Classroom-Based Assistive Technology: Collective Use of Interactive Visual Schedules by Students with Autism

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ABSTRACT
vSked is an interactive and collaborative assistive technology for students with autism, combining visual schedules, choice boards, and a token-based reward system into an integrated classroom system. In this paper, we present the results of a study of three deployments of vSked over the course of a year in two autism classrooms. The results of our study demonstrate that vSked can promote student independence, reduce the quantity of educator-initiated prompts, encourage consistency and predictability, reduce the time required to transition from one activity to another. The findings from this study reveal practices surrounding the use of assistive technologies in classrooms and highlight important considerations for both the design and the evaluation of assistive technologies in the future, especially those destined for classroom use.

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Assistive technology, autism, visual schedules

ACM Classification Keywords
K.3 Computers and Education; K.3.1 Computers Use in Education; K.4.2 Social Issues

INTRODUCTION AND MOTIVATION
Autism is characterized by impairment in communication, social interaction, emotional expression, and emotional recognition [3]. Visual supports can ease these challenges by augmenting communication with visual cues. Children with autism and school-based teaching staff (*e.g.*, teachers, teachers assistants, speech and language pathologists) use visual supports to complete tasks, manage daily routines, and engage in social interactions [12]. To capitalize on the benefits of current paper-based visual supports, teachers design and customize visual communication materials. However, after investing substantial time and money, these kits can still easily be lost or damaged.

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To address some of these challenges, Hirano *et al.* developed an interactive and collaborative assistive technology for visual schedules called vSked [11]. vSked is comprised of individual devices for each student coordinated by the teacher through a large touch screen monitor at the front of the classroom. For students, this system combines three paper-based visual support practices often used in school: visual schedules, choice boards, and a rewards system.

The design of vSked stands in contrast to many of the assistive technology devices currently used in classrooms in that it focuses on the classroom as the unit of intervention. Previous work on assistive technology has largely focused on meeting an individual learner's specific cognitive and motor needs. Research findings from professional programs [30] and literature for teacher preparation [8] suggest that teachers choose appropriate assistive technologies for children with autism based on "careful assessment and individualization" [20] for each student. Teachers are instructed to make decisions for "specific learners, in specific contexts, to meet specific needs" [20 as cited in 30]. However, meeting the needs of individual students runs the risk of overlooking the interplay of students, technologies, and staff that can impact adoption and use in a classroom setting. Design recommendations that place classrooms and groups of students at the forefront are not as prevalent, and therefore are the focus in this work.

By combining practices and offering new affordances for the classroom, use of vSked encourages emergent group practices for students with autism. Past work on vSked addresses the use of paper-based visual support systems and the resultant vSked system requirements as well as a preliminary feasibility study of the system in use [10,11]. In the work presented here, we focus on the practices that emerged with the use of vSked within the classroom, specifically concerning student independence and prompting, consistency and predictability of events, and community building activities. We focus on the classroom-level practices as well as the experience of students using the system.

BACKGROUND AND RELATED WORK

Extensive work has been done in assistive technologies, technologies for autism, and educational technologies. In this section, we first provide some background information on visual supports in classrooms and then outline those research projects in autism and educational technologies most relevant to our work.

Visual supports in classrooms

Visual supports can be therapeutically effective for children with autism. These techniques may present "clear advantages with regard to ease of use and intelligibility for communication patterns" [20]. In one survey, 51% of classrooms reported using visual supports "most of the time," and 29% of classrooms "some of the time" [29].
Visual supports typically include the exchange or display of a variety of images, drawings or photographs on laminated cards to represent tasks, needs, goals and rewards (Fig 1). These visual supports are a type of aided, augmented communication common to special education classrooms used to provide support for learning and socialization [29].

There are many ways to use visual-graphic cards to assist children with autism, and often one large set of cards is used across a number of practices. Here we describe three common classroom tools in more detail: 1) visual schedules, 2) choice boards, and 3) token-based rewards.

