



# Understanding Heterogeneous Patterns of Family Engagement with Educational Technology to Inform School-Family Communication in Linguistically Diverse Communities

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# **Understanding Heterogeneous Patterns of Family Engagement with Educational Technology to Inform School-Family Communication in Linguistically Diverse Communities**

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## **Abstract:**

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## **Introduction**

Families and schools are both important elements of children's educational success (Fan & Chen, 2001; Houtenville & Conway, 2008; Todd & Wolpin, 2007), and family educational engagement is an important factor in children's own engagement and learning (Raftery, Grolnick, & Flamm, 2012). As schools continue to refine their efforts to engage families, a likely legacy of the COVID-19 pandemic will be an increased use of technology. Importantly, family engagement, or "parents' interaction with schools and with their children to promote academic success," (Hill & Taylor, 2004, p.1491) encompasses a variety of activities and mindsets (Epstein, 1990). Similarly, educational technology includes a broad array of interventions that target substantively different problems from online learning to access to broadband internet (Escueta et al., 2020). In this way, educational technology includes both specific learning resources, like app activities, and platforms for communication, like text-messaging.

Whether this increased reliance on technology to both provide resources and communicate will strengthen ties between families and schools remains an important question. While there is emerging evidence that school-based messaging can increase family engagement (Asher et al., 2022; Doss et al., 2019; Kim et al., 2019; York et al., 2018), other resources like parent portals and virtual tutoring often suffer from low participation and inequitable access (Bergman, 2020; Kraft & Bolves, 2021; Robinson, Bisht, & Loeb, 2022). Prior work has documented variation in parental preference in school communication and resource (e.g., Cortes et al., 2019a, Cortes et al., 2019b), suggesting that blanket policies may not engage all families.

In this study, we investigate this heterogeneity in two forms of technology-supported family engagement: how families facilitate their children's learning outside of school when provided access to a free educational app and two-way texting. To do this, we leverage time-stamped app log data and the text message records from over 3,500 families during the summers

of 2019 and 2020. We use Latent Profile Analysis, a type of person-centered analysis, to identify distinct family groups based on their patterns of technology engagement, and we complement these findings with in-depth interviews from a subset of Spanish- and English-speaking families. Our analysis makes several contributions. It is the first, to our knowledge, to explore the variation in family engagement with education technology when offered both an educational app and two-way texting. In particular, our use of person-centered analyses differentiates us from most other rigorous analyses of educational technology that use variable-centered approaches. Second, we explore whether family engagement patterns shifted as school-provided resources changed in response to the COVID-19 pandemic. Finally, data from the app and messaging platforms allows us to move beyond families' self-reported feelings and activities; instead, we can directly observe their behaviors.

Our findings show that families tended to engage with either the educational app or text messaging platform, but often not both. We create descriptive categories, calling families with a preference for the app, "Independent Users," while those who leverage two-way texts are labeled "Interaction-Supported Users." In the rarer cases where families use both technologies, it was often to use two-way texts to resolve technological issues with the educational app. We also find that as access to translated versions of other school resources decreased during the pandemic, Spanish-speaking families were significantly more likely than English-speaking families in to engage with educational technology across all profiles of families, highlighting that language-based needs have implications for school-family relationships. Our results identify testable assumptions of how to improve school-family relationships and suggest that schools may need to employ a variety of strategies to connect with families with different engagement preferences.

*Use of technology to facilitate family engagement*

Technology could be a mechanism for encouraging family engagement in student learning. It can facilitate communication between schools and families and has the potential to be scaled at a low cost. Direct forms of communication, such as texting, have shown promise for increasing family participation in student learning (Escueta et al., 2020). Such initiatives focus on providing parents timely and actionable information with concrete steps that reduce common communication frictions between parents and schools. Several studies show that providing information can change parents' educational decision and influence students' learning activities outside of school (Doss et al., 2019; Kim et al., 2019; York et al., 2018; Asher et al., 2022, Cortes et al., 2019a; Cortes et al., 2019b; Kraft & Monti-Nusbaum, 2017). While there is excitement about technology's potential to transform school-family communication, questions remain whether all types of technology-supported communication are equally effective and whether the effects are equitably distributed among families. While many districts use portals to provide parents with information about their child, and sometimes facilitate two-way communication, these platforms often suffer from low take-up by families, even when behavioral nudges or technological support is provided (Bergman, 2020; Kraft & Bolves, 2021; Robinson, Bisht, & Loeb, 2022). Furthermore, there is often differential take-up by family income and race, which could further exacerbate existing gaps between demographic groups (Kraft & Bolves, 2021).

Another key component of out-of-school family engagement is the use of self-contained technological resources, such as educational apps, sometimes called "computer-assisted learning software" (Escueta et al., 2020). These are programs that focus on improving particular academic skills (Rouse & Krueger, 2004). Use of at-home software was already growing exponentially prior to the pandemic, and recent reviews indicate that some of these programs can improve

achievement (Escueta et al., 2020; Kim et al., 2021). These resources could provide a tool for families to implement targeted practice at home. However, few studies have explored whether these programs work at scale. Moreover, during the pandemic, device use varied dramatically across families, often due to inconsistent Wi-Fi access or incapacity to support students' use, calling into question whether all families can access these offered resources.

### *Heterogeneity in family preferences and needs*

The widespread variation in take-up of education technology may stem from variation in underlying family preferences for how to engage with children's education. For example, some families might appreciate a self-contained education app, whereas others appreciate being texted about activities that do not require any technology (e.g., questions to ask a child while reading a book) to support learning. Recent work on messaging interventions has also found that both the number of texts families receive per week (Cortes et al., 2019a) and the timing of the message (Cortes et al., 2019b) significantly affect engagement. Since prior research has often focused on one particular education technology solution, our understanding of engagement is one dimensional as opposed to multi-faceted. If the goal is to reach as many families as possible, technology-based interventions should factor in this variation.

