially engage with different features of a new technology. Indeed, this is where Shih & Venkatesh argue that progress is more likely to be made in efforts to better characterize consumer behavior. To capture the predicted variation, they propose modeling use in terms of two dimensions: frequency of technology use and variety of feature use (Figure 2). Against this space of possible technology behaviors, there are four expected use patterns. These include *intense use* (high frequency and high variety), *specialized use* (high frequency and low variety), *non-specialized use* (low frequency and high variety), and *limited use* (low frequency and low variety). To our knowledge, use diffusion has only minimally been used as an approach to conceptualizing appropriation of technologies within educational settings (Maull, et al., 2011; Pennington, 2004), as much of the existing discourse has often focused simply on technology adoption (e.g, Rogers, 2003). If our hypothesis that feature usage in the CCS is diffuse, then use diffusion theory may be a useful framework for capturing that usage pattern variation in practice.

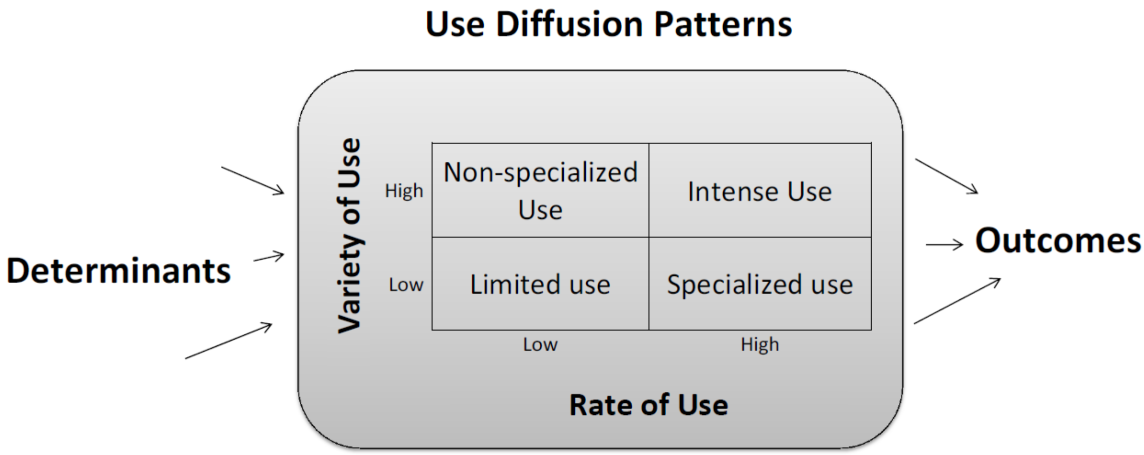

Figure 2. A depiction of Shih and Venkatesh's (2004) use diffusion model.

Yet, while use diffusion is helpful for characterizing how usage of a technology differs, it does not capture *why* those variations appear. Because of this limitation, we have also been drawing upon socio-technical systems perspectives to help us understand some of the ways that people shape and are shaped by their technology use (e.g., Bowker, Star, Tuner, & Gasser, 1997; Hollan, Hutchins, & Kirsh, 2000). These approaches typically focus on factors in a person's context that ultimately affect how technology is used, such as access to other tools or the norms of a local community. We refer to these mediating influencers collectively as "contextual contingencies."

As the CCS is relatively new, research on how the tool is used is still limited. However, one relevant example of recent work has highlighted how such contextual contingencies influenced use of the CCS within different school districts in a single academic year (Lee, Recker, & Sumner, 2013; Lee et al., in press). Specifically, the authors argued that the local culture with respect to sharing instructional resources and the policies of a district could both have influence on the degree to which the CCS was used by a given district. While that study successfully identified factors influencing teachers' use of the CCS, it was limited in that it only considered a single dimension of use (frequency). Also, it treated the school district as the primary unit of analysis, rather than the specific teachers who worked in those districts. When an analysis is focused at the level of individual teachers and on two dimensions of use, we anticipate additional variation. This variation we believe can also be attributed to more specific contextual contingencies.

Research Design and Methods

Our data come from a multi-site, yearlong study of over 70 9th grade Earth science teachers in 5 different school districts in the western United States. The districts were all provided with training resources to help them navigate the CCS and learn about its various features, and user accounts were provided for each teacher in the study so that they could discover, share, and recommend online resources to others in their school district.