Visual schedules display "planned activities in symbols (words, pictures, photographs, icons, and actual objects) that are understood in the order in which they will occur" [13]. Schedules act as reminders of the day's events, preparing students for activities and transitions and providing students with structure to reduce anxiety and support better self-organization (Fig 2). Schedules can represent an "in task" sequence, in which each step of a procedure is displayed, or, a "between task" sequence, in which the cards represent the day's activities [21]. In classrooms, "between task" visual schedules act as reminders of the day's events, preparing students for daily activities and transitions between activities. *Choice boards* or *communication boards* allow students with verbal language deficits to participate in multiple choice assessments, voice personal preferences, carry out functional communication, and participate in classroom activities [20]. In *token-based reward systems*, students earn tokens for desired classroom behavior, such as staying on task and completing activities [19]. Once a set number of tokens are earned, the reward, often tangible, is delivered and the tokens are removed, resetting the count.

Fig 1. Teachers often provide every student a copy of each card and supplement replacement cards for those that are lost and worn. Libraries can become extensive and cumbersome to manage.

Fig 2: (clockwise from top left) A paper-based choice board, visual schedule, and token board used in the classrooms before the introduction of vSked.

Assistive technologies for autism

Assistive technologies for special education classrooms include tools for augmenting student communication [22], game learning [24], or development of social skills [6, 22]. Most relevant to our work are technologies for visual schedules.

Computer-based interactive displays have been used to ease the management of visual schedules. Some of these solutions involve the use of multimedia tools for increasing the interactivity of visual schedules [14, 15], and different input devices for ease of use [4]. The evaluation of these works has provided insight regarding issues related to the acceptance and use of the system (*e.g.*, the physical placement of the displays). Our work differs from this literature by focusing on how classroom practices change due to the extended use of a system.

Evaluation of other classroom-based technologies

Additionally, there are studies of technology use in neurotypical classrooms that consider the entire classroom for analysis. Neurotypical is a term used by the autism community to denote students who have average cognitive functioning and no autism diagnosis. A review of the literature on these systems and their evaluation is out of the scope of this paper, but here we describe some research that is most relevant to our work.

ClassroomPresenter allows students to interact with instructor materials through individual Tablet PCs. Likewise, Classroom2000 (now known as eClass) [1], and the associated StuPad system [31] allow for integration of student note-taking devices with instructor PowerPoint™ slides. Evaluations of these systems and other similar systems have largely centered on university students, often in computer science or engineering classes [2, 5]. The work we present here differs from these projects in several ways. First, vSked enables true synchronous communication rather than allowing integrated content to be stored in an archive. Second, the primary role of vSked is as an assistive technology for students with significant impairments. In this paper, we demonstrate how considering the classroom experience of assistive technology can lead to greater insight about the use of technology in special education.

THE VSKED SYSTEM

vSked is an interactive and collaborative assistive technology that replicates the functionality of visual schedules, choice boards, and token-based rewards in an integrated system. vSked collectively presents and controls student schedules and activities on a touch screen display at the front of the classroom. vSked was designed with group classroom activities in mind, reflecting the need not only to augment each individual student's communication capabilities but also to enable synchronized group interaction and shared experiences.

The vSked system is comprised of an ultramobile PC (UMPC), a touch screen handheld device, for each child wirelessly connected to a large, central display (Fig 3). Software links the student handhelds with the information on the large monitor, creating a collaborative assistive technology for the entire classroom. The touch screen acts as a master timetable showing the daily schedule for each student. A picture and nametag for the student appears at the top of each schedule. Each UMPC has personalized features: the name and photo of the student, tokens earned, a reward, and the choice board (Fig 4). The teacher starts an activity by using the large touch screen, pressing on the picture of an activity. At the same time, a series of corresponding prompts are sent to the students' devices, appearing in the choice board area.