Relatedly, in linguistically diverse communities, the ability of the school to provide accessible and welcoming resources in families' home language is crucial (Linse, 2010; Quiñones & Fitzgerald, 2019). For example, if information on student behavior and performance is provided only in English, this could cause non-English speaking parents to feel unable to support their child. This might, in turn, disengage them from school communications, yielding the opposite of the intended effect. Recent studies focusing on younger children have shown that Spanish-speaking families appreciate receiving text and video messages in Spanish (Pila et al.,

2019) and that a Spanish-language messaging intervention can improve parental engagement with literacy activities (Garcia et al., 2022). For Spanish-speaking families, the presence or absence of information and resources in Spanish could drive some of the variation in engagement observed in prior research.

### *Current educational context*

While schools use a variety of means to provide educational resources and communicate with families during the school year, use of educational technology during the summer is a particularly helpful context to understand. Unlike during the school year, when all students have access to similar materials and reading instruction, both access to resources and the amount of time spent on learning varies considerably during the summer (Gershenson, 2013; Guryan, Hurst, & Kearney, 2008; Zvoch & Stevens, 2015).

In many ways, summer learning variability was mirrored in the early days of the pandemic. While districts made different choices about in-person schooling for the 2020-21 year (Goldhaber et al., 2022), almost all schools “went virtual” during the Spring of 2020. This abrupt and significant pull-back in school-provided resources left families scrambling to find additional supports to educate children at home (Bacher-Hicks et al., 2021). Given the unanticipated speed with which Spring 2020 closures unfolded and the uncertainty of how long they would last, most schools had no existing structures for how to best reach families during this time period – in essence causing a more extreme pullback of information and resources than what typically happens over summer. Moreover, the transition’s urgency meant that some districts had less capacity to translate resources, and two-way conversations between teachers and caregivers were often conducted only in English, which may have had equity implications for Spanish-speaking families.

### *This study*

In this study we utilize a mixed method approach to explore families' patterns of engagement when offered access to an educational app designed to improve reading engagement and comprehension along with two-way text communication in Spanish and English.

Specifically, we ask the following research questions:

- 1) How do families' patterns of engagement with an educational app and text messages during summer differ?
- 2) How did families' patterns of engagement with technology change after the start of the COVID-19 pandemic?
- 3) How are the engagement patterns different for families who speak English vs. Spanish at home?

### **Methods and Procedures**

#### *Sample*

This study contains a longitudinal sample of 3,602 students who attended 30 elementary schools in a large, Southeastern district for both the 2019 and 2020 school years. At the end of Spring 2019, first and second graders received access to an educational reading app containing short e-books along with leveled reading activities (Kim et al., 2023). Throughout summer, these students' families also received a two-way text messaging intervention in Spanish or English. The text messages covered a variety of topics, such as information about the educational app, resources and activities to help with summer reading, and general encouragement to engage their child in literacy activities (Asher et al., 2022). Families received, and could respond to, two messages per week over the course of nine weeks. Despite interruptions in learning and the move to virtual instruction caused by COVID-19, students continued to received access to the



educational app during Summer of 2020, after it had been updated with new resources and activities, and again received two-way text messages with similar content and frequency.

The families in our sample are demographically diverse (Appendix Table 1). Approximately 20% identify as White, 35% as Black, and 35% as Hispanic. Thirty percent of families reported speaking Spanish at home and received text messages in Spanish. The sample is also socioeconomically diverse: 40% live in low-income, 37% in medium-income, and 22% in high-income neighborhoods.

In the summer of 2020, a subsample of 51 parents was invited for interviews to understand how they adapted their daily routines under the constraints of the COVID-19 pandemic. To recruit families, the research team identified six representative elementary schools from the broader sample. Families were stratified by student gender, academic performance in reading, and whether they spoke Spanish; a subset was then invited via email to participate in interviews. The final interview sample included representation from second and third grade, communities of different socioeconomic status, and approximately even numbers of Spanish- and English-speaking families. The sample was also racially diverse, with just over half identifying as Hispanic, 35% as Black, 10% as White, and 4% as Asian or Native American. Interviews were conducted over Zoom in either English or Spanish, and usually lasted 60-90 minutes.

### *Data and measures*

#### *Qualitative data*

The interview protocol had two components: one section containing close-ended questions about basic household information and one with open-ended and questions adapted from Weisner's Ecocultural Family Interview (EFI) manual (1997). The coding strategy was

modeled on the conceptual dimensions described in the manual, where each dimension “comprises a selection of the resources and constraints, goals and values, abilities and needs of families” (p. 16). Using these categories as a starting point, a coding scheme was developed after initial rounds of pilot coding and discussion. The coding team included four members; all interviews were coded by two individuals independently, and disagreements were resolved through discussion. Interviews conducted in Spanish were coded by two native Spanish speakers.

### *Quantitative data*

We use log-level data from the educational app and text messages to characterize the nature of family engagement. The educational app tracks detailed information, including when students first logged in and when they completed each of the activities. The texting platform contains records of all text messages sent to and from families during the study period. We aggregated this data to the student-level with seven measures that capture the quantity, duration, timing, and interest of families’ behavioral engagement with technology (see Grolnick and Slowiaczek, 1994 for a discussion on types of engagement) using the following constructs:

- Quantity: total number of app sessions and messages sent by parents
- Duration: weeks between the first and last app session and text message
- Timing: proportions of app sessions and parental text messages sent during standard business hours
- Interest: whether families opted out of receiving text messages

### *Model Selection*

In each year, we separated out “Non-Users,” the sample who never engaged with either technological resource. The remaining sample, who used the app or responded to text messages at least once, were included in the Latent Profile Analysis (LPA). Using the “mclust” package in

R, quantitative analyses were conducted using an increasingly complex set of person-centered analytical approaches (Nylund, 2007). Using the seven variables representing quantity, duration, timing, and interest of technology use described above, we fit a series of latent profile models with an increasing number of profiles (from  $K=1$  to  $K=9$ ) at each time point, under four different covariance matrix structures. We ultimately selected the “EEV” covariance model (see Appendix for details) and with this covariance structure in place, we evaluated the optimal number of latent profiles in 2019 and 2020 following the guidelines in Masyn (2013), which include both quantitative and substantive considerations. As described in the Appendix, we evaluated model fit according to several different indicators, and ultimately concluded that the fit statistics suggested a 6-profile solution for 2019, and an 8-profile solution in 2020.<sup>1</sup>