Our analyses were guided by the following research questions. First, what does the use diffusion framework reveal about variability in teacher usage patterns in the CCS and, second, why do these variations occur?

Data Sources and Analyses

Throughout the yearlong period of research into CCS usage, we obtained both computational and qualitative data from the five school districts. Our computational data included automatically collected usage log files that recorded each teacher's online activities (clickstreams) within the CCS environment. Automatically collected clickstream data have begun offering a number of insights into the behavior of students in technology-supported learning environments (Baker & Yacef, 2009; Bienkowski et al., 2012). While clickstream data from teachers have not been featured as prominently in the growing body of research on educational data mining and learning analytics, initial efforts to use clickstream data as recorded in other online tools to understand teachers' online behavior have been promising (Xu & Recker, 2012). The automatically collected CCS clickstreams included data about time, date, duration of login, types of resource accessed (e.g., publisher materials, OERs, etc), and operations performed on accessed resources such as whether it was opened, added, or removed from teachers' collections.

To analyze these data, we first completed a recommended phase of log file data cleaning and extraction, e.g., parsing log files, verifying accurate records, and performing some transformations on raw data, such as a logarithmic transformation on the number of CCS logins (Bienkowski et al., 2012). We then reduced our computational data to include only *active CCS users* from across the five school districts. As is often the case, there were teachers who expressed initial interest in the CCS but did not use it during the school year. We operationalized active users as those teachers who had logged in more than 3 times during the year (N=43). Next, to examine variety of usage, using a binary count, we coded the usage logs to see if a teacher had ever used a particular CCS feature (+1) or not. A use variety index score represented a sum of that count. We then used a best fit line between a plot of these two dimensions (the number of logins [log transformed] and use-variety score), and a line orthogonal to this best fit line to partition were used to partition teachers into the four quadrants recommended by Shih & Venkatesh (2004) (see Figure 3). This partitioning allowed us to identify, relative to our clickstream data, what we might consider *specialized use* rather than an *intense* or *limited use*.

Without a priori knowledge of what the usage patterns would be, we also recorded interview data from 26 participating teachers throughout the year. A minimum of two trained researchers jointly interviewed the 26 participants by phone at least twice during the school year using a semi-structured interview protocol designed to help the research team understand current district initiatives and pressures, in addition to individual teachers' perceptions and uses of the CCS. Also, 15 of those teachers were observed at least one day within their classroom settings on days when they intended to use the CCS so that we could see and record firsthand how the CCS was being used.

We then developed a grounded coding scheme of recurring themes in the interview data that was iteratively refined until it was systematically applied to the entire corpus and then cross-validated by three analysts across the entire interview corpus. Following that coding, we compiled dossiers of each teacher for whom qualitative data had been collected and then used the entire range of data at our disposal (e.g., interviews, clickstreams, observations, etc.) to prepare brief case reports of the teachers. After the teachers were mapped onto the use-diffusion matrix, we then examined specific examples and sought to identify from our case reports the contextual contingencies that could help to explain why a teacher's pattern of CCS use throughout the year unfolded the way that it did.

