EduFeed: A Social Feed to Engage Preliterate Children in Educational Activities

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ABSTRACT

In this work, we present EduFeed, a system that enables preliterate children to explore an algorithmically-mediated social feed of learning exercises, select activities to engage in, and share them with their peers. We deployed EduFeed as a technology probe to three classrooms of ESL students in the first year of elementary school in India who had limited English literacy and limited experience with touchscreen technology. We found that children were able to self-direct their engagement with the system and were initially motivated by digital sharing, while social context surrounding the system in physical space was also important. Based on our design and probe deployment, we reflect on issues relevant to adapting the social feed paradigm to this context, such as ranking algorithms, physicality, immediacy, and bridging physical and digital collaborative experiences.

Author Keywords

Social feeds; education; children; CSCL; literacy; ICT4D.

ACM Classification Keywords

K.3.1 Computers in Education: Collaborative Learning

INTRODUCTION

There are approximately 250 million children globally who cannot read, write, or understand basic numbers and arithmetic, and the majority of these children reside in developing countries that do not have consistent access to quality schools or teachers [37]. As programs work to build schools and train teachers to provide education to children in these areas, there is still a need for approaches to supplement learning in the meantime [37]. Technology provides a foundation for one such approach, which, unlike traditional infrastructure-dependent approaches, can be scaled to serve large populations.

In 2014, the Global Learning XPRIZE [37] launched a worldwide competition to develop touchscreen tablet-based software solutions to help children in developing countries self-teach basic reading, writing, and arithmetic to begin to close this educational gap. Yet, the question of what types of technology can consistently engage children in these contexts, be localized to be culturally appropriate, bootstrap use by novice, preliterate, and illiterate users, facilitate learning in the absence of instructors, and overcome other infrastructural challenges is still an open problem.

Motivated by the Global Learning XPRIZE, we were interested in answering some of these questions. In this work, we explore the ability of a tablet-based social feed to engage preliterate children in practicing their numeracy and English literacy skills. Specifically, we asked: how might we promote engagement, sharing, and collaboration among users by adapting social networking feeds to educational activities on a touchscreen tablet? As part of this design exploration, we present a system called EduFeed. EduFeed is an Android tablet application that enables preliterate children to explore a stream (or "feed") of educational activities, select and complete these activities, and then share them with their peers digitally. We designed three variants of the feed to explore different ways in which social activities might be realized. We then deployed these three versions of EduFeed to three classrooms of Indian ESL (English as a Second Language) students in their first year of elementary school as technology probes [16], which allowed us to collect data about the use of the system in a classroom context. Through this design case, we reflect on our design process, probe deployment, and our data collected in situ. We discuss how this new class of social system has potential to provide preliterate students with virtual and physical space to self-direct their educational skills practice and receive social support when engaging with software-based numeracy and literacy activities.

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Our contribution to the CSCW community is twofold. Our first contribution is the EduFeed system, a prototype designed for computer-supported collaborative learning (CSCL) and information and communication technologies for development (ICT4D). This system embodies the novel concept of adapting algorithmic social feed mechanisms to be suitable for (1) early childhood education and (2) a population of preliterate users. The EduFeed prototype introduces innovative educational activities whose design is customized for this purpose, and a presentation paradigm and interaction style tailored to this unique population and goal set. Second, we present a design case that includes the design of EduFeed, a study of its use as a technology probe, and reflection on this process and the outcomes. From this design case, we contribute insights into the strengths and limitations of social feed applications to engage preliterate children in educational activities in digital and physical space and pose new research directions in this area.

RELATED WORK

Student-Centered Learning & Social Support for Learning

Student-directed learning is an educational methodology driven by self-determination theory. In student-directed learning, students' motivation to pursue academic goals is directly related to their engagement in learning tasks [29] and, as such, uses students' interests and autonomy as the prime motivators of learning. Student-centered, self-directed approaches to education have proven effective for students in both motivation and achievement outcomes. Student-centered classroom curricula matched individually to students' instructional level give opportunities for self-directed learning and increase students' mastery of academic skills [33]. Moreover, self-referential standards are better than normative standards, lead to academic gains, and promote self-efficacy [33]. Self-management in the instructional environment relates to students' feelings of autonomy, motivation, and achievement [33].

Social support has also been shown to be integral for learning, motivation, and persistence for students. Vygotsky [35] and Piaget [27] emphasized social interactions in theories of child development, leading to more research into the ability of sociality to positively affect learning in the classroom. For example, Wentzel [36] found that peer relationships are fundamental in influencing motivations for learning and academic success, as students internalize peers' positive values of academic success. Consequently, developmental and educational psychologists have shown that peers can also mediate student-centered learning experiences to positively affect students' persistence and motivation to achieve [28]. Due to the positive and powerful impact that peer interactions have on student academic motivation and achievement, peer-assisted learning (PAL) interventions have been developed and incorporated into the elementary school classroom with the goal to enhance learning, motivation, and achievement [28]. These PAL interventions explicitly engage peers socially and have been most effective with younger, urban, low-income, and minority students [28].

Teacher-student social interactions can also positively influence students' motivation and success. Through these social interactions, teachers communicate their goals and expectations and also provide contexts, structure, guidance, and autonomy that are conducive to learning [28] and lead to positive, motivational outcomes [31].

These theories of student-centered learning and social support for learning provided a basis for our design of a social feed for children to practice their numeracy and English literacy skills. By tailoring educational activities algorithmically for individual students and presenting them in a social feed, children have opportunities for both self-direction and peer-motivation within or outside of formal academic contexts. Teachers may also provide individualized contextual guidance when implemented in a classroom, all existing in a common physical and digital space dedicated to learning.

CSCL and ICT4D

While there has been past research at the intersection of CSCL and ICT4D in the world's emerging markets, there is a lack of research into the possibilities of tablet hardware and software in particular to positively affect children's engagement and collaboration in these areas. A number of technology deployments have been made that aim to empower children to teach themselves using desktop and laptop computers, such as the Hole in the Wall [23] and the OLPC [21] projects. While innovative, the shortcomings of the OLPC project point to the need for more independent investigations of such systems in relation to their local context of use [21]. Additionally, Pawar et al. [26] and Amershi et al. [2] explored how PCs could be cheaply shared by adding support for multiple connected mice to allow large groups of students to simultaneously engage with educational content. This groupware is motivating but does not necessarily allow for individualized student-directed approaches because of its single display.

In terms of mobile devices, Jain et al. [17] explored the differences in effects of projected single display and multiple mobile phone displays on co-located collaborative gameplay and English learning for young teens in India. The multiple mobile phone displays allowed for mobility, potentially allowing for learning to occur "nearly everywhere" (p. 89). Yet, in both of these display set-ups, children had issues collaborating when they were paired in competing teams that contributed to the same game, resulting in verbal and physical fighting. Rather than depending on competition, we ground our design in self-direction and social support via sharing content.

Finally, Zurita and colleagues [38, 39] found mobile CSCL supported and enhanced collaborative work for first graders in a low-income school in Chile. Here, the mobile form factor encouraged mobility necessary for collaboration (similar to Jain et al. [17]), and the game scaffolded not only *collaboration around computers* but also *collaboration through computers* [15, 38]. When learners *collaborate through computers*, the computer structures and defines their collaboration, resulting in *computer supported social networks* [15]. We build on this concept by explicitly designing a type of digital social network in EduFeed.