## **Results**

### *2019 Family Profiles*

The 6-profile solution from the 2019 LPA corresponds to meaningfully distinguishable profiles among the families. We have named them based on qualitative differences (Figure 1). Panel A displays each profile’s characteristics for quantity and duration of engagement, and Panel B shows timing. Families that only utilized the educational app are in gray, while those who responded to any text message are in black. In panel A, the variables to the left of the “App vs. Text” dotted line relate to use of the educational app, while those to the right of the line relate to text message responses. In most profiles, we only observe positive values for characteristics associated either with the app or texting, showing that most families engaged with only one type of educational technology. Additionally, Panel B shows that most families either engaged

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<sup>1</sup>In both years, we observed a pair of profiles with identical mean characteristics and all individuals were more likely to belong to the first profiles than the second profile. We do not show the lower likelihood profile in our results, but include robustness checks in the Appendix.

exclusively during business hours or exclusively outside of business hours. The two largest app-using profiles were the Workday App Users (n=645) and the Robust App Users (n=510). The Robust App Users used the app more often and over a longer period of time compared with the other app user groups, Workday App Users and Downtime App Users (n=270), who used the app excusably during business hours and non-business hours, respectively. Families who only responded to text messages tended to do so only during business hours (Workday Texters, n=133).

The two user groups that break the “either/or” categorization are Non-Users (n=1720), who never engaged with either technology, and the Resource-Seeking Users (n=324), families who used both text messaging and the app. The Resource-Seeking families used the app less than the Robust App Users, but more than the other profiles, and they responded to text messages at similar levels of the Workday Texters. The Resource-Seeking and Robust App Users were also both equally likely to engage during business and non-business hours.

The content of family text messages also revealed interesting patterns. Almost half of families sent at least one message noting their appreciation of the summer resources provided to students (Appendix Table 6). After sorting text message content into a set of mutually exclusive themes, we saw mostly similar patterns across the different family profiles. However, Resource-Seeking Users were significantly more likely to send at least one message asking about the app technology or hardware compared with Workday Texters. Based on the content of these messages, we collectively categorize the app-only profiles as “Independent Users” of technology and the texting profiles as “Interaction-Supported users.”

*2020 Family Profiles*

Figure 2 shows the profile mean characteristics for the quantity and duration (Panel A) as well as timing (Panel B). Many of the profiles from 2019 are similarly present in 2020, with similar engagement characteristics. However, unlike in 2019, two app-focused profiles, the Workday App Users (n=138) and Downtime App Users (n=107) also sent an occasional text message. This is part of a broader pattern where almost all groups, including those we categorize as “independent users” of technology are responding to more two-way texts than they did in the prior year. Furthermore, the total number of families in the independent-user profiles (i.e., Robust App Users, Workday App Users, Downtime App Users) decreased from 1,425 families in 2019 to only 381 families in 2020. We also found a corresponding increase in Non-Users from 1,720 to 2,205 families over this time.

The biggest difference between 2019 and 2020 is that in 2020, we observed two new profiles of interaction-supported users who only engaged in text messaging. Downtime Texters (n=259) only sent text messages outside of business hours, whereas Robust Texters (n=206) sent a relatively large number of texts during both business and non-business hours.

In 2020, we leveraged multiple qualitative data sources to further unpack the profiles of technology use. Table 1 explores the content of family text messages. Like 2019, gratitude was a common sentiment, with most families sending at least one message expressing appreciation. Additionally, both Resource-Seeking Users and Robust Texters were significantly more likely than other profiles to ask questions about technology. While Resource-Seeking Users often focused on the inability to use technology and asked for help, Robust Texters were more likely than any other profile to inquire about physical resources like books. Thus, the Robust Texters in 2020 were interested in using the app, but when faced with internet, hardware and software issues, wanted to ensure that their child had access to physical books. In late June we texted

families who had not yet logged into the app with a one-question multiple choice pulse survey about barriers to app use. While only 382 families responded to this survey, the plurality (37%) of responding families indicated that they needed additional help to use the app. The next most common response was that they didn't have enough time to get their child on the app (19%) or didn't have a device that could run the app (17%).

Our parent interviews focused on several dimensions of technology use including access to, ability to use, and perceptions of the value of technology. Ninety-six percent of families (49/51) reported their children using any form of technology (e.g., kindle, apps, tv) while 57% (29/51) reported their child using educational software with some frequency during the week. Sixty-five percent (33/51) of the interviewees spoke positively about the benefits of their children's technology use. Parents believed children can learn a lot from it, in both educational and non-educational settings. One family member noted, "They can learn so many things, . . . with the apps. There are so many of them. So, it's kind of like no cap on what they can learn. I think the apps are beneficial." Concerns about their child's technology use largely centered around social media and its potential harms, such as bad information or exposure to predators, as opposed to concerns about educational technology use.

At the same time, more than a third of parents (18/51) spoke negatively about their own technology capabilities and did not feel prepared to support their child's technology use. One parent noted, "I don't understand the internet very much. So, it makes it a little difficult for me to help my kids". This aligns with our pulse survey results, which indicated that many parents struggled with technology access. Other parents (13/51 or 25%) that used the technology found text reminders helpful. A parent noted, "And then I get the text messages too . . . , 'Hey, we saw that your daughter hasn't signed on yet', and I was like, 'Oh shoot, I forgot that we had it.'"

These qualitative results help us better understand the patterns of engagement we observed, and reinforce that some families need additional interaction or support to take advantage of technology-based educational resources, whereas others did not.

#### *Family Transitions from 2019 to 2020*

Table 2 shows how individual families transitioned between profiles in 2019 and 2020. Across both years, the Non-Users were the modal family profile, representing 1,720 families (48%) in 2019 and 2,205 (61%) in 2020. Most families used technology in at least one year; only 1,191 (33%) never engaged with either technology. However, many families disengaged from technology in 2020, at least 40% of all the 2019 profiles became Non—Users in 2020, highlighting how family engagement during COVID-19 differed.