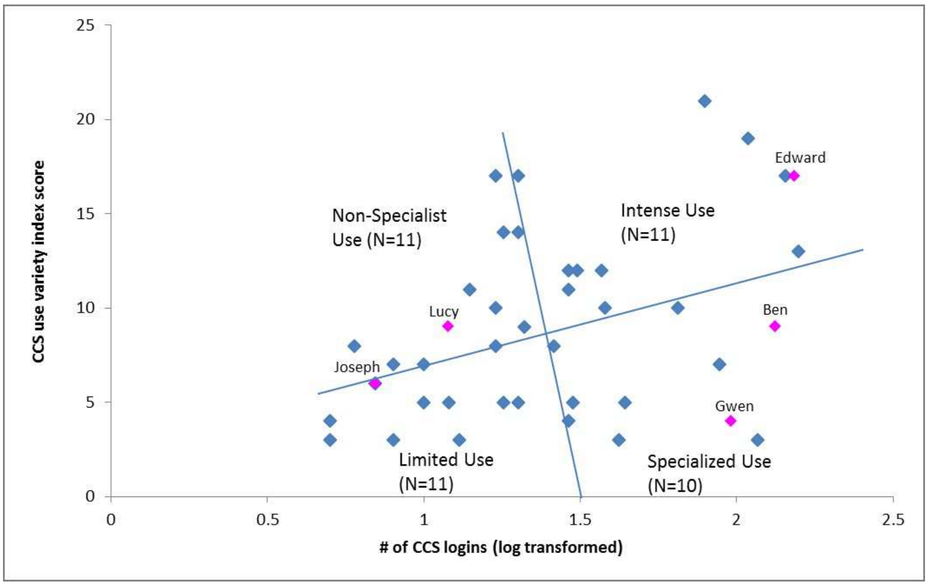

Figure 3. CCS active teacher users in the use diffusion framework and the selected teacher examples.

Results

With respect to our first research question, Figure 3 indeed shows variations along the two dimensions of frequency and variety of use. Among active users, the use variety index ranged from 3 to 21, and the number of (untransformed) logins ranged form 4 to 157. Depending on the type of usage (e.g., specialized use, intense use), the features used most included accessing digital versions of the textbook and embedded assessments from the publisher materials, along with seeking images and visualizations from OERs. The least used features were teaching tips in the publisher materials and the sets of inquiry data provided in OERs. Accessing shared materials showed a wide range of use. This approach to looking at teacher usage was especially helpful as teachers rarely reported on the specifics of what they accessed. However, even though this approach for looking at clickstream data helped us to see that variation along both dimensions, it did not tell us *why* this variation appeared. Thus, to address the second research question, we present examples of teachers from each of the quadrants (see Figure 3), and, when relevant, the contextual contingencies at play that could explain some of this variation.

Example 1: Intense Use Fitting with an Intended Use

Edward (all names are pseudonyms) was a teacher with eight years of teaching experience and was the lone Earth science teacher at his high school in a school district that had made a very strong commitment to using the adopted publisher materials as their curriculum of choice (as reflected by the financial investment, consistent use of publisher materials reported by other teachers in his district, and custom professional development activities led by the publisher of the materials). His contextual contingencies made him well-suited as a user of the CCS because he did not have immediate access to specific content area colleagues at his school who could help him in his topic specific planning or resource gathering routines. In fact, Edward had the highest number of logins in his school district, which already had a very high level of CCS usage relative to all the other districts in the study. Perhaps unsurprisingly, partitioning of teachers in terms of the use diffusion framework placed Edward into the *intense user* quadrant. Indeed, his reported CCS activity patterns fit quite well with how the CCS was originally designed to be used. When asked about whether and how he used the CCS, he responded emphatically that he did use the CCS and that it was beneficial for him because:

> All of the resources that are provided from [publisher materials] are there…I use it [the CCS] for storing things that I find [through repositories] that are useful and I want to include with all of my resources. I can save things to it and keep it in the [learning goals] section where it's useful.

Even from that brief transcript excerpt, we can catch a glimpse into the variety of Edward's CCS use. Edward was essentially reporting that he was accessing the embedded materials provided by the publisher of the adopted textbook, that he was using the CCS as a storage tool to help him remember what resources he had identified and thought would be useful, that it was a portal for him to explore OERs above and beyond what was provided by the textbook publisher, and that it was an organization tool for matching resources to specific lessons and learning goals.

Beyond the above transcript excerpt, Edward also reported that he was using the CCS to find resources that had been marked in the system as recommended by other teachers in his district. Additionally, he also reported that the CCS was an aid in his efforts to differentiate his instruction. For instance, he reported using the CCS to find resources he could download and modify for use with the subset of students who were English language learners because he felt that "they need[ed] more attention for reading and reading skill development."

Edward also separately indicated that use of the CCS led to changes in his lesson planning routine. As he put it, "I don't use a regular [paper based] plan book anymore. I can just plan it all online and then pull it up on my computer [during class]. That's a lot handier for me."

In many respects, this was the kind of use case for which the CCS was designed. Because he was the sole Earth Science teacher at his school, Edward was relatively isolated from his colleagues. He also had a diverse enough student population that required him to do some additional work to curate a set of resources that could be customized for his classes. These factors all worked in such a way that he was enabled and implicitly encouraged to become an *intense user*.