Overall, we expand on this body of knowledge about developing CSCL applications for emerging market audiences to increase motivation and engagement, considering how new collaborative paradigms (e.g., social feeds) and a different form-factor (e.g., small low-cost touchscreen tablets) may be leveraged in this context.

Social Networking & Education

In relation to student-centered learning, social support for learning, and CSCL, social networks have the ability to foster social relationships, allow people to make recommendations to others, and enable people to self-direct their own exploration of content [1, 19]. However, research in this area has focused primarily on teens and adults in non-educational contexts [4], primarily because laws in many countries, such as the U.S.'s Children's Online Privacy Protection Act [8], result in sites officially restricting children under age 13 from creating accounts. Drawing on this potential of social networks to contribute to educational contexts, one project named FeedLearn embeds microlearning exercises into Facebook feeds [20]. We expand on this concept by designing for preliterate children in particular to create a social feed dedicated to educational activities rather than embedding exercises into an existing feed.

As we explain further in the following sections, we draw on Vygotsky [35] such that activities in the feed increase in difficulty as children complete easier activities. In this way, a social feed can allow preliterate children to be active, social participants in their educational practice, guided by their abilities and without the necessity of being able to read. Moreover, while there has been extensive work in designing technology user interfaces to be accessible to novice and low-literate users [34], to the best of our knowledge, this is the first design and investigation of a social feed for preliterate children.

SYSTEM DESIGN

To provide a social learning experience for preliterate children with no familiarity with the concept of a social feed, the following goals guided our system design:

- The system should be *usable without requiring literacy*. This is necessary because our target population of children were developing English literacy skills (as one of the purposes of the software was to engage students in practicing their basic literacy skills).
- The system should *show users content within their zone of proximal development (ZPD*) [35]. Within their ZPD, learners can complete relevant tasks with appropriate guidance or scaffolding [35]. This design goal ensures that engagement and learning will not suffer from the tasks being too easy, while both the system (and other people) can provide scaffolding for the activities as they advance in difficulty.
- The system should *enable users to share activities with their peers*. Sharing can happen in digital space through the software and in physical space due to the shape and size of the tablet. This criterion is included to enhance engagement with the system via the beneficial incentives and effects of peer learning.

With these goals in mind, we developed the concept of adapting the social feed structure commonly used in applications targeted at teens and adults in the developed world (e.g., Facebook's News Feed). The feed structure and the autonomy it engenders can allow students to be engaged and motivated through self-direction in their choice of specific educational exercises to complete [1, 19]; however, the social nature of the feed makes this interface paradigm differ from menus of activities common in children's educational apps, and provides an opportunity to integrate peer learning. Further, the algorithms selecting and ordering feed content can be designed around concepts like ZPD.

We iterated on our design first with informal testing sessions with younger (4- to 5-year-old) preliterate children in the United States and then with four first graders in India. An education expert was involved in the iterative design process to ensure we addressed pedagogical needs. In the following section, we describe the features of our prototype system that resulted from this iterative design process.

SYSTEM FEATURES

The EduFeed system is a tablet application that consists of a number of activities that can be accessed and shared with peers through a social feed. Each activity gives users opportunities to practice a particular basic numeracy or literacy skill. Numeracy skills include number identification, addition, subtraction, and multiplication. Literacy skills include letter identification and word recognition. To make content accessible and learnable by preliterate children, directions and content were spoken aloud by the system in English. The system played this audio automatically when a user entered into an activity. It could also be replayed by the user by tapping on a speaker icon or on the words/numbers in the activity.

EduFeed is implemented as an Android application built with web technologies (Polymer, with each activity implemented as a web component) and the Chrome Mobile Web Apps

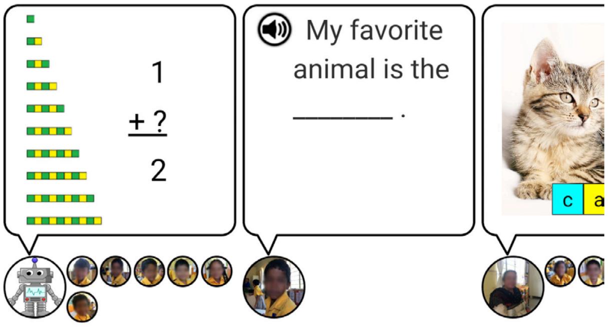


Figure 1. The social feed displays thumbnails previewing different types of educational exercises, along with thumbnails of the poster and users who have completed it. A speech bubble metaphor is used to convey the metaphor of social sharing to a preliterate audience. The robot icon indicates an item inserted in the feed algorithmically by the system, rather than one shared explicitly by a classmate.

framework (a fork of Apache Cordova that enables web applications to be deployed as native Android or iOS applications). The application is meant to be used in landscape mode with one user per device. The device we deployed on was the 2013 Nexus 7, a 7-inch tablet. Activity syncing between tablets is accomplished by having a local server running a CouchDB instance that replicates the database between the tablets, allowing real-time activity sharing to work in the absence of Internet access.

Social Feed

The social feed (Figure 1) displays thumbnails of available activities and who shared them with the user. Our feed displays the available activities from left to right, in order of how recently they were added. As we explain in more detail later, this results in an ordering that corresponds to a combination of when activities are shared with a user and when new, more difficult activities are provided to the user by the system. The feed uses a side-scrolling interface to enable users to navigate through the list. We chose a left-to-right direction for the feed, as opposed to the top-down direction used in systems such as Facebook, both to match the left-to-right reading direction of English, as well as to make the feed suitable for use in landscape mode (as we found the additional horizontal space to be more suitable for several of our activities, such as the typing activities). The feed also shows smaller thumbnails of each of their peers (i.e., classmates) who already completed the activity. This indication of completion can potentially serve as a signal that the activity is enjoyable and popular, similar to how displaying "likes" helps surface popular content in a traditional social feed.

Activities are shown in the feed after either the user's peers, teacher, or an algorithmic selection shares them with the user. Our feed visually indicates the source of an activity using an avatar – either a picture of the peer or teacher for shared activities, or a picture of a robot for algorithmic suggestions.

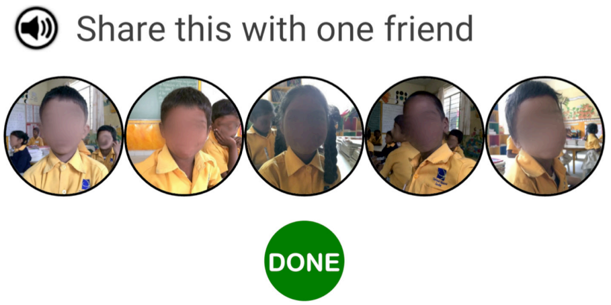
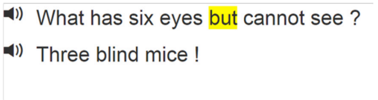


Figure 2. The activity sharing screen allows users to share the activity they have just completed with a peer.