Approximately 900 families (25%) engaged with at least one technology medium in both years. Among these families, there was significant transition between the two years, typically from belonging to an Independent User profile to an Interaction-Supported User profile. For example, in 2019 approximately 900 families were either in the Workday App Users and Downtime App Users profiles. While about 60% of these families disengaged from any technology in 2020, 27% transitioned into one of the four Interaction-Supported User profiles. Additionally, we see that very few families of any type remained or became Independent Users in 2020 (11%). Thus, as school resources were pulled back in the context of the pandemic, and families were faced with other challenges unique to the COVID-19, some families preferred the support and interaction associated with two-way messaging. These results complement the qualitative patterns we found, as many families had problems using technology and needed additional assistance.

#### *Language Differences in Profile Membership*

To understand whether our language-diverse families engaged differently with educational technology, we fit a multinomial logistic regression predicting profile membership based on whether families received text messages in Spanish instead of English. The results of these analyses are presented in Table 3, which includes separate models for our 2019 and 2020 profiles, with and without additional baseline covariates. The coefficients represent the difference in log-odds of families belonging to a specific profile relative to the log-odds of being a Non-User. The large, negative, and statistically significant constants across both samples and all model specifications reflects our earlier finding that Non-User were the modal profile in both 2019 and 2020, especially among families that received English text messages.

The positive coefficients on the Spanish language text messages indicate that these families were more likely to belong to each of the user profiles than families receiving English-language messages. In 2019, these differences were only significant for Robust App Users and for Resource-Seeking Users, and, controlling for other baseline characteristics, only Robust App Users. In 2020, however, in the unadjusted model, families receiving Spanish-language messages were significantly more likely than English-message families to belong to every user profile. Moreover, the magnitude of the log-odds differences are consistently larger in 2020 than in 2019. Even controlling for other baseline characteristics, Spanish-message families were significantly more likely to be members of the highest-usage profiles: Robust App Users, Resource-Seeking Users, and Robust Texters. They were also significantly more likely to be Workday App Users.

Our interviews in 2020 deepen our understanding of these patterns. In many ways, Spanish and English families expressed similar sentiments about school engagement: almost all (49/51) parents' interviews mentioned positive aspects of school engagement, and about half (25/51) also mentioned negative aspects of school engagement. Although many viewpoints were



common across Spanish- and English-speaking families, obstacles experienced by Spanish-speaking families were exacerbated due to the reduction of resources available in Spanish during the pandemic. More than 50% of Spanish-speaking families (13/25) mentioned language or culture at some point during their interview. In addition to a reduction in Spanish-language resources sent home to families, parents also mentioned the inability to ask the teachers clarifying questions. For example, while parents from both groups struggled to upload their children's work online, a Spanish-speaking mother who called their teacher for assistance found it hard to understand the teacher's English-only responses. Relatedly, when talking about the text messages they received, a parent noted, "The messages were sent to me in Spanish. Yes, they [the messages] did support us a lot because with the calls I do stay at zero because, when I get the English calls from school, no, I don't understand anything." While the school district historically had been able to translate family resources to Spanish, the school system needed to suddenly adapt to the challenges brought on by the pandemic, investing more effort into providing Chromebooks, internet and food. With less time and resources available to translate materials, the two-way messaging in Spanish was able to fill an unmet need.

## **Discussion**

Leveraging latent profile analysis and time-stamped logs of app use and two-way text messaging, we identified distinct profiles of families. Most families chose to engage with one of the two resources, but often not both. Among the families that utilized both forms of technology, the content of their text messages often related to seeking assistance on how to get onto the app. These quantitative findings that some parents prefer two-way texts - Interaction-Supported Users - align with themes that emerged from our interviews. Despite valuing the benefits of technology for their children, some parents struggled to use it themselves. This suggests that for some

families, having the opportunity to receive support through two-way messaging in their home language could be beneficial to increase usage of existing technology-based resources. Other parents preferred to use the app and never responded to our text - Independent User profiles. This perspective highlights how using technology both as a resource and as an efficient mode of communication can increase parental engagement with students' learning. These findings are consistent with research by Kim et al. (2019), who found that a combination of gamifying an educational app with one-way text messages to parents improved technology engagement and student outcomes more than gamification alone.

We also identified important differences in when families used technology. In our sample, families usually engaged with technology either during or outside of traditional business hours, but rarely across both. This builds on earlier work by Cortes and colleagues (2019b), who found that one-way messaging programs are more effective for some families when they were delivered during non-business hours. If messages are supposed to provide timely and actionable information or support, the variable needs of families make scaling such an intervention difficult. However, for the Independent Users who benefited from the one-way text messages to engage with the app, implementation may be more straightforward. Many technologies allow messages to be scheduled days or months in advance, facilitating that schools could schedule messages during normal work hours to be sent during times that are more convenient for parents to take action.

Multinomial logit functions also show that families receiving Spanish-language messages were more likely to belong to all of the technology-using profiles than English-speaking families, and that these differences were particularly notable in 2020. Interview data indicated that while some of the books, resources, and information shared by the school were provided in multiple

languages, Spanish speaking parents faced additional barriers to using educational technology because follow-up communications happened almost exclusively in English. These challenges both exacerbated parents' concerns about their child's school performance and made the switch to home-schooling more difficult. While our app was in English, two-way text messaging was provided in both Spanish and English, and our results suggest that this effort facilitated engagement of both English- and Spanish-speaking families. For the school district in this study, the challenge to provide resources to families in multiple languages was specific to the context of the pandemic. However, our results also provide suggestive evidence that similar interventions could be particularly effective in smaller districts, where there might be less funding to translate resources in multiple languages, or in larger districts if a family's preferred language represents only a small proportion of the overall student population.

Family patterns of technology engagement changed meaningfully between 2019 and 2020. Families were much less likely to use the educational app, but more likely to engage in two-way text messaging – while many families disengaged from technology resources altogether, families who did engage were much more likely to be in the Interaction-Supported User profile. Additionally, the differences between families receiving Spanish- versus English-language messages increased and were more robust. Our interviews and the content of families' text messages in 2020 suggest the increased texting activity was related to a heightened need for clarification and support. While our results are descriptive in nature, they point to important implications for how the medium, timing, and language of communication can influence how families engage. They also provide further evidence that a single strategy might be insufficient to bridge the divide between schools and the diverse types of families present in school communities.

