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Teacher Learning Online: Detecting Patterns of Engagement

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Abstract: Learning online is now ubiquitous. However, teachers' self-directed and guided learning online deserves further exploration because most research on successful teacher professional learning has been conducted on in-person programs. The present study examined teacher behaviors in an online platform designed to support teachers' professional learning in elementary mathematics. In particular, this study explored whether teacher behaviors on an online professional learning platform clustered in ways that suggest distinct use cases and whether those behaviors were associated with particular teacher characteristics. Results revealed a cluster of teachers who predominately focus their behaviors on the guided learning modules on the website, which was associated with teacher characteristics, including being less likely to enjoy teaching mathematics and being newer to teaching the curriculum supported on the website. Implications for future research and for supporting teacher learning are discussed.

Introduction

Elementary teachers have long had a need for professional learning opportunities for teaching mathematics to their students (Stigler & Hiebert, 1999). Especially since the pandemic, teachers have needed to rely more and more on online resources to support their professional learning (e.g., Aguilar et al., 2021), and have needed to learn in increasingly self-guided ways. However, traditionally, teacher professional development (PD) has taken place in person and has identifiable features linked to success (Archie et al., 2021; Desimone et al., 2002). Thus, we have much to learn about how teachers use online resources for their professional learning.

In most research on teacher PD, teacher learning opportunities have been offered as after-hours PD seminars, which are typically sustained, in-person sessions, led by a trained facilitator, and attended by like-minded teachers (e.g., Roth et al., 2017). Not only do online learning spaces relieve barriers to attend high-quality in-person PD opportunities, but also these spaces tend to provide a less-constrained collaborative platform than formal PD classes, which provides key advantages in teacher learning (Coughlin & Kajder, 2009; Little & Housand, 2011). The distributed nature of online communication and communities reflects a process in which learning is situated (Lave & Wenger, 1991) and highlights the overall relational interdependence of agent, world, activity, and professional learning.

Some online PD sites allow teachers a great deal of control over when and where they participate and access on-demand learning opportunities, which is related to educator- and school-related success (Shaha & Ellsworth, 2013). Moreover, self-guided online PD enables teachers to acquire knowledge that they implement immediately, which improves student performance (Magidin et al., 2012). Relatedly, researchers have argued that for PD to be effective, teachers must be given a large role in choosing what they learn (Saclarides & Lubienski, 2018), while failure to do so undermines their sense of professionalism (Knight, 2007). Expanding on this idea, Shaha and Ellsworth (2013) argued that "on-demand" PD allows teachers to "learn about what they are most interested in, or most in need of, at the time of interest or need, rather than when it fits sequentially into any prescriptive curriculum" (p. 20). Given the massive shift to online learning, it is important to understand how teachers learn from these online professional learning communities to support their professional growth.

The present study

Previous work has shown that teachers are likely to learn and benefit from online teacher mathematics PD sites (Bragg et al., 2021), but little is known about who uses these sites and how they use them. These gaps in knowledge lead to questions about the types of learning profiles that exist among users (e.g., module-followers vs. self-guided learners) and how teacher background characteristics interact with these profiles. Uncovering these profiles could lead to improving PD sites to serve teachers better, as well as to understand successful professional learning. To investigate this, we examined what sorts of background features distinguish the teachers who visit an online teacher mathematics PD site, the Virtual Learning Community (VLC; https://vlc.uchicago.edu/), and what behaviors teachers exhibit on this website, to begin to unravel how teachers go about learning from this rich online resource. Understanding how teacher learning takes place online ultimately can inform both how to build supports for teacher learning and learning online, writ large, leaving us with two research questions:

- **RQ1:** What behavior clusters emerge from teachers who visit the VLC, an online teacher professional learning site, and what can we infer about their learning goals from these behaviors?
- **RQ2:** What are the background characteristics of teachers use the VLC in different ways? Do these characteristics give us insight about how different teachers can learn from an online teacher professional learning website?

Method

Dataset

We first sought to characterize the overall nature of teachers' interactions with the VLC, as measured by summary statistics of the dataset. A total of 1,377 teachers visited the VLC while logged in during the August–September 2023 period we analyzed in this study. The median number of pages visited per teacher was 10 (interquartile range or IQR = [4, 25]), with a heavily right-skewed distribution and a mode of 1 (8.8% of teachers visited only 1 page). Visiting a single page is a common usage pattern for teachers viewing a resource linked to from another source, such as a regular email update sent to VLC users. Other teachers' behaviors included navigating from page to page searching for resources, often starting from the homepage (visited by 65.4% of teachers).