When a student completes an activity (which can only happen if answered 'correctly' or 'entirely', depending on the type of activity), we replace that activity in the feed with a new activity or activities. We implemented three algorithms for adding new activities: (1) add one new activity to the feed of the same type as the completed activity but with new content, in order to promote depth of one skill; (2) add one new activity that is a different type from the completed activity, in order to promote breadth of skills; and (3) a combination of (1) and (2) – add one new activity of the same type as the completed activity but with new content, and also one new activity of a different type.

For the deployed version of EduFeed, we chose to only utilize scheme (1), replacing the completed activity in the feed with a new activity of the same type. This ensures that the added activity has new content that is within the user's zone of proximal development, as determined by their completion of the prior activity. Specifically, we select this new activity algorithmically by assigning a difficulty level to each individual exercise within an activity type, and selecting a new exercise that increments this difficulty level. For our current prototype, there was only one exercise per level. For example, for the addition task, addition of smaller numbers is an easier and more basic task, so it has a lower difficulty level and is suggested first. We only suggest the more difficult problems once the easier activities have been completed, in line with the principles of mastery learning [6] and ZPD [35]. For larger exercise sets, the algorithm could be modified so that a student must complete a particular number of exercises at a target difficulty level before advancing to the next level.

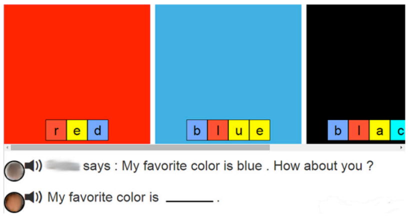
Upon completing an activity, users are shown a screen where they can choose to share the activity they have just completed with a peer, shown in Figure 2. The screen shows the pictures of the peers, and reads aloud instructions to share the activity with one friend. Once the user has selected a peer to share the activity with, it is shared with them in real-time, appearing at the start (left-hand terminus) of the selected peer's feed, independent of what difficulty level they may be at in regard to the shared activity. This may lead to children receiving activities that are outside of their zone of proximal development. Given our emphasis on ZPD as a key design criterion, we could have chosen to modify peer-shared



What has six eyes but cannot see ?

Three blind mice !

Figure 3. The reading activity reads the sentence aloud, highlighting word by word. Users tap a word to hear it in isolation.



[redacted] says : My favorite color is blue . How about you ?

My favorite color is ______ .

Figure 4. The social fill-in-the-blank activity allows users to complete a sentence and send their response to their peers.

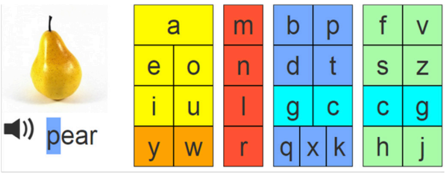


Figure 5. The word typing activity asks users to input the letters in the pictured word on a phonetically arranged keyboard. Pear image by ©Joe King.

activities so that the content was at the receiver's current skill level, or to wait to show these shared activities until the receiver was at the appropriate level. However, for this first prototype of EduFeed with a limited number of exercises, we chose to implement simple, real-time sharing. We accomplish this real-time sharing by having each of the tablets sync to a database that stores the list of activities that should be displayed.

Activity Types

As with any educational system, the content presented by EduFeed was critical for its success. We developed educational activities for preliterate users that work well within the paradigm of an educational social feed. Our team, including an education professional, designed and implemented nine types of educational exercises for practicing both numeracy and literacy skills on tablets. These activities illustrate designs for making content appropriate to a preliterate audience (e.g., use of audio cues and simulation of physical manipulatives), without teacher direction (e.g., new activities start by providing an audio and video tutorial), as well as for a social feed paradigm (e.g., progressive leveling of content within an activity type, social incentives for sharing, and building up on content). Our accompanying video figure demonstrates interactions with sample exercises.

Literacy Activities

We designed four types of activities for reading and writing skills. We briefly describe them below, emphasizing aspects pertaining to preliteracy and social activities.

Our basic reading activity focused on skills such as word segmentation and how words can be organized into sentences that are separated by spaces and read from left to right. We proposed a set of short sentences read aloud via speech synthesis, highlighting the word as it is spoken (Figure 3). Users can tap on a word to hear it in isolation, or have the entire sentence read out loud. The sentences are chosen from a corpus of passages meant to be read by children, so they are easily decodable and contain content that is targeted towards children.

To stimulate peer learning and reinforce the social feed paradigm [13, 18], we designed social activities enabling children to share text with each other (Figure 4). We provided scaffolds such as restricting the task to filling in a single word, or providing a list of options for words that can be used to fill in the blank, to reduce the difficulty of the task to a level appropriate to the student's current skills. Figure 4 illustrates one of our social writing exercises in which a student sharing an activity via the feed displays their answer to a question, deepening the social incentives in completing the writing task.

Two of our literacy-skill activities involved typing letters. While the basic-level activities involved typing the first letter of a word (e.g., type 'p' as in "pear"), the more advanced activity had children type an entire word. Targeting a preliterate audience led us to design a special keyboard, scaffolding the process of learning how to type letters. Our keyboard is phonetically arranged [7], grouping together letters that represent similar phonetic sounds into color-coded blocks, as shown in Figure 5. We designed the position and color of each key to reflect the phonetic properties of the letter, providing an additional cue to help the users remember letters' sounds. The system also pronounces the sound of the letter that is touched, as a further reinforcement. To help scaffold users in the task of learning to type words, children first start by seeing only a portion of the keyboard, one letter at a time. As they progress, more letters become available at once, eventually leading to typing specific letters from the entire keyboard. Incorrect entries trigger a visual and audio cue and restart the progressive keyboard process. We assign difficulty levels to words based on the number of new letters that the learner has not yet covered. We also prioritize words that are "decodable" – that is, they lack letters that are silent or have a sound that is different from the normal one, which would make the process of spelling by sounding out the word more difficult for beginners [30]. The assignment of difficulty levels is important metadata for allowing the feed to factor ZPD into account in content selection.

Numeracy Activities

We selected five types of numeracy activities, which are digital analogues to manipulatives used in Montessori curricula [3, 9, 24]. The activities we selected are particularly well-suited for touch interactions as they rely on dragging visual elements in space to understand the concept of number and multi-digit number, and to learn addition, subtraction, and multiplication.

The bar activity emphasizes the concept of number by analogy to bar lengths. Several bars are labeled with numbers corresponding to their lengths, and the user has to order them

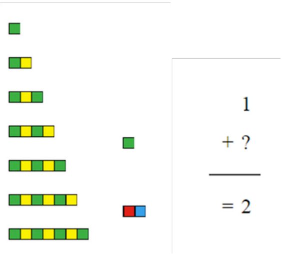


Figure 6. The addition activity uses a bar-length analogy. Users select a bar of the appropriate length to add to a given bar and reach the total (shown in red/blue).

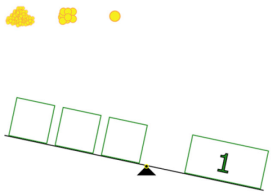


Figure 7. The multi-digit number activity uses a weight analogy. Users drag groups of 1, 10 or 100 items onto boxes on the balance to match the number.