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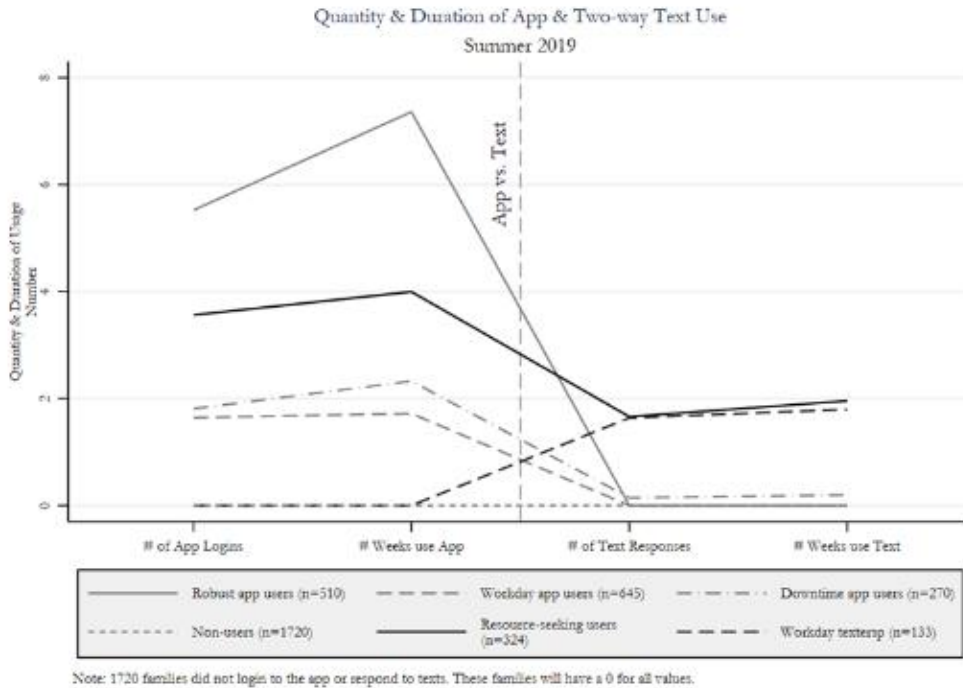
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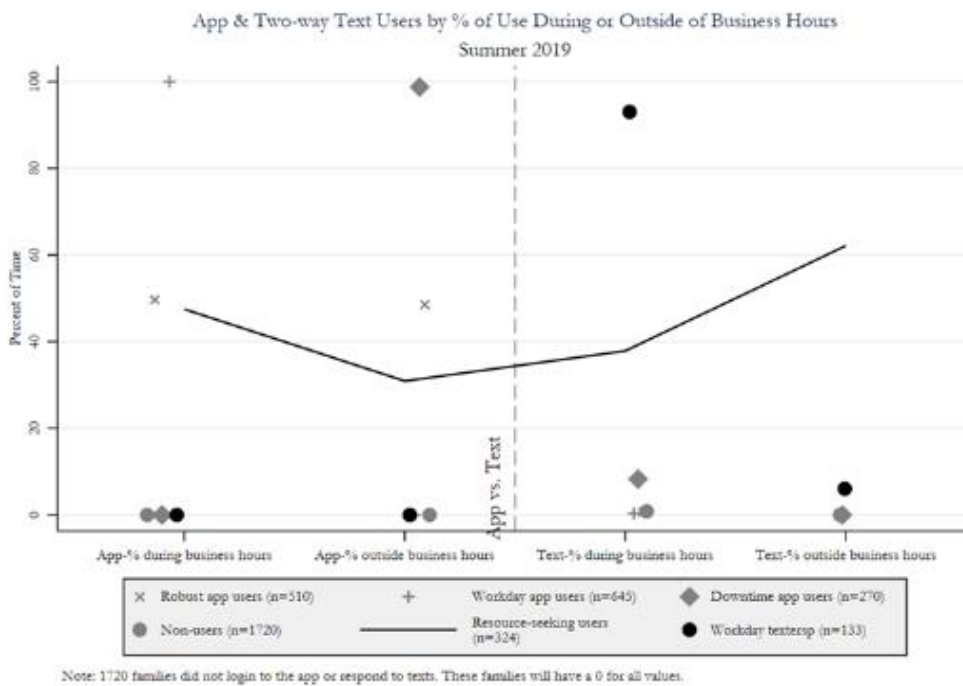
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**Figure 1**  
 Mean Characteristics of the Families by Profile Membership in 2019

Panel A: Quantity & Duration of Independent & Interaction-Supported Use



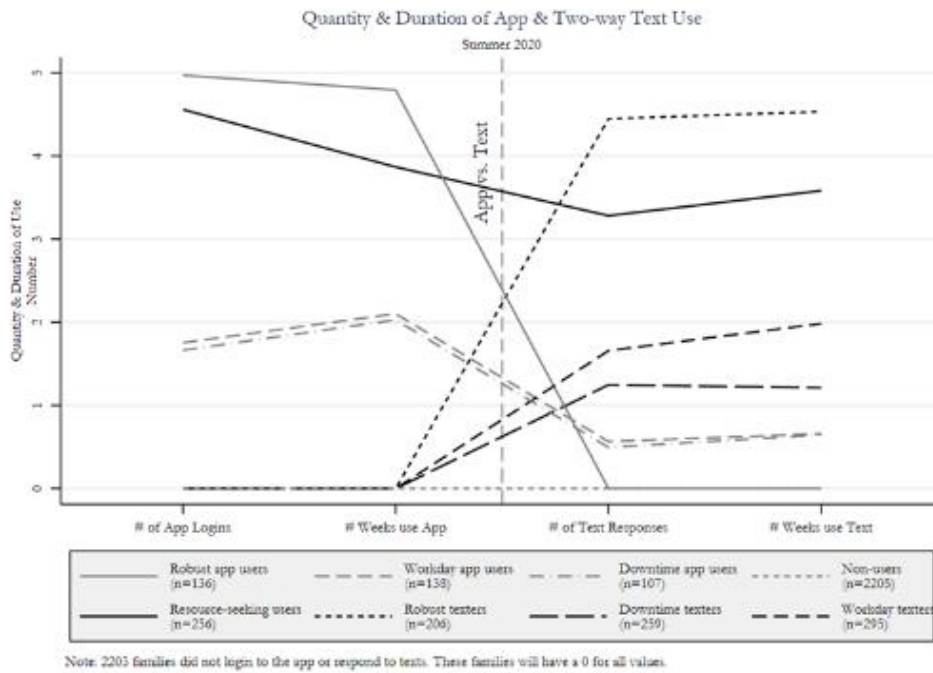
Panel B: Independent & Interaction-Supported Users by % of Use During or Outside of Business Hours