Because experience with teaching—and experience with the VLC—may influence teachers' interactions with the VLC, we also summarized those characteristics of teachers. Teachers reported teaching experience on an ordinal scale of 0–1 years, 2–5, 6–10, 11–15, or 16+ years; median and mode of teaching experience (reported when they first registered as users) were 11–15 and 16+ years, respectively, while the median account age was 1.261 years (IQR = [0.143, 6.613]) at the end of the data collection period. Hence, most teachers had substantial experience teaching and over a year's experience on the VLC.

Clustering of behaviors

We clustered behaviors to discover patterns of usage that could indicate different purposes for using the VLC. VLC usage was typically sparse—most often, a teacher exhibited some particular behavior once, such as visiting a type of page, or did not. Thus, for consistency and simplicity, we computed all numeric indicators of behavior as binary variables, computed per-teacher. These variables included 27 indicators of whether or not a teacher had visited each high-level section of the VLC, ranging from rarely visited sections (e.g., saved bookmarks—visited by 0.15% of teachers), to the most common sections (e.g., the resources—visited by 75.1% of teachers). We extracted another 27 related variables that indicated whether or not the proportion of visits a teacher made to a particular type of page (out of all their page visits) was higher than the mean proportion calculated from all teachers. The proportion-type variables served to distinguish between teachers who visited many pages on the VLC, but spent more of their time on one type of activity than another. Finally, we extracted three higher-level variables: (1) whether teachers interacted more with the VLC than the median amount, (2) whether they had more than the median number of sessions interacting with the VLC (with "session" defined as a set of actions separated by at least 30 minutes), and (3) whether they had more actions per session than the median number. Thus, we extracted 57 binary behavioral indicators to represent the behavior of each teacher.

Clustering similar teachers requires defining a measure of "distance," or dissimilarity, between teachers based on their behaviors. Given the binary nature of our behavior variables, we measured distance via the Hamming distance: teachers were considered more similar to each other if they exhibited similar behaviors (i.e., matching "1" values) and similarly absent behaviors (i.e., matching "0" values). We fit an agglomerative hierarchical clustering model (Ward, 1963), which is a tree-structured clustering method that progressively joins pairs of small clusters into larger clusters according to whichever pair has the smallest distance. We chose two clusters as the simplest possible case, but plan to explore a larger number of subdivided clusters in future work. We thus obtained two clusters of teachers with distinct behaviors, which required further analysis to interpret, as described next.

Cluster interpretation

Clustering is an unsupervised learning method, and thus the resulting clusters have no "label" describing what they represent; hence, they require interpretation. In this study, we treated the clusters as labels for a supervised machine learning problem to predict the cluster that each teacher belonged to via an interpretable machine learning model, then examined that model to determine what behaviors best characterized each cluster. In particular, we trained a decision tree classifier via *scikit-learn* (Pedregosa et al., 2011), with a required minimum of 20 samples per leaf and all other hyperparameters at default values. We then computed a χ^2 test for each decision in the tree to determine if the subset of data selected by that decision (and its ancestors in the tree) resulted in a significantly different ($p < .05$ with a Bonferroni correction) distribution of cluster assignments than the original dataset.

Finally, we converted the statistically significant tree decisions to equivalent decision rules that isolate the important decisions without needing to trace through a tree.

In this study, we also interpreted clusters in terms of teacher characteristics. In particular, we used five self-reported teacher characteristics (race/ethnicity, time teaching [on the ordinal scale from 0–1 years to 16+ years as described above], time teaching the VLC-associated curriculum [on the same ordinal scale], school context [urban, suburban, or rural], and feelings about teaching math [on an ordinal scale of "I rarely/usually/always enjoy teaching math"]). We also extracted two variables describing each teacher's VLC account: whether their account was recently created (i.e., newer than the median account age of 1.261 years) and whether they were subscribed to daily (as opposed to weekly) update emails from the VLC, as a measure of their involvement with the VLC. Given the interdependence of agent, activity, and environment during professional learning, we thus extracted rules that describe behavior clusters at a high level in terms of a few behaviors and of what teacher characteristics significantly predicted belonging to one particular cluster.