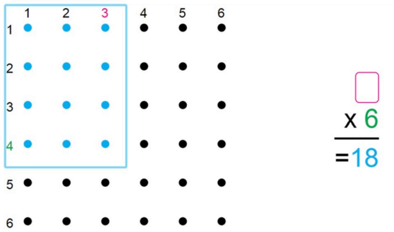


Figure 8. The multiplication activity uses an area analogy. Users select an area covered in dots to match the total.

in increasing order of length. The number is read out loud when the user interacts with the corresponding bar to reinforce the association between the bar length, the symbol for the number, and its pronunciation. The addition activity (Figure 6) extends this length metaphor by having users add a missing bar to an existing one to reach a desired target length. A formula is displayed on the right to show the correspondence between the symbolic representation and the bar-lengths representation of the addition formula. Similarly, the subtraction activity involves having users add "negative" bars to an existing one, to reach the lesser target length. The formula is displayed on the right to show the correspondence between the symbolic representation and the bar-lengths representation of the subtraction formula.

The balance activity (Figure 7) focuses on how to identify multi-digit numbers by having users drag items that are in groups of 1, 10, or 100 onto a balance to match a number. This is similar to the Montessori-inspired BEAM system for teaching arithmetic, but we have a simplified interface that stresses the association between quantities and the symbolic representations of the numbers [22].

The multiplication activity (Figure 8) uses a grid of dots to highlight the concept of multiplication via an area analogy. The user can select dots via a rectangular box, and the dots selected will equal the number of columns multiplied by the number of rows. Whenever the number of selected dots changes, a voice reads out the current product. This activity begins with a free-play version where the user can experiment with the grid and observe the corresponding formula on the right.

The number of bars, the number to match, and the size of the grid increase with progressively higher difficulty levels.

TECHNOLOGY PROBE DEPLOYMENT

Deploying EduFeed as a technology probe allowed us to collect data of its use in a real-world setting and field-test the system, while also inspiring us as designers to think about new technologies in this space [16]. As such, we deployed three variants of the EduFeed system on thirteen Nexus 7 tablets in a classroom in peri-urban India to explore how a social-feed-based tablet application for practicing numeracy and English literacy skills could engage and motivate preliterate children and affect their collaboration in digital and physical space. As part of our design exploration, this probe deployment allowed us to reflect on the ways in which children used the application individually and collaboratively in a school setting and how they chose and persisted with the activities.

Feed Variants

We implemented several variants of the social feed for our probe deployment (Figure 9). The variants included the same underlying educational activities but surfaced them to children differently. By creating slightly different versions of our feed, we were able to explore how variations in digital collaboration, sharing, and suggestions impacted children's experiences. To keep choices manageable for children, all variants displayed a maximum of ten activities, ordered from the most recent (on the left) to the oldest (on the right). Once

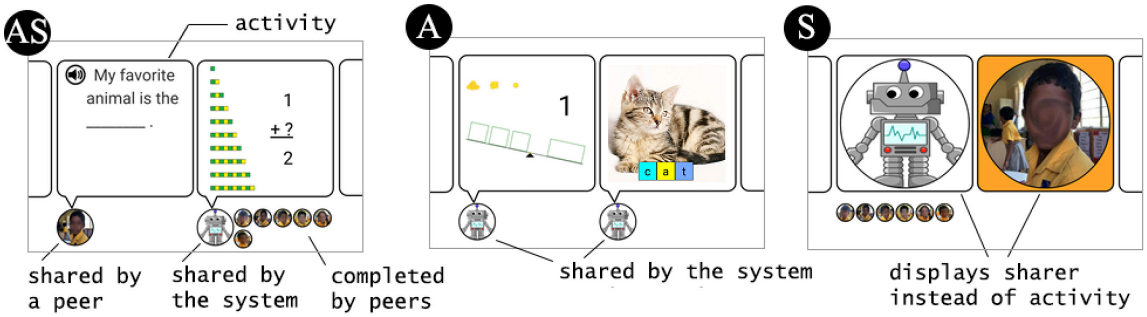


Figure 9. Feed variants. (AS) activity- and sharer-driven; (A) activity-driven; (S) sharer-driven.

completed, activities were removed from the feed, which made room for the more recent activities queued in the database suggested by the system or peers.

The first variant is **activity- and sharer-driven (AS)** (Figure 9AS). This variant was the main prototype design that we presented earlier in the section 'Social Feed'. As described, this feed displays activity content in thumbnails and is also sharing-enabled. To study more specific social engagements with this type of system, we removed features from the original prototype to create the next two variants.

In the **activity-driven (A)** variant (Figure 9A), we removed the sharing component. Thus, all activities were suggested by the robot, i.e., via algorithmic suggestion of new activities of the same type as prior completed activities, based on the user's zone of proximal development. Users were not able to share activities with their peers, and there was no indication of other users completing activities. This variant allowed us to investigate a purely physical collaboration via the tablets in the classroom, as opposed to virtual or mediated collaboration through the feed.

In the **sharer-driven (S)** variant (Figure 9S), we removed the ability to view activity content in the thumbnails. Instead, the thumbnails displayed large pictures of the person or robot that suggested/shared the activities. The sharer-driven version of EduFeed enabled us to explore how digital sharing might solely influence how children used the system without the impact of knowing the types of content of the activities.

For the sharing-enabled variants of EduFeed (AS & S), to ensure that activities suggested by peers, the teacher, and the robot were all represented in the feed at any given time, a *maximum* of six peer-shared activities were displayed. The remaining thumbnails were teacher-shared and robot-shared activities. All of these activities were displayed in order of recency of being added to the feed. If two or more peers shared the same activity (i.e., the same type with the same content) to the same user, all of these duplicate activities would appear in the feed in order of recency. Once the user completed one of these duplicate activities, they would all be marked as completed and removed from the feed. We limited the number of choices on the activity sharing screen to five peers in the class (Figure 2). Four of the five peers were randomly selected from the class. However, to ensure that children always had at least one person they had strong ties with to choose from, we privately asked children for the name of their best friend and always included that person in their list of sharing-recipient options.

Additionally, algorithmically-selected activities in the sharing-enabled variants of EduFeed (AS & S) were randomly assigned a robot or the classroom teacher picture. We hypothesized that there might be a difference in how children treated activities associated with their teacher vs. the robot, though ultimately we did not find any difference.

Participants

Our participants included 70 children, aged 6 to 8 (mean = 6.7 years), in three first grade classrooms at a school in peri-urban Bangalore that provides K-12 education to children whose family incomes fall below the poverty line; 28 were male, and 42 were female. This school uses English as the primary medium for instruction; thus, the first graders understand English and speak English semi-fluently as their second or third language, in addition to Hindi and Kannada. While the students use desktop computers as part of their school curriculum, they all had limited experience with touchscreen technology. Due to age restrictions on social media, none of the students were Facebook users and likely had little to no experience with social network feeds.

Each first grade class was randomly assigned to use one of the three variants of EduFeed: (1) the **activity- and sharer-driven (AS)** variant, (2) the **activity-driven (A)** variant, and (3) the **sharer-driven (S)** variant. Twenty-three children interacted with AS, 23 with A, and 24 with S. All children participated in three or four sessions of working with the tablets. The first session for each group of children was used to provide some initial exposure to the activities and general use of the tablets; this data was excluded from the analysis, leaving us with two or three sessions for each group.