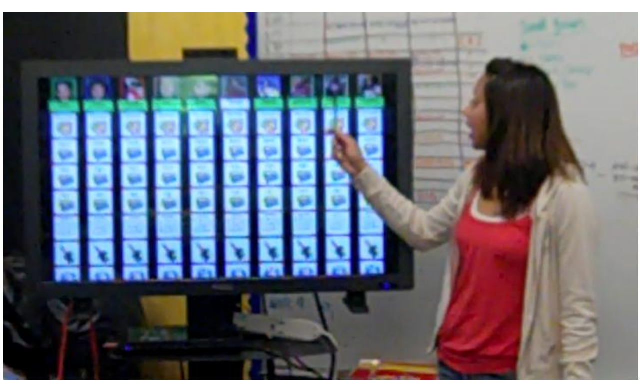

Fig 3: The teacher manages the schedule for the entire class through a large interactive touch screen.

Fig 4: On the UMPC, the student views her choices (left side), self portrait, stars (not shown) and reward (bottom right).

The system allows for three kinds of interaction: multiple choice questions, voting, and alerts. Activities with correct answers (*e.g.*, What day is it?) provide feedback for an incorrect choice in two ways: flagging the correct option and removing incorrect ones. For activities in which there is no correct answer (*e.g.*, "Do you want milk or water?") votes allow students to select choices based on personal preferences. A graph of students' responses can be shown on the large monitor. Alerts are used during transitions between activities. On the individual devices, each student presses the picture of the activity to confirm the start of the activity. All interactions in vSked are tracked, and teachers can generate progress reports.

METHODS

The results presented in this paper include analysis of observations, interviews and logs of system use for three deployments of vSked. The students were observed for two weeks before deployment of the system in both Spring 2010 and Summer 2010. They were then observed for one week during Spring 2010 and three weeks during Summer 2010. Previously, students were observed for three weeks of system use during the Summer of 2009 [11].

Observations conducted before and during each deployment totaled 202 hours (Table 1). During Summer 2009 and Spring 2010, observations were open-ended, and data analysis was primarily inductive. Building on these results, during Summer 2010, in addition to open-ended observations, we video-recorded one teacher, two aides and nine students for fifteen minutes, three days a week. We scored these videos for the following:

- Transition time between activities
- Levels of consistency and predictability in the schedule
- Levels of interactivity and coordination among staff
- Student anxiety
- Use of vSked as a visual schedule, choice board, or token system
- Teacher awareness of rewards and on-task behavior

Teachers and aides participated in weekly short interviews, and a 90 minute group interview at the end of each deployment. The weekly interviews were individual and semi-structured, and participants were asked to discuss how the classroom's use of the system went during that particular week. They were encouraged to tell stories and discuss what they found interesting, surprising, or different that week. On average, interviews lasted approximately 30 minutes and were recorded and transcribed.

vSked was essentially the same in all deployments. However, slight changes in the administration interface were made between the first and second studies. During the three deployments vSked was used in 2 classrooms, among 16 students (4girls), 2 teachers, and 8 aides.

Participants

Special education teachers coordinate the classroom and develop Individualized Education Plans (IEP), which lay out the goals for each student in special education. They coordinate the work of teacher assistants and others involved in the child's well-being, including parents, social workers, school administrators, and therapists. Across the three deployments, two teachers were enrolled in this study. Each teacher received one hour of training focused on schedule creation and management and spent additional time exploring the systems on their own.

The *teacher assistants (aides)* help classroom teachers to complete instructional and administrative tasks. Additional classroom duties include preparing materials for lessons, tutoring and assisting students one-on-one, and managing behavior. Across the three deployments, eight aides from two classrooms were enrolled in this study.

All 16 students in this study were between the ages of six and ten and diagnosed with moderate to severe autism. They demonstrated little to no verbal communication skills.

Analysis

All field notes, interview transcripts, images, and videos were inspected together using a mixed-methods approach. Researchers first analyzed the data for evidence that vSked supported the needs of teachers and students in relation to the literature on visual supports. Researchers used open coding and multi-phased affinity analysis to uncover emergent themes from the interview data, in particular in relation to the collective uses of the system. The entire team then discussed these themes in detail. During the course of the first deployment, classroom staff reported that the amount of work they were doing to manage transitions, prompt students, and so on was reduced with use of vSked. Thus, in the 2010 deployments, we conducted a preliminary quantitative analysis of these issues by collecting descriptive statistics as reported in the results section. We used an ANOVA and a Tukey post-hoc test to compare the captured behaviors with and without using vSked. The data presented a normal distribution.