**Figure 2**  
 Mean Characteristics of the Families by Profile Membership in 2020

Panel A: Quantity & Duration of Independent & Interaction-Supported Use



Panel B: Independent & Interaction-Supported Users by % of Use During or Outside of Business Hours

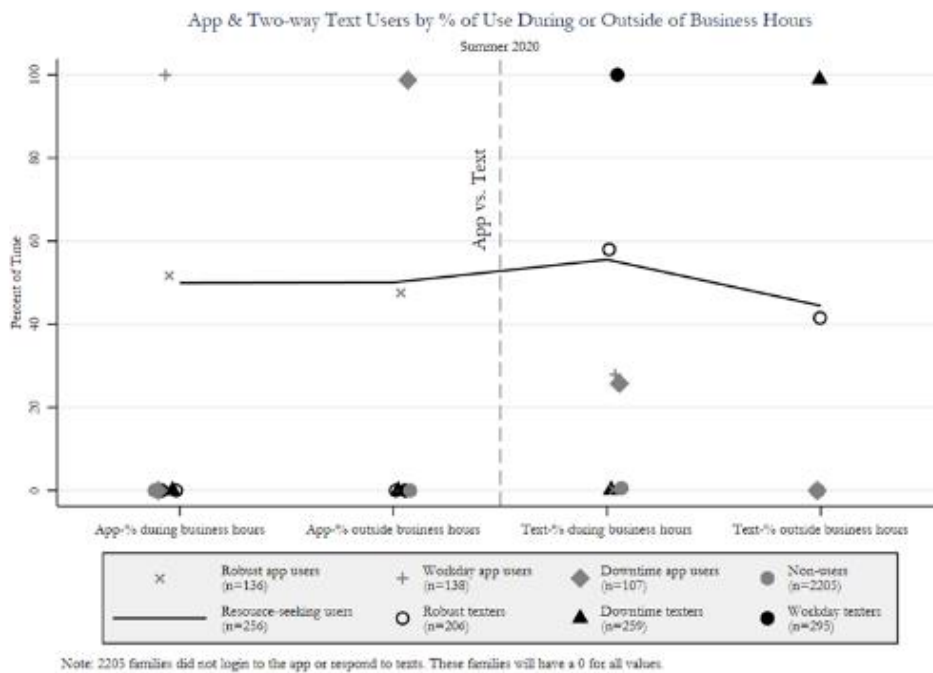


Table 1

*Characteristics of text messages by profile membership in 2020*

	Workday app users	Downtime app users	Resource-seeking users	Workday texters	Downtime texters	Robust texters
<b>Panel A: Sentiments Expressed by Families</b>						
Ever mention grateful for service	0.632	0.556	0.605++	0.454	0.089	0.641
	-0.489	-0.506	-0.49	-0.499	-0.285	-0.481
Ever mention needing help	0.079	0	0.078+	0.027	0.035	0.112
	-0.273	0	-0.269	-0.163	-0.183	-0.316
<b>Panel B: Families' Message Topics, Ever Used</b>						
Confused (e.g., who is this) (%)	0	0.037	0.012	0.037	0.015	0.044**
	0	-0.192	-0.108	-0.19	-0.124	-0.205
Opting Out (%)	0.053	0.037	0.016++	0.183	0.073	0.078**
	-0.226	-0.192	-0.124	-0.387	-0.261	-0.268
Mention app, hardware, or technology (%)	0.158	0.148	0.496++	0.122	0.127	0.398*
	-0.37	-0.362	-0.501	-0.328	-0.334	-0.491
Mention alt to tech (e.g., no screens) (%)	0	0	0.008	0	0	0
	0	0	-0.088	0	0	0
Request changes (e.g., updated phone number) (%)	0	0.074	0.023	0.01	0.019	0.01
	0	-0.267	-0.152	-0.101	-0.138	-0.098
Responded to 2020 pulse survey	0.105	0.111	0.23++	0.071	0.575	0.383**
	-0.311	-0.32	-0.422	-0.258	-0.495	-0.487
Mention resources (e.g., books)	0.263	0.148	0.293+	0.2	0.054	0.379*
	-0.446	-0.362	-0.456	-0.401	-0.227	-0.486
Engagement (e.g., follow-up questions)	0	0	0.004	0	0	0
	0	0	-0.063	0	0	0
Other content	0.395	0.407	0.453	0.264	0.185	0.563
	-0.495	-0.501	-0.499	-0.442	-0.389	-0.497

Note: Sample is those who sent any texts in 2020. Means for each category are shown, with standard deviations in parentheses. Each text was evaluated and families were given an indicator if any text ever mentioned the following topic or sentiment. Panel B reflects a set of mutually exclusive categories; however, because the same family could have sent text in multiple categories or none of the categories, the proportions will not total 100 percent. Standard errors are clustered at the school-grade level for cross-group comparisons. Comparison of Resource-Seeking and Workday Texters +  $p < 0.05$ ; ++  $p < 0.01$ ; Comparison of Resource-Seeking and Robust Texters \*  $p < 0.05$ ; \*\*  $p < 0.01$

Table 2  
*Cluster Membership Transitions Between 2019 and 2020*

Cluster Membership in 2019	Cluster Membership in 2020								Total
	<u>Independent Users</u>				<u>Interaction-Supported Users</u>				
	Non-users	Workday app users	Downtime app users	Robust app users	Resource-seeking users	Workday texters	Downtime texters	Robust texters	
Non-users	1,191 69%	50 3%	35 2%	41 2%	58 3%	130 8%	126 7%	89 5%	1,720
<b>Independent Users</b>									
Workday app users	420 65%	20 3%	9 1%	18 3%	47 7%	53 8%	46 7%	32 5%	645
Downtime app users	151 56%	17 6%	16 6%	12 4%	20 7%	18 7%	22 8%	14 5%	270
Robust app users	244 48%	37 7%	29 6%	46 9%	67 13%	38 7%	29 6%	20 4%	510
<b>Interaction-Supported Users</b>									
Resource-seeking users	132 41%	11 3%	13 4%	16 5%	50 15%	42 13%	25 8%	35 11%	324
Workday texters	67 50%	3 2%	5 4%	3 2%	14 11%	14 11%	11 8%	16 12%	133
<b>Total</b>	2,205	138	107	136	256	295	259	206	3,602

Notes: Percentages refer to the proportion of that row's total number of 2019 families that transitioned to each of the 2020 profiles. The sum of percentages across a row should total 100%.