Deployment

For the deployment, the researchers took pictures of every participant and then manually created an EduFeed account for each of them with these images. Early testing indicated that letter typing and the concept of number (bar) activities were too easy and multiplication was too difficult for our participants. Thus, the initial feeds of all participants for the pilot was populated with seven robot-shared activities of level one difficulty: addition, subtraction, balance, social fill-in-the-blank, non-social fill-in-the-blank, word typing, and sentence reading. All sentence reading activities were removed after the first session because the sound levels in the classroom made it very difficult to hear (we discuss this more in the 'Findings' section).

The probe deployment was conducted in one of the school's computer rooms with the three different first grade classes. Two to three researchers facilitated the EduFeed use sessions while one or two teachers from the school (the computer teacher and/or the first grade teacher) supervised. Each session involved the researchers connecting each tablet to the school Wi-Fi network and then logging in half of the students in a class into their accounts. Next, the students used EduFeed for 10 to 15 minutes at tables or while sitting on the floor, while the other half engaged in other activities as part of their normal curriculum. The number of students that were able to engage with EduFeed at the same time was limited by the number of available tablets, an economic constraint of conducting research in the developing world [23].

The children used EduFeed however they liked, whether that be working in groups and talking to each other about the

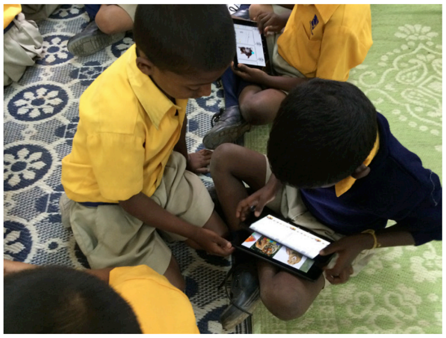


Figure 10. A student helps his peer find an activity in his feed.

activities or using the system alone. This also included allowing the children to direct their own use by choosing which activities to try, complete, or stop on their own. If children asked for help with an activity, a researcher or teacher gave assistance in a natural manner. When their session ended, the students switched places and the other half were logged in and used EduFeed for 10 to 15 minutes.

At the beginning of the first activity session for each class, one researcher explained what the students would be doing by using paper printouts of the screens. This first session allowed children to learn in-situ how the activities and feed worked, practice tablet gestures, and populate their feeds with activities for the future sessions. This data was excluded from analysis, as it was considered a pilot session for learning how to use EduFeed.

Following this first "pilot" session, classrooms A and S participated in two activity study sessions each. For classroom AS, one of the study sessions was abbreviated, so we added one additional session to give them equal time, for a total of three study sessions for this group.

Data Collection & Analysis

Data were collected from different sources, including log files, video recordings, photographs, and field notes. System logs tracked the number of each type of activity attempted and completed by each child and the amount of active time spent working on activities and exploring the feed. Qualitative observations, notes, and recordings of system use focused on sharing behaviors, engagement, and persistence with the feed interface and individual educational activities. We ran descriptive and inferential statistics on the relevant measures, and reviewed the qualitative data via thematic analysis to find consistent, emergent themes.

FINDINGS

The introduction of EduFeed into the classrooms shifted the typical paradigm of non-collaborative, teacher-centered instruction. The tablet application not only allowed the children to engage in self-direction where they were able to choose and pace their own educational activities in digital space, but it also fostered group collaboration and sharing in physical space as well.

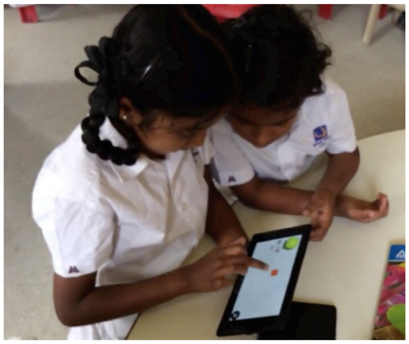


Figure 11. A student completes an activity for her peer so that they can spell the same word.

Self-Direction

There was broad variation in the rate at which children worked through the EduFeed activities, as they paced themselves differently according to their own abilities and needs. At a maximum, one child in classroom AS finished a total of 54 activities, while at a minimum, another child in classroom S finished 9 activities (mean = 30.6 activities; SD = 11.3). Moreover, while the children preferred some activities to others, i.e., literacy over numeracy activities, some children persevered with activities that were more difficult and less popular. For instance, once given assistance initially for the balance activity, a student in classroom S successfully completed 15 balance activities while many of her schoolmates did not complete any.

Additionally, many children showed their pride in completing activities on their own. Often, the students held up the tablet to show the researchers that they successfully completed an activity or when they were recommended a new, more advanced one after the completion.

Social Support

The social support surrounding EduFeed appeared to be reinforcing for children when they were physically co-located in the classroom setting. Most classmates played with the tablets sitting together in groups, and most of the time they wanted to engage with their classmates as they were using the system. This was an interesting behavior, given that social feeds among adults are typically meant to facilitate collaboration on disparate devices rather than support co-located, shared device interactions.

Children shared with each other in physical space when using all three variants of EduFeed. They saw what each other were playing and tried to find the same activities in their own feeds. Sometimes children physically switched tablets. In one case, a boy took his peer's tablet to help him find the same activity he was doing in his peer's feed (Figure 10). In another case, a girl completed the spelling activities for her friend, so that her friend could get to the same word activity as her (Figure 11). Having peers playing near each other in physical space encouraged them to find the same activities as their friends and then persist to complete the activities to get to the same levels as well.

However, the classroom setting and physical collaboration with EduFeed made for a very loud environment. In this setting, the application's audio interactions aimed at supporting preliterate users (i.e., the spoken sentences, words, and numbers) were very difficult to hear and understand. After the first pilot sessions, we decided to disable audio for the remainder of the deployment. This also meant we had to remove the sentence reading activities because they were too complex to read without audio for this age group.

Impact of Virtual Sharing

The children who used the S and AS variants of EduFeed (these included peer- and teacher-suggested activities) were enthusiastic about the faces in the interface. The children were visibly excited when they saw their friends' and teachers' faces in the thumbnails of the feed in the sharer-driven variant (Figure 9S). They were also visibly excited to see their peers' faces when were asked to share the activity (Figure 2). We observed the children showing each other their faces on the screens and pointing at the faces. These students were consistently eager to finish activities so they could get to the sharing screen to see their classmates' faces too.

Despite these benefits, the initial engagement that resulted from sharing was sometimes distracting. Quantitatively, students who used the activity-driven interface (A), without any sharing component, completed an average 69.4% of the activities they entered (SE = 3.1%); students who used the activity- and sharer-driven interface (AS) completed a mean 57.2% of the activities they began (SE = 3.1%); and students who used the sharer-driven interface (S) only completed an average 46.0% of the activities that they started (SE = 3.1%). These differences are statistically significant ($F(2, 67) = 14.05$, $p < 0.001$, partial $\eta^2 = .295$, $1\text{-}\beta = .998$); post-hoc Bonferroni-corrected tests showed that each of the completion rates were significantly different from each other as well ($p < 0.05$ for all three comparisons).