RESULTS

Although the focus of this analysis is the group experience of classroom-based assistive technologies, there is no group without a collection of individuals. Thus, we also describe the ways in which themes uncovered in our evaluations reveal tensions in the classroom that require designers to balance the needs of the classroom as a whole with those of each individual student.

	Summer 2009	Spring 2010	Summer 2010	Total
Hours of observation	97	21	84	202

Table 1. Hours of observations

Independence, prompting, and reinforcement

In addition to the traditional call-and-response or question-and-answer models employed in classrooms, educators of children with autism often make use of explicit scaled prompting systems. For example, when a teacher prompts a student to make a choice, they may use hand-over-hand (a physical prompt) to point to the choice or say aloud the choice (a verbal prompt), depending on the student's needs. Teachers and aides offer various levels of prompting to encourage students to provide responses, adjust behaviors, and so on. In autism classrooms, these prompts can remind students to focus on and complete a task. At the same time, however, prompting can disrupt the group classroom experience. Thus, a goal of educators is often to reduce prompting both to increase individual student independence and to decrease classroom distractions.

Student goals focused on "independence" are measured in school assessments according to the quantity and quality of the human-initiated prompts required to help a student complete an activity. In observations, many of the students, given a sequence of choice-making activities using vSked, would progress through the activities without prompts from the teaching staff. For example, the instructors noted that during the first few days of use, students answered questions in the calendar activity (*e.g.,* What is day is it?) faster and with less prompting than without vSked.

> *A1[1]: …they are wanting to work... they are wanting to look at it….they are wanting to make the choices… they want to hurry and get to the next one because they want see what happens next … so I think that's huge because they want to work…*

The previously reluctant students were also noted as being more interested in participating.

> *A1: Nathan, I was really surprised by him. He was looking. You could see him… paying attention, to this part… [Without vSked] he would never pick candy. He wouldn't even pick! He had no interest whatsoever in the reinforcer….Where the other kids would be like, "Whoa! This is mine, this is what I am gonna get"… There was nothing motivating for him. This time [using vSked] he was motivated.*

[1] For ease of reading, teachers are represented by T, aides as A and then a number, and students with pseudonymns.

In our quantitative assessment, prompting by instructors when students use vSked (mean=5.18, SD=3.32) was 54% lower than without (mean=10.38, SD= 5.97; F=8.79, p=0.005). Classroom staff attributed the fewer prompts to the usability of the system itself (*e.g.,* students knew to press the screen) and to student comprehension (*e.g.,* students knew to select an answer). Specifically, teachers described some students as going "*straight to the answer.*"

> *T1: ... it was really amazing to see that Sharon correctly answered the [calendar questions] when using vSked ... that never happened before… and it makes me think "Oh! I didn't even know that she was able to do that."*

vSked provides some automatic prompting if a student selects an incorrect answer in a choice-making activity. On the first mistake, the correct image shakes to encourage its selection. On the second mistake, a random incorrect answer disappears. The teaching staff reported that the students responded to the shaking prompts if they were unsuccessful in their first attempt.

> *A1: If they choose the wrong one, they kind of look at [the correct answer] really fast and they'll see it shaking, and then they'll pick it.*

This kind of scaffolding is considered a highly desirable and positive outcome of using the system.

> *A1:… all the cues are there.. They are going to pick it up themselves instead of us having to say, you know, "check this, check that .. you know, try again" [….]so, they are just kind of looking at it themselves, and they're focusing more …*

Despite a general push for independence, and thus less prompting, classroom staff described being comfortable with students continuing to receive prompting from vSked. They described vSked as analogous to the digital calendars used by many adults. We were curious, however, about the relationship between overall prompting from instructors and vSked (mean=6.06, SD=5.178) as opposed to overall prompting when vSked was not available (mean=10.38, SD=5.87; F=3.681, p=0.063). We did not find significant differences. However, this result warrants further investigation with a larger controlled sample.