Results

Clusters in terms of behaviors

Twenty out of the 28 decision rules extracted were statistically significant. We thus focused on only a few of the simplest rules, which differentiate the clusters best. The first two rules separated teachers into those who never visited the online PD modules page (rule 1) and those who did (rule 2). Rule 1 matched 1,134 teachers (82.4%), indicating that most teachers never visited the PD modules page; rule 1 also corresponded well to the first behavior cluster (odds ratio [OR] = 4.921). This subset of behaviors matching rule 1 is large and heterogeneous, which will be an area to explore further in future work with a greater number of clusters. Rule 2 matched the other 243 teachers (17.6%) who visited the PD modules page. Rule 2 corresponded well to the second behavior cluster (OR = 11.405), suggesting that this second cluster may be a set of behaviors that are common among teachers using the VLC for formal PD, resulting in behavioral patterns that are distinct from other ways of using the VLC.

Clusters in terms of teacher characteristics

Explaining clusters in terms of teacher characteristics reveals whether teachers with certain characteristics are more likely than others to behave in a particular way. In the model predicting behavior clusters from teacher characteristics, we found 3 significant rules, indicating that there were indeed associations between teacher characteristics and behaviors. All 3 of the rules were positively related to the second (i.e., PD modules) cluster. Rule 1 selected teachers who self-reported the lowest level of feelings regarding teaching math (i.e., "I rarely enjoy teaching math") and who had relatively recently created accounts (i.e., newer than the 1.261 years median account age). Rule 2 refined that same selection, adding a criterion for teachers who had spent 0–1 years teaching the curriculum associated with the VLC, and rule 3 refined rule 2 by adding a further criterion for teachers who had subscribed to weekly (rather than daily) email updates from the VLC. These three rules were quite selective, especially given the relatively smaller size of the PD cluster, but significantly related to that cluster (rule 1 OR = 2.762, n = 70 teachers; rule 2 OR = 4.017, n = 45; rule 3 OR = 5.099, n = 24). Thus, although much remains to be determined regarding other teachers not included in these rules, these results indicate that teachers with certain characteristics varied systematically in the way they used the VLC, which may provide insights into how to improve their math teaching experiences through the VLC.

Discussion

Online PD provides many benefits, and knowing how teachers use online PD websites can potentially be used to improve access and learning from these websites. Hence, the goal of this study was to explore teachers' behaviors on an online website devoted to their professional learning around teaching elementary mathematics and teachers' background characteristics associated with these behaviors. Results indicated that analyses of teacher behaviors and teacher backgrounds yielded two distinct clusters of use profiles: one that included teachers who interacted with structured PD modules and the other that did not interact with these modules and, instead, spent time with other resources offered on the site. We also learned about which teachers were associated with these clusters. In particular, teachers who did not enjoy teaching mathematics, were new to the website, and were new to teaching with the curriculum featured on the website were associated with the PD-module cluster.

We can use these findings to make sense of how teachers navigate online PD websites and structure their learning. We do not know if the teachers—who may have been required to use the modules given their recent introduction to the curriculum—were enjoying or benefitting from the modules, but we can say that they did not appear to be agentic or to feel confident in their teaching of mathematics, at least with a curriculum that was

relatively new to them. This may be a necessary step in the learning process, and one that we will explore in future investigations using other methods (e.g., surveys, interviews) to understand how they approach the learning process. The other teachers explored the bevy of resources on the website. Here, too, we will conduct additional research to understand why and how they choose to learn from the VLC. In any case, we expect that the teachers using the modules may benefit from support to increase their enjoyment of teaching mathematics and from providing empowering options within the modules. This finding provides further corroboration for conclusions from previous research, that for PD to be effective, teachers must be given a large role in choosing what they will learn (e.g., Lieberman & Pointer Mace, 2008; Saclarides & Lubienski, 2018), since failure to provide this autonomy detracts from teachers' sense of professionalism (Knight, 2007).

In conclusion, online PD websites can be used in different ways. Understanding how they are used, and by whom, can help teacher educators and website developers to build in supports to help teachers navigate these spaces most advantageously. Future research should provide additional insights into exactly what those supports look like to maximize teacher learning from online PD websites.

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