Observations corroborated this quantitative finding and indicated that students were attempting more activities and then not completing them when using the sharer-driven interface (S) because they were trying to find particular activities that they *physically* saw their peers playing or that they knew they wanted to play. This was likely because in this variant, children could not determine what an activity type or activity content was without opening it (thumbnails only included the recommender, as shown in Figure 9S). For instance, one child chose to do an activity with his best friend's face as the thumbnail but immediately exited when he realized that the activity that was recommended to him was not what his best friend was playing as he sat next to him; rather, this activity was something that was shared with him from earlier in the session. Because they could not tell which activity was which when using the sharer-driven interface, children often asked the facilitating researchers how to find a particular activity they saw their friend was playing.

Therefore, we found that digital sharing in the sharing-enabled variants of EduFeed (AS & S) was often overpowered by physical sharing, as physically seeing their friends completing activities was more motivating than seeing an abstract representation of their friend who shared an activity with them. As mentioned in the prior section, the small tablets allowed for different configurations of children, including switching of devices and sitting in groups, which allowed them to collaborate in physical space in a way that is different from our normative concept of social feed sharing for adults. Thus, the physicality of the interactions appeared to be more important than the virtual social support that we built into the system.

Along these same lines, it was unclear if the students understood the concept of virtual sharing or digital recommendations within the two sharing versions of EduFeed. While they were excited about seeing their peers in the interface, no children gave evidence during the sessions that they grasped the fact that they were receiving or giving suggestions for activities. Sometimes virtual sharing was more obvious in real time. For instance, one boy in classroom S played a literacy activity, finished it, and then shared it with his peer; his peer immediately received the shared activity, chose the thumbnail of the sharer's face, and started playing it himself. Yet, most of the time, the shared activities did not immediately appear in their chosen peer's feed due to how we limited the number of activities in the feed. By setting a maximum of peer-shared activities in a feed while the rest were queued, this sharing experience was not designed for immediacy on the receiver's end. Sometimes shared activities did not appear in the receiver's feed because that user had already completed that same activity after it was shared by a different peer or suggested by the system.

Similarly, children who used the activity- and sharer-driven (AS) version of EduFeed appeared to focus on the content and ignore the smaller, less noticeable faces below the thumbnails (i.e., other peers who had done the activity), as seen in Figure 1. The children did not appear to understand the purpose of these smaller faces (i.e., that the activity had been completed by these users); they tried to tap these faces and asked us why the buttons did not do anything. After the first pilot sessions, we removed these smaller faces, so they would no longer be distracting.

DISCUSSION

Through the design, implementation, and deployment of EduFeed as a technology probe, we explored the ability of a tablet-based social feed to engage young, preliterate ESL students in practicing their numeracy and English literacy skills and to promote collaboration among these children in digital and physical space.

Our social feed facilitated self-direction, as children could choose their own activities and progress in these activities at their own pace. In addition, encompassing activities within a social feed allows for the implementation of new types of activities (e.g., writing, drawing, or other content creation and social activities) that can be incorporated into the system easily. We were also able to leverage the social feed paradigm to allow students to view and build off each other's educational output (like with our social-fill-in-the-blank activity). Our algorithm, which focused on linear progression of difficulty according to children's zone of proximal development and recency of sharing, was able to engage the students, while the inclusion of their peers and teachers in the interface caused excitement. There was a spike in motivation when peers' faces were foregrounded in the interface, but ultimately it did not necessarily hold users' attention because the content, instead of the recommendations, appeared to be more important for this age group. Our design goal of showing users' content in their ZPD was addressed with the variants of EduFeed that displayed activity thumbnails (AS and A variants), but future work needs to rigorously assess learning and the sustainability of their engagement.

Ranking Algorithms

It is important to note that the algorithm for combining system suggestions with peer recommendations (without modification) in a particular ratio was just one of many that we could have chosen to implement and study. We propose that in this context, we could explore presenting activities in a non-linear fashion, in a live view, and through a multitude of other ranking algorithms to utilize a more constructivist perspective [27]. We designed our feed horizontally with an emphasis on activity completion, as it shows a historical record of completed activities and sharing can only occur after completion. What would it mean to organize activities on the screen in a grid or completely randomly, or to make certain activities discoverable or searchable instead? What if the feed was designed to provide a live view of what activities other users were engaged in at that time, and sharing could happen regardless of completion? More synchronous immediacy could support children in co-located environments to see what their peers are doing "right now" vs. our current paradigm, which concentrates on what peers have already done.

Other researchers, like Bian et al. [5], have studied robust, effective ranking of social media content for adults. For preliterate children in this context with this type of system, there is more room to explore what robust, effective ranking may entail. How would it affect children if the activities were ranked according to weightings that took into account both their zone of proximal development *and* social factors? While we chose to allow shared activities to appear on receiver's feeds even if the activities were outside their ZPD, this might become frustrating for users when a system has more extensive and advanced activities. What would it mean for engagement and learning to manipulate or queue shared activities in receiver's feeds? What if there were no limits on the number of activities in a feed, but they were ordered according to a user's ZPD?

Furthermore, we attempted to emphasize "popularity" of activities by displaying small thumbnails of peers' faces under the activities they completed, which our participants did not grasp. A ranking algorithm could incorporate popularity as a relevant factor, but we could also consider other visual ways to surface popularity of activities to drive peer-motivation when users do not have mental models of social networking. In our system, we could have also explored not prioritizing recency and/or using our other algorithm implementations that promoted breadth of activity types in addition to depth in one area. The design and evaluation of feed ranking algorithms for educational social feeds is an area that warrants further research.

Along these same lines, researchers Eslami et al. [10, 11] and Hamilton et al. [14] have studied how adults in the United States understand—or actually *do not* understand— social feed algorithms and how these often misunderstood curated feeds impact users' experiences. If understanding invisible algorithmic processes is difficult for adults in a developed context, then teasing apart the understanding of young children in developing regions with less technical experience presents an interesting challenge and line of inquiry for the emerging area of social algorithmic understanding.

Physical Sharing vs. Digital Sharing

In our deployment, physical sharing was highly motivating since the physicality and immediacy of seeing friends complete activities appeared to be more accessible than the metaphor of digital sharing, which may have been too complex for the current stage of development and digital literacy of these children. Even though our software was not designed with co-located physical collaboration or sharing in mind, as it more readily aligned with a current adult feed paradigm, the tablet form factor and our deployment setting supported these types of physical engagements, which turned out to be exciting for our participants. When designing social feeds for this type of audience, our experience with EduFeed suggests it is important to design around the idea of shared screen/co-present interactions allowing for co-use of tablets, tablet swapping, and other physically collaborative behaviors, which is different from the current conception of typical and popular social networking feeds aimed at adults. Further, any digital sharing experiences in co-located space should also prioritize immediacy, such that the transfer of one shared activity to a receiver's feed can be experienced instantly for both children. Future work should investigate if and how these findings may transfer to other areas of the world and other age groups.

Still, there may be situations in which children might play with this type of system remotely and physical collaboration may not be possible. For example, Gelderblom [12] is currently using participatory design to design a social-media-based cross-age tutoring system for teenagers from privileged communities in South Africa to give online homework support to young children in disadvantaged communities. This type of remote context can provide a space to explore what it means to have social support for learning for children in underserved regions. If similar systems to EduFeed were deployed in this way, would digital sharing and collaboration lead to greater learning and engagement in these remote situations, or is this paradigm of digital collaboration too complex for this age group developmentally? Does it matter if children do not have mental models to grasp the loop of digital sharing and receiving, or is the incorporation of peers and teachers in some way sufficient for consistent engagement? How might we design an interface that may better communicate the concept of recommendations, including sharing and receiving those recommendations, through in-app features to exploit the benefits of cooperative play and learning in these remote contexts? These questions indicate interesting directions for future investigation.