Example 2: Non-Specialized Use Due to Preferred Alternatives

Lucy was in her third year of teaching and also served as the lead teacher for Earth science at her high school. She worked in a different school district that was much larger than Edward's. Through various interviews in this school district, we discovered that Lucy and her colleagues were facing a number of unique local community pressures that ultimately resulted in the CCS having a diminished priority within new district-level reform initiatives. As a result, her school district had relatively low overall usage of CCS relative to the other school districts.

When we spoke with Lucy in her interviews, she reported a genuine interest and enthusiasm for online resources for teaching, but she did not rely on the CCS in the same way that Edward did. She treated the various resources as all being generic things to find on the Internet:

> As a teacher I use the Internet a lot to find sources that will help, you know guide whatever I'm going to be doing in class. I do it for my own knowledge of the material before I present it to the kids to make sure, you know I can kind of back it up too and give them a different source to look at it if they want to expand their learning.

When asked to elaborate on the online resources she used, she reported visiting a number of sites and services such as *Edmodo*, streaming video services, and even simply running Google searches. After some more direct questioning about the CCS, Lucy did report using and appreciating the CCS as one of many tools, but that did not come up until she was asked about the CCS specifically. When she did talk about the CCS, she commented that it was especially useful for helping her find specific animations and simulations to use in class:

> It's [the CCS] been really helpful to find those animations and to find those simulations, especially when you're teaching a class. For instance, when I was teaching waves there were kids who weren't understanding what I was trying to explain to them. I couldn't think of how to explain it differently. Originally my first thought was to pull up Google and try to do a quick Google search and then I remembered that there is a category on the CCS that has the animations and I went through it there and immediately I found the simulation that they use for the *slinkies*. And [that was] exactly what I was trying to use.

While Lucy was speaking in a manner complementary of the CCS, it is worth noting that her "first thought" was to "do a quick Google search" until she "remembered that there is a category on the CCS that has the animations". Thus, the CCS was not her primary source in the same way as it was for Edward. Like many other people, she turned to a reliable and widely known search engine that already serves a number of information discovery purposes. Lucy's pattern of using a broad range of technology tools in support of her teaching seemed to work for her in that while she may not have used the CCS as her primary platform for her teaching, her prior exploration of many different features as a *non-specialized* user of the CCS provided her with enough familiarity that she could remember there was an animations category that could, on occasion, serve her purposes. For Lucy, the contextual contingencies at play appeared to be a lack of a strong district encouragement to use the CCS and what appeared to be a combination of a comfortable familiarity with and access to a range of tools that could provide a number of other resources sufficient for her teaching needs.

Example 3: Specialized Use for Certain Features

Ben and Gwen were both *Specialized users* in terms of their frequency and patterns of use of the CCS, but interview data revealed that their specialized use patterns of the CCS were for very different reasons. Ben was in his first year of teaching high school Earth science, and although he was very comfortable using technology, he was less confident in the content he is teaching. He used two areas of the CCS, the materials shared by other teachers (referred to by a link called "shared stuff") and the publisher provided materials. He reported to us in his first interview that, "it's really been helpful to look at the "shared stuff", things other teachers have put together, good websites they have found for interactives and activities and whatnot." During his second interview, he reiterated his appreciation for this area of the CCS. He also mentioned being less familiar with the content he was teaching, which was why he used the shared area and publisher materials:

> "Being my first time teaching the content and obviously first time using this textbook and this curriculum, it was great to get on there [the CCS] the first couple of week and see how other teachers had done something or the resources that they were using. It's been great to collaborate with other teachers and wonderful networking."

Gwen, on the other hand, typically used the CCS to access only the publisher provided materials, and specifically PDF versions of textbook pages. She was a more seasoned teacher, in her eighth year of teaching Earth science. Her student population included a high number of English language learners. She frequently logged into the CCS and then logged out, with her average time on the site being less than four minutes according to the clickstream data. Her interviews revealed the reasons for her usage patterns: "I access the CCS to access the textbook so I can project it onto my screen." She stated that projecting the textbook provides all students (especially those who have forgotten their book) the opportunity to follow along and "no excuse for not having a textbook." She also had students read aloud from the projected PDFs, which she thought was useful for her many English language learners. In sum, both *Specialized users* showed high frequency of use with the CCS but low variety use of the tools' features, reflected in their different teaching needs and preference for feature use.