In addition to prompting when students chose wrong answers, vSked also provided reinforcement for correct answers and task completion. First, the right side of the screen displayed images of the tangible rewards toward which the students were working, and images of themselves, which they viewed while completing activities (see Fig. 4). Viewing these images in close proximity to their work activities could be motivating for many students.

> *A1: ... they're paying attention to it ... even if they like kind of look away… they still kind of like glancing back at it like "wow [my reward] is still here."*

Second, students received an animated fireworks graphic after every correctly answered question and every time they earned enough tokens to receive rewards. The fireworks excited and intrigued the students. The fireworks provided students with an immediate reward for progressing through an activity. Feedback mechanisms, like the fireworks and the touch screen interactions, often drew the students to the device in ways that the paper-based tools could not.

> *A2: …when Adele got her fireworks… her reinforcer page came up and she automatically already pushed what she wanted… I was like "hey that's pretty good" ... like she saw the fireworks and she was like… she kind of got the concept like "Okay I need to push something."*

Perhaps even more interesting when considering the role of classroom-level assistive technologies, students also reacted to the fireworks display on other students' devices. This kind of attention to other students in the room was surprising for the teaching staff considering the social challenges of autism. We describe this kind of sociality in depth in a later section.

Teachers and aides typically "fade out" prompts, using them less as a student progresses. Thus, the design of technological scaffolding and reinforcement can hold many implications for a student's progress, especially given the notion that prompts need to fade out over time, which was not a functionality of vSked. Our observations indicate that successful adoption of vSked rested in many ways on the interplay of classroom notions of, and tensions between, dependence and independence, and the ability of technology to respond to such tensions.

Consistency and predictability

Building and sustaining a routine is an integral component of well-managed autism classrooms. Teachers are often encouraged to establish clear classroom practices and reduce clutter and distraction [7, 26, 27] with the promise of reductions in severe problem behavior [23, 28]. However, classrooms are dynamic and ever-changing places, and the teaching staff who work in them are inherently human, which is to say somewhat inconsistent [9], and current tools sometimes attempt to be so general as to be flawed.

In practice, vSked allowed for more accuracy in the representations of activities and objects within visual supports. Whereas paper-based tools tend to use generic, often cartoonish imagery to make repurposing easier, vSked users tended to provide a mix of these general sketches and photographic images of actual activities or items (*e.g.,* Swedish Fish and "candy" in Fig. 4). Exact images help students to predict upcoming events and reduce the uncertainty associated with unexpected events. During interviews, teachers suggested that they appreciated the ability to add photorealistic images so that students could better anticipate activities.

As a common classroom practice, students check their schedules at certain times throughout the day to prepare for the next activity and practice sequential processes. Before vSked, teachers set up the schedule every morning. Throughout the day students removed a finished activity from the schedule one at a time. Teaching staff reported that manually removing activities off of the paper-based schedule was an inconsistent practice, often resulting in inaccurate schedule displays. With vSked, the large touch screen updated the students' schedules collectively.

> *T1: They can see the whole day right there in front of them and know that they are ok. Also, with the old fashioned schedules that we had…sometimes I would have to flip them over, for half the day, you know… The first half of the day, because they did so much, was on one side. Then after lunch, ok, let's turn it around to see what we are doing the rest of the day. So I would have kids that would have fits. They wouldn't know what is coming. So I think [vSked] helps them see what they have to do.*

When the teacher starts an activity, the students first view this change together on the large screen and then touch a corresponding icon on their handheld devices. When moving on to the next activity, schedules were automatically updated to show the remaining activities for the day. With vSked, the students also could not alter their own schedules, reducing the classroom management challenges experienced from such changes.

> *A3: Before [vSked] each child had their own schedule and you had to find all their [visual cards] and put them of there … because if they want, they will take off all the morning cards to have more time for recess or lunch … Now they can't do that, that is a good part … they can't cheat.*
> *A4: And sometimes you don't know when they moved their schedule and you can actually see that everybody is [in the same task.]*

The teaching staff also reported that this helped the students focus and reduced distractions when transitioning between tasks. Delays in transition times can dramatically impact the classroom as a whole, even if they are not particularly problematic for an individual student. For example, the delay of one student might disrupt another student who is ready for the next task to begin. Classroom staff described faster and easier transitions between activities when using vSked. In our quantitative analysis, transition time from one activity to another was reduced by 61% with vSked (mean=60.62sec, SD=39.31) than without (mean=158sec, SD= 112.52; $F=4.762$, $p=.045$).