Table 3

*Multinomial logistic predictions of profile membership based on messaging language*

	2019 Clusters, Unadjusted		2019 Clusters, Adjusted		2020 Clusters, Unadjusted		2020 Clusters, Adjusted	
	Point Estimate	(SE)	Point Estimate	(SE)	Point Estimate	(SE)	Point Estimate	(SE)
Workday app users								
Language of text in Spanish	0.0865	(0.139)	0.221	(0.224)	0.843***	(0.214)	1.125*	(0.448)
Constant	-1.008***	(0.132)	-1.831*	(0.897)	-3.032***	(0.130)	-4.322**	(1.338)
Downtime app users								
Language of text in Spanish	0.0354	(0.148)	0.601	(0.321)	0.565**	(0.209)	0.411	(0.443)
Constant	-1.854***	(0.0937)	-0.00180	(1.037)	-3.178***	(0.127)	-2.626	(1.685)
Robust app users								
Language of text in Spanish	0.457***	(0.107)	1.158***	(0.237)	0.755***	(0.184)	1.061*	(0.524)
Constant	-1.357***	(0.0877)	-1.988*	(0.925)	-3.020***	(0.144)	-18.62***	(1.165)
Resource-seeking users								
Language of text in Spanish	0.615***	(0.124)	0.223	(0.264)	1.593***	(0.163)	1.504***	(0.337)
Constant	-1.865***	(0.0966)	-14.37***	(0.666)	-2.792***	(0.111)	-0.767	(0.986)
Workday texters								
Language of text in Spanish	0.0965	(0.187)	-0.405	(0.384)	0.660***	(0.175)	0.383	(0.413)
Constant	-2.568***	(0.101)	-15.16***	(1.097)	-2.212***	(0.104)	-13.44***	(0.900)
Robust texters								
Language of text in Spanish					1.033***	(0.170)	0.765*	(0.368)
Constant					-2.708***	(0.124)	-0.525	(1.316)
Downtime texters								
Language of text in Spanish					0.360*	(0.155)	0.445	(0.358)
Constant					-2.239***	(0.0771)	-1.446	(1.133)
Observations	3543		3502		3543		3502	
Includes baseline covariates	No		Yes		No		Yes	

Note: Results come from a multinomial logistic regression model where Non-users are the base outcome profile. Standard errors, presented to the right of each point estimate, are clustered at the school-grade level.\* p<0.05; \*\* p<0.01; \*\*\* p<0.001

## APPENDIX

Appendix Table 1  
*Descriptive Statistics for the Longitudinal Sample*

	2019 Mean	2019 SD
Race/Ethnicity		
White	0.19	0.39
Black	0.35	0.48
Hispanic	0.35	0.48
Male	0.50	0.50
AIG	0.06	0.24
IEP	0.08	0.27
LEP	0.24	0.43
Text Spanish	0.30	0.46
SES		
Low SES	0.40	0.49
Med SES	0.37	0.48
High SES	0.22	0.42
MAP Spring 2019 Reading (RIT)		
Grade 1	175.48	16.2
Grade 2	188.11	16.21
N		3602

Note. Sample size for MAP Pretest is lower due to missing data. AIG = Gifted Program, LEP = Limited English Proficiency, IEP = Individual Education Plan, SES = Neighborhood Socio-economic status level

Appendix Table 2  
*Measures of Engagement, by Domain and Technology Medium*

Domain	Measure from App	Measure from Text Message Records	Original Units Before Log Transformation
Quantity of engagement	Total number of app sessions	Total number of text messages sent by family	Count
Duration of engagement	Weeks between first and last app session	Weeks between first and last family-sent text message	Weeks
Timing	Relative proportion of app sessions began during standard business hours (Mon-Fri 8am-6pm)	Relative proportion of family-sent text messages sent during standard business hours	Percentage points
Interest		Whether families ever opted out of receiving text messages	Binary indicator

Appendix Table 3

*Fit statistics for latent profiles using baseline and follow-up using app and texting engagement*

	Log Likelihood	AIC	BIC	CAIC	SABIC	BLRT	p
2019							
Profile 1	-13,352	-26,709	-27,112	-26,711	-26,703	NA	NA
Profile 2	-11,183	-22,374	-23,120	-22,378	-22,363	4,339	0.00
Profile 3	-10,063	-20,138	-21,227	-20,146	-20,122	2,239	0.00
Profile 4	-8,148	-16,313	-17,744	-16,322	-16,290	3,830	0.00
Profile 5	-6,981	-13,983	-15,757	-13,995	-13,955	2,334	0.00
Profile 6	-5,704	-11,432	-13,550	-11,447	-11,399	2,555	0.00
Profile 7	-5,783	-11,595	-14,055	-11,612	-11,556	-159	1.00
Profile 8	-5,784	-11,599	-14,402	-11,618	-11,555	0	1.00
Profile 9	-5,784	-11,603	-14,749	-11,625	-11,553	0	1.00
2020							
Profile 1	-12,948	-25,901	-36,297	-25,903	-25,895	NA	NA
Profile 2	-9,112	-18,233	-29,351	-18,238	-18,222	7,672	0.00
Profile 3	-8,896	-17,805	-28,425	-17,812	-17,788	432	0.00
Profile 4	-7,658	-15,333	-25,023	-15,342	-15,311	2,476	0.00
Profile 5	-5,838	-11,696	-22,033	-11,708	-11,669	3,641	0.00
Profile 6	-5,762	-11,548	-20,084	-11,562	-11,515	152	0.00
Profile 7	-5,762	-11,552	NA	-11,569	-11,513	0	0.00
Profile 8	-5,158	-10,347	NA	-10,366	-10,303	1,209	0.00
Profile 9	NA	NA	NA	NA	NA	NA	NA