Audio Output in Co-located Settings

We aimed to have our system be usable without requiring literacy by designing the feed and activities with an education expert and by incorporating graphical elements, touch input, and audio output into the interface, similar to other user interfaces for low-literate and illiterate adult communities [34]. EduFeed was successful in this way, as the children were able to access and use the system. But, due to the loud environment, we chose to turn off the audio components, which has implications for both learning and collaboration. Hearing and seeing English words is educationally beneficial, as multiple modalities are important for second language learning [32]. Yet, had we required children to wear headphones to play with EduFeed, their ability to collaborate and socialize in physical space would have been impeded. Our choice to prioritize physical collaboration led to a meaningful and engaging aspect of our system. It remains an open question which or if either of these experiences should be emphasized, or how future systems can be designed to support both audio and co-located collaboration.

Limitations & Future Work

This research prompts the question of whether the benefits of our system outweigh the infrastructural and equipment costs. This is an important question in ICTD research, particularly in education [25]. We take the position that this work is forward-looking; while such a system is unlikely to be used in classrooms *today*, device costs and infrastructure will continue to improve. We believe that tablet-based educational software will be common in environments such as the one we explored here, and that lessons learned in pilots such these will be helpful for the future.

Infrastructural challenges, like unreliable Wi-Fi and limited deployment support from adults, prevent us from making stronger claims, especially in regard to quantitative measures in our deployment. Due to scheduling constraints, we were not able to get children's subjective opinions about EduFeed as well. As such, we consider our work to be an intermediate short-term design case that situates the system in a context beyond what a laboratory study would but does not fully take into account the people and ecological systems in place over a longer period of time. A future long-term deployment is necessary to understand how students, teachers, and the context take to and change with the system over time. This exploration could include if children eventually comprehend what different interface elements represent or if the classroom becomes quieter after the initial excitement of using the system. This type of study would also allow for an analysis of students' learning and any transfer of pedagogical outcomes.

Additionally, our reflections may have relevance to other regions (developed or developing) with fewer or similar infrastructural challenges, including the United States. We hypothesize that the ways that children engaged with, through, and around the system relates to their developmental age and technical literacy; in this respect, the first grade students we studied in India may not be that different from children in wealthier regions. Future work must address how and why children in different contexts, who have more or less technology literacy, might engage with such a system in similar or different ways.

CONCLUSION

In this design case, we explored how a social feed-based tablet application can help preliterate children in developing regions practice their numeracy and English literacy skills in self-directed and socially supported ways. We designed, implemented, and deployed EduFeed as a technology probe to understand how such a system might engage students and promote collaboration. This process prompted us to re-envision this design space and ask new questions about what sharing educational activities means for this population.

By critiquing our own design decisions and discussing the use of EduFeed in a real-world context, we reflected on the ability of the system to facilitate children's self-direction, motivate users by including their peers and teachers in the interface, and mediate social support in physical space. We identified the potential of collaborative learning with social feed-based educational software to engage users, due to participants' desire to share and collaborate in real time and their initial responsiveness to activities suggested by their peers. We also found that the traditional paradigm of social media sharing, which hinges on adults' complex understanding of the passage of time and is optimized for geographically distributed networks of individuals, is one that needs to be tailored and scaffolded to fit the needs of our target population, who were physically co-located. Lastly, we propose future work to develop educational social feed paradigms that are grounded in a taxonomy of ranking algorithms, physical sociality and collocation, immediacy, and features that can bridge physical and digital collaborative experiences.

In this research, we provide two contributions to the CSCW community: EduFeed, a social feed-based application for preliterate children to explore educational activities; and insights and new research questions stemming from our probe deployment of EduFeed.

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REFERENCES

1. Carlos Alario-Hoyos, Mar Pérez-Sanagustín, Carlos Delgado-Kloos, and Mario Munoz-Organero. 2014. Delving into participants' profiles and use of social tools in MOOCs. *IEEE Transactions on Learning Technologies*. 7, 3 (July 2014) 260-266. http://dx.doi.org/10.1109/tlt.2014.2311807
2. Saleema Amershi, Meredith Ringel Morris, Neema Moraveji, Ravin Balakrishnan, and Kentaro Toyama. 2010. Multiple mouse text entry for single-display groupware. In *Proceedings of the 2010 ACM conference on Computer Supported Cooperative Work* (CSCW'10). ACM, New York, NY, USA, 169-178. http://dx.doi.org/10.1145/1718918.1718950
3. Jean Avery. 2009. *Mathematics manipulative board*. U.S. Patent 7,549,865.
4. Selami Aydin. 2012. A review of research on Facebook as an educational environment. *Educational Technology Research and Development*. 60, 6 (December 2012) 1093-1106. http://dx.doi.org/10.1007/s11423-012-9260-7
5. Jiang Bian, Yandong Liu, Eugene Agichtein, and Hongyuan Zha. 2008. A few bad votes too many?: towards robust ranking in social media. In *Proceedings of the 4th International Workshop on Adversarial Information Retrieval on the Web*, 53-60. http://dx.doi.org/10.1145/1451983.1451997
6. Benjamin S. Bloom. 1971. Mastery learning. In J. H. Block (Ed.), *Mastery Learning: Theory and Practice*, 47-63.
7. Edmund Coleman. 2002. *Phonemically organized keyboard attached to a speech synthesizer: a machine for teaching the sounds of the letters to young children*. U.S. Patent Application 10/212,158.
8. COPPA - Children's Online Privacy Protection Act. 2013. Retrieved May 19, 2016 from www.coppa.org.
9. Mark A. Donabella and Audrey C. Rule. 2008. Four Seventh Grade Students Who Qualify for Academic Intervention Services in Mathematics Learning Multi-Digit Multiplication with the Montessori Checkerboard. *TEACHING Exceptional Children Plus*. 4, 3 (January 2008).
10. Motahhare Eslami, Karrie Karahalios, Christian Sandvig, Kristen Vaccaro, Aimee Rickman, Kevin Hamilton, and Alex Kirlik. 2016. First I "like" it, then I hide it: Folk Theories of Social Feeds. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI '16). ACM, New York, NY, USA, 2371-2382. http://dx.doi.org/10.1145/2858036.2858494
11. Motahhare Eslami, Aimee Rickman, Kristen Vaccaro, Amirhossein Aleyasen, Andy Vuong, Karrie Karahalios, Kevin Hamilton, and Christian Sandvig. 2015. "I always assumed that I wasn't really that close to [her]": Reasoning about Invisible Algorithms in News Feeds. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI '15). ACM, New York, NY, USA, 153-162. http://dx.doi.org/10.1145/2702123.2702556
12. Helene Gelderblom. 2014. Giving children voice in the design of technology for education in the developing world. *South African Computer Journal*. 54, (October 2014) 34-42. http://dx.doi.org/10.18489/sacj.v54i0.242
13. Robert Godwin-Jones. 2005. Emerging technologies: Messaging, gaming, peer-to-peer sharing: Language learning strategies & tools for the millennial generation. *Language learning & technology*. 9, 1 (January 2005) 17-22.
14. Kevin Hamilton, Karrie Karahalios, Christian Sandvig, and Motahhare Eslami. 2014. A path to understanding the effects of algorithm awareness. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '14). ACM, New York, NY, USA, 631-642. http://dx.doi.org/10.1145/2559206.2578883
15. Caroline Haythornthwaite. 1999. Collaborative work networks among distributed learners. In *Proceedings of the 32nd Annual Hawaii International Conference on System Sciences*. IEEE, 1-16. http://dx.doi.org/10.1109/HICSS.1999.772707
16. Hilary Hutchinson, Wendy Mackay, Bo Westerlund, Benjamin B. Bederson, Allison Druin, Catherine Plaisant, Michel Beaudouin-Lafon, Stéphane Conversy, Helen Evans, Heiko Hansen, Nicolas Roussel, and Björn Eiderbäck. 2003. Technology probes: Inspiring design for and with families. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '03). ACM, New York, NY, USA, 17-24. http://dx.doi.org/10.1145/642611.642616