Example 4: Limited Use Due to Technology Skills and Other Options

Joseph fell into the *Limited use* category. He had taught Earth science for four years, had abundant access to technology (he taught in a school with a 1:1 student:laptop ratio), and he was very technology savvy. In his interviews he reported the various projects he was working on within his school and district, including his use of Google Docs and the Prezi zoomable presentation service. He and a colleague were also working on creating an interactive digital curriculum map for the district, mapping the state curriculum standards using Prezi.

> "So the Prezi will- [when] you go into it, it outlines an inquiry lab for each, um, standard, objective I guess each objective in each standard, and then it sends it out to resources within Google Docs. You know, any sort of worksheet or lab write-up they'll need will be in shared folders within Docs. So it's kind of a combination of the two, the way we use it."

During the school year, his school district had actually not yet adopted a textbook, so no publisher materials were available in the CCS for teachers in this district. He did have access to all of the open educational resources and a district-wide shared resource collection. At the beginning of the school year Joseph commented to us that he was exploring the CCS and seeing "there wasn't a lot of [online] resources for the topic I happened to be on." He tried again at different points throughout the year but was again not satisfied with what he found. He stated, "I have a pile of other teachers materials I already use and I just go to Google and type in what I want and can usually find really good resources that way." Teachers in Joseph's district were in their first year of using the CCS, and from analysis of the district, we found that all the teachers had many other alternative means to share resources with one another. Consequently, little was added to the shared resources area in the CCS. Joseph indicated he was excited about the CCS and would have been more likely to use the CCS along with the long list of other online resources and tools he typically used if the shared area had contained more materials. However, the district context in which he worked, coupled with his familiarity with other tools, diminished the need he perceived to use the CCS or any of its features.

Discussion and Conclusion

In this paper, we examined variability in usage patterns as teachers used an online tool designed to support instructional planning, the Curriculum Customization Service (CCS). Like recent research examining student learning in online environments, we looked to usage log files to extract teacher patterns, and then analyzed these using the use diffusion framework. This analysis helped reveal different patterns of CCS use along the dimensions of frequency and variability of feature use. We then examined qualitative records of teachers' experiences during a single academic year, principally teacher interviews and classroom observations. Focusing on the experiences of teachers from each of the four use diffusion quadrants, we distilled some of the contextual contingencies that influenced how they ultimately used the CCS.

This approach demonstrates the potential for understanding teacher's online behaviors as a source of meaningful patterns of automatically collected usage data. In much of the recent discussion related to educational data mining and learning analytics (Bienkowski, et al. 2012), students' button clicks and online actions have been made the primary focus. But as many learning scientists are well aware, teachers play a critical role in structuring a formal learning experience. We feel that it is important that attention continue to be paid to the work of teaching, especially as new computational methodologies emerge. Moreover, we must continually anchor our interpretations of results from computational analysis with other known methods.

We believe that the approach modeled here with the CCS demonstrates that. It also may help encourage the field to recognize that teacher technology use more than simply a question about adoption. Rather, use of an "adopted" technology can vary greatly from one group of teachers to another. This variation can be made more visible when the use of different features is considered as an important dimension in how teachers work with technology. Of course, much work remains to be done to understand the range of factors that influence how a given support tool is appropriated by different teachers. However, our initial multi-method look at examples of teachers distributed across the space we have mapped out suggests there may still be much to learn at the level of an individual classroom and an individual teacher.

References

Baker, R. S. J. D., & Yacef, K. (2009). The State of Educational Data Mining in 2009: A Review and Future Visions. *Journal of Educational Datamining, 1*(1), 3-17.

Bienkowski, M., Feng, M., & Means, B. (2012). *Enhancing teaching and learning through educational data mining and learning analytics: An issue brief.* Washington, DC: Office of Educational Technology, US Department of Education, 1-57.