Appendix Table 4

*Mean characteristics for each 2019 LPA profile, including "ghost" profile*

	Independent Users				Interaction-Supported Users	
	Workday app users	Workday app users (Alternate)	Downtime app users	Robust app users	Resource-seeking users	Workday texters
N	645	0	270	510	324	133
Number of Text Responses	0.0	0.0	0.1	0.0	1.5	1.4
Number of App Logins	1.5	1.5	1.6	4.7	2.1	0.0
How many weeks did you use text	0.0	0.0	0.1	0.0	1.5	1.4
How many weeks did you use the app	1.4	1.4	1.7	5.9	2.2	0.0
Was the text an opt out?	0.0	0.0	0.0	0.0	5.4	5.4
Text - % during business hours	0.0	0.0	0.4	0.0	6.7	90.7
Text - % outside business hours	0.0	0.0	0.0	0.0	23.1	0.9
App - % during business hours	100.0	100.0	0.0	45.7	15.3	0.0
App - % outside business hours	0.0	0.0	100.0	46.4	6.6	0.0



Appendix Table 5

*Mean characteristics of each 2020 LPA profile, including "ghost" profile*

	Independent Users				Interaction-Supported Users				
	Non-users	Workday app users	Downtime app users	Robust app users	Resource-seeking users	Workday texters	Workday texters (Alternate)	Downtime texters	Robust texters
N	2205	138	107	136	256	295	0	259	206
Number of Text Responses	0.0	0.3	0.3	0.0	2.7	1.5	1.5	1.2	3.9
Number of App Logins	0.0	1.5	1.5	4.3	3.5	0.0	0.0	0.0	0.0
How many weeks did you use text	0.0	0.3	0.3	0.0	2.7	1.5	1.5	1.1	3.8
How many weeks did you use the app	0.0	1.7	1.6	4.2	3.1	0.0	0.0	0.0	0.0
Was the text an opt out?	0.0	1.5	0.9	0.0	2.0	20.9	20.9	7.6	10.2
Text - % during business hours	0.0	2.6	2.2	0.0	24.2	100.0	100.0	0.0	55.3
Text - % outside business hours	0.0	0.0	0.0	0.0	17.7	0.0	0.0	100.0	38.6
App - % during business hours	0.0	100.0	0.0	48.7	26.1	0.0	0.0	0.0	0.0
App - % outside business hours	0.0	0.0	100.0	45.1	28.1	0.0	0.0	0.0	0.0

Appendix Table 6

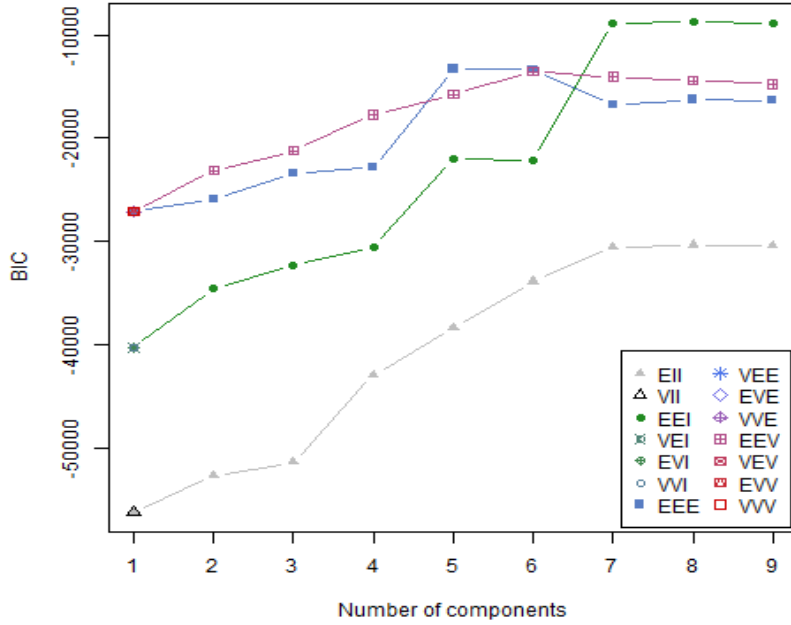
*Mean text characteristics by profile membership in 2019*

	Downtime app users	Resource- seeking users	Workday texters
<b>Panel A: Text Mentioned the Following Reason</b>			
Mention grateful for service	0.476	0.478	0.489
	-0.512	-0.5	-0.502
Mention needing help	0.048	0.034	0.023
	-0.218	-0.181	-0.149
<b>Panel B: Text Placed in Mutually Exclusive Content Areas</b>			
Confused (e.g., who is this) (%)	0.048	0.105	0.135
	-0.218	-0.307	-0.343
Opting Out (%)	0	0.052	0.053
	0	-0.223	-0.224
Mention app, hardware, or technology (%)	0.381	0.275**	0.143
	-0.498	-0.447	-0.351
Request changes (e.g., updated phone number) (%)	0	0.022	0.015
	0	-0.146	-0.122
Mention resources (e.g., books)	0	0.08	0.045
	0	-0.272	-0.208
Other content	0.476	0.38	0.376
	-0.512	-0.486	-0.486

**Note:** Sample is those who sent any text in 2019. Means for each category shown the standard deviation is in parentheses. Because the same family could have sent text in multiple categories or none of the categories, the proportions will not total 100 percent. Standard errors for the difference between profiles are clustered at the school-grade level, but are not shown. Difference between Resource-seeking and Workday texters \*  $p < 0.05$ ; \*\*  $p < 0.01$

Appendix Figure 1  
 Bayesian Information Criteria (BIC) for profiles with differing covariance structures

**Panel A: 2019 Sample**



**Panel B: 2020 Sample**