17. Mohit Jain, Jeremy Birnholtz, Edward Cutrell, and Ravin Balakrishnan. 2011. Exploring display techniques for mobile collaborative learning in developing regions. In *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services* (MobileHCI '11). ACM, New York, NY, USA, 81-90. http://dx.doi.org/10.1145/2037373.2037388
18. Matthew Kam, Anuj Kumar, Shirley Jain, Akhil Mathur, and John Canny. 2009. Improving literacy in rural India: Cellphone games in an after-school program. In *Information and Communication Technologies and Development (ICTD)*, 139-149. http://dx.doi.org/10.1109/ICTD.2009.5426712
19. Anna Kasunic, Jessica Hammer, Robert Kraut, Michael Massimi, and Amy Ogan. 2016. A Preliminary Look at MOOC-associated Facebook Groups: Prevalence, Geographic Representation, and Homophily. In *Proceedings of the Third (2016) ACM Conference on Learning @ Scale* (L@S '16). ACM, New York, NY, USA, 205-208. http://dx.doi.org/10.1145/2876034.2893415
20. Geza Kovacs. 2015. FeedLearn: Using Facebook Feeds for Microlearning. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA '15), 1451-1466.
21. Kenneth L. Kraemer, Jason Dedrick, and Prakul Sharma. 2009. One laptop per child: vision vs. reality. *Communications of the ACM.* 52, 6 (June 2009), 66-73. http://dx.doi.org/10.1007/s00779-014-0773-4
22. Zeina Atrash Leong and Michael S. Horn. 2010. The BEAM: a digitally enhanced balance beam for mathematics education. In *Proceedings of the 9th International Conference on Interaction Design and Children* (IDC '10). ACM, New York, NY, USA, 290-292. http://dx.doi.org/10.1145/1810543.1810594
23. Sugata Mitra, Ritu Dangwal, Shiffon Chatterjee, Swati Jha, Ravinder S. Bisht, and Preeti Kapur. 2005. Acquisition of computing literacy on shared public computers: Children and the "hole in the wall." *Australasian Journal of Educational Technology.* 21, 3 (January 2005), 407-423.
24. Maria Montessori. 1917. *The Montessori elementary material, tr. by A. Livingston*. Vol. 2. Frederick A. Stokes Company.
25. Rabin Patra, Joyojeet Pal, Sergiu Nedevschi, Madelaine Plauche, and Udai Pawar. 2007. Usage models of classroom computing in developing regions. In *International Conference on Information and Communication Technologies and Development,* 1-10. http://dx.doi.org/10.1109/ICTD.2007.4937401
26. Udai Singh Pawar, Joyojeet Pal, Rahul Gupta, and Kentaro Toyama. 2007. Multiple mice for retention tasks in disadvantaged schools. In *Proceedings of the SIGCHI Conference on Human factors in Computing Systems* (CHI'07). ACM, New York, NY, USA, 1581-1590. http://dx.doi.org/10.1145/1240624.1240864
27. Jean Piaget and Barbel Inhelder. 1972. *The psychology of the child*. New York: Basic Books.
28. Cynthia A. Rohrbeck, Marika D. Ginsburg-Block, John W. Fantuzzo, and Traci R. Miller. 2003. Peer-assisted learning interventions with elementary school students: A meta-analytic review. *Journal of Educational Psychology.* 95, 2 (June 2003), 240-257. http://dx.doi.org/10.1037/0022-0663.95.2.240
29. Richard M. Ryan and Edward L Deci. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist.* 55, 1 (January 2000), 68-78. http://dx.doi.org/10.1037/0003-066X.55.1.68
30. Deborah C. Simmons, Edward J. Kame'enui, Mike Stoolmiller, Mike Coyne, and Beth Harn. 2003. Accelerating growth and maintaining proficiency: A two-year intervention study of kindergarten and first-grade children at risk for reading difficulties. *Preventing and remediating reading difficulties: Bringing science to scale,* 197-228.
31. Ellen A. Skinner and Michael J. Belmont. 1993. Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology.* 85, 4 (December 1993), 571-581. http://dx.doi.org/10.1037/0022-0663.85.4.571
32. Pippa Stein. 2000. Rethinking resources in the ESL classroom: Rethinking resources: Multimodal pedagogies in the ESL classroom. *TESOL Quarterly*. 34, 2 (June 2000), 333-336. http://dx.doi.org/10.2307/3587958
33. Deborah J. Stipek. 1996. Motivation and instruction. In David C. Berliner and Robert C. Calfee (Eds.), *Handbook of Educational Psychology*, 85-113. New York: Simon & Schuster Macmillan.
34. Indrani Medhi Thies. 2015. User Interface Design for Low-literate and Novice Users: Past, Present and Future. *Found. Trends Hum.-Comput. Interact*. 8, 1 (March 2015), 1-72. http://dx.doi.org/10.1561/1100000047
35. Lev S. Vygotsky. 1980. *Mind in society: The development of higher psychological processes.* Harvard University Press.
36. Kathryn R. Wentzel. 1999. Social-motivational processes and interpersonal relationships: Implications for understanding motivation at school. *Journal of*

Educational Psychology. 91, 1 (March 1999), 76-97. http://dx.doi.org/10.1037/0022-0663.91.1.76

37. XPRIZE Foundation. Global Learning XPRIZE Overview. 2016. Retrieved July 7, 2015 from http://learning.xprize.org/about/overview
38. Gustavo Zurita and Miguel Nussbaum. 2004. Computer supported collaborative learning using wirelessly interconnected handheld computers. *Computers & Education*. 42, 3 (April 2004), 289-314. http://dx.doi.org/10.1016/j.compedu.2003.08.005
39. Gustavo Zurita, Miguel Nussbaum, and Mike Shaples. 2003. Encouraging face-to-face collaborative learning through the use of handheld computers in the classroom. In *Human-computer interaction with mobile devices and services*, 193-208. Springer Berlin Heidelberg. http://dx.doi.org/10.1007/978-3-540-45233-1_15