Bowker, G., Star, S.L., Turner, W., & Gasser, L. (Eds.) (*1997*). *Social science, technical systems and cooperative work: Beyond the great divide.* Hillsdale, NJ*:* Erlbaum
Butcher, K., Ferrara, L., & Devaul, H. (2013, June). Teachers' use of an online curriculum planning tool: Usage patterns associated with student learning. *Proceedings of EdMedia 2013: World Conference on Educational Media & Technology.* Chesapeake, VA: AACE.
Dede, C., Ketelhut, D. J., Whitehouse, P., Breit, L., & McCloskey, E. M. (2009). A research agenda for online teacher professional development. *Journal of Teacher Education*, *60*(1), 8-19.
Fishman, B. J. (2003). Linking On-Line Video And Curriculum To Leverage Community Knowledge. *Advances in research on teaching*, *10*, 201-234.
Fishman, B., & Davis, E. A. (2006). Teacher learning research and the learning sciences. In R. K. Sawyer (Ed.), The Cambridge handbook of the learning sciences (pp. 535-550). New York: Cambridge University Press.
Hollan, J. D., Hutchins, E. L., & Kirsh, D. (2000). Distributed cognition: A new theoretical foundation for human-computer interaction research. *ACM Transactions on computer-human interaction, 174-196*.
Horn, I. S. (2005). Learning on the job: A situated account of teacher learning in high school mathematics departments. *Cognition and Instruction, 23*(2), 207-236.
Lee, V. R., Leary, H., Sellers, L. & Recker, M. (in press). The role of school district science coordinators in the district-wide appropriation of an online resource discovery and sharing tool for teachers*. Journal of Science Education and Technology*, doi: 10.1007/s10956-013-9465-5
Lee, V. R., Recker, M., & Sumner, T. (2013). *Variable appropriation of an online resource discovery and sharing tool*. Paper presented at the CSCW In Education Workshop, San Antonio, TX.
Maull, K., Saldivar, M. G., & Sumner, T. (2011). *Understanding digital library adoption: A use diffusion approach*. In *Proceedings of ACM/IEEE Joint Conference on Digital Libraries* (pp. 121-130), ACM, New York.
Pennington, M.C. (2004). Cycles of innovation in the adoption of information technology: a view for language teaching. *Computer Assisted Language Learning, 17*(1), 7-33.
Recker, M., Yuan, M. & Ye, L. (2013). *CrowdTeaching: Supporting Teachers as Designers in Collective Intelligence Communities*. Manuscript under review.
Renninger, K.A. & Shumar, W. (2002). Community building with and for teachers: The Math Forum as a resource for teacher professional development. In K.A. Renninger & W. Shumar (Eds.), *Building virtual communities: Learning and change in cyberspace*. New York, NY: Cambridge University Press.
Rogers, E. M. (2003). Diffusion of Innovations, 5th Edition. New York, NY: The Free Press.
Schlager, M. S., & Fusco, J. (2003). Teacher professional development, technology, and communities of practice: Are we putting the cart before the horse?. *The Information Society*, *19*(3), 203-220.
Schneider, R. M., Krajcik, J., & Blumenfeld, P. (2005). Enacting reform-based science materials: The range of teacher enactments in reform classrooms. *Journal of Research in Science Teaching*, *42*(3), 283-312.
Shapiro, R. B., & Wardrip, P. S. (2011). Interactive representations of student activity to inform teacher collaborations: Results from a formative exploration. In *Proceedings of CSCL2011 9th International Computer-Supported Collaborative Learning Conference* (pp. 494-501).
Sherin, M., & van Es, E. (2005). Using video to support teachers' ability to notice classroom interactions. *Journal of technology and teacher education*, *13*(3), 475-491.
Shih, C., & Venkatesh, A. (2004). Beyond adoption: Development and application of a Use-Diffusion model. *The Journal of Marketing, 68*(1), 59-72.
Sumner, T. & CCS Team. (2010). Customizing Science Instruction with Educational Digital Libraries. In *Proceedings of the 10th ACM/IEEE-CS Joint Conference on Digital Libraries (JCDL 2010)* (p. 4), New York: ACM.
Xu, B., & Recker, M. (2012) Teaching Analytics: A Clustering and Triangulation Study of Digital Library User Data. *Educational Technology & Society Journal, 15*(3), 103-115.
Ye, L., Walker, A., Recker, M., Leary, H., Devaul, H., Butcher, K., & Sumner, T. (2013, April). *Integrating Technology, Curriculum, and Online Resources: A Multilevel Model Study of Impacts on Science Teachers and Students*. Poster presented at the American Educational Research Association annual conference, San Francisco, CA.

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