Finally, our results indicate that vSked may have allowed the students to receive their tokens and rewards in a more consistent manner than with the paper-based system. The paper-based system consisted of a token board at each student's desk on which teaching staff placed tokens when students completed work or demonstrated desired behavior. These paper systems require substantial human effort to maintain them. Teachers and aides were often inconsistent in their delivery of rewards and reinforcement to students both among different students and over time. In classrooms in which multiple students and multiple instructors are interacting together, individual students can sometimes be overlooked. At the same time, some students may be given double rewards from more than one instructor. Furthermore, the time it takes to recognize and reinforce behavior, particularly across multiple students, prevents tokens from always being closely linked to the behavior being reinforced, which can limit their effectiveness.

With vSked, the teacher administered the reward stars from the large touch screen. Stars then appeared on a student's device. Teaching staff reported they were less likely to make mistakes, because the token count for all the students was displayed on the large monitor

> *T1: in the past I had to walk to everybody's individual desk […] the desks were spaced out.. I forget certain kids half the time you know… and so this is nice that I can be like "OK we just had this work session, I do remember you guys being good… oh I remember you had a hard time so you're not getting a token."*

Rather than having to wait for a member of the classroom staff to recognize that enough tokens had been earned for the student to receive a reward, a fireworks simulation appeared on the large monitor and on the individual's handheld device. This feature ensured automatic notification to both the student and the classroom staff, thereby making the reinforcement both more immediate and more consistent.

When a student earned a reward triggering the fireworks display on the large screen, other students often cheered. n our observations, we noted students wanting to work faster to earn their own rewards after seeing a peer do so. This emergent behavior among the students was both promising and surprising given the level of social disability exhibited by the participants. This kind of social support is extremely rare in autism classrooms. The classroom staff reported that they would consider how communication of rewards might encourage even greater interaction among students in the future.

vSked provided new features and functionality for the teaching staff in the form of automation of some work, and for the students in the form of photorealistic images and instant, visible feedback. The central visual display helped the teachers keep to the schedule with up-to-date information without much effort. The flexibility to provide realism in visual representations along with automation are key areas in the design of assistive technologies that may contribute to improved student response to the structure and transition of daily events.

Community and Interactivity

Building social skills and seeing themselves as part of a community of learners are important goals for any student, but especially for students with autism. Researchers have examined approaches to support both peer interactions and student-teacher interactions in autism classrooms [25]. In particular, Krantz and McClannahan used printed cues in visual schedules to support students initiating social contact with peers [16, 17].

vSked takes these kinds of interventions a step further by mimicking the typical call-and-response experience of regular education classrooms and providing a central display to support communication and interaction. In this way, both individual behaviors and classroom-wide activities become more visible, making both students and teaching staff more accountable to each other through these cues. For example, using traditional tools, a caregiver would need to visit each student's desk to observe if a task was completed. While progress across activities throughout the day is not displayed on vSked, the large screen at the front of the room showed each student's progress within an activity. As a student completed tasks on the digital choice-boards, the green progress bars displayed how close a student was to finishing an activity (Fig. 5). The progress bar indicated to the teaching staff which students engaged in and successfully completed the tasks.

> *T1: …I'm checking like when their names turn green that they've completed the task, and it seems like they're completing tasks quicker.*

vSked provides greater visibility into not only what activities are upcoming but also how the current activities are progressing. Thus, the teaching staff was able to assign tokens the moment students finished their activities, and to identify students who might need assistance. In our observations, teachers often encouraged students who had yet to finish a task by commenting aloud about another student's progress to the rest of the class. For example, A6 commented in the middle of instruction: *"Wow! Look how fast Tommy finished! Let's give him two tokens!"*

The teaching staff also used the large screen for remediation when a child was having a difficult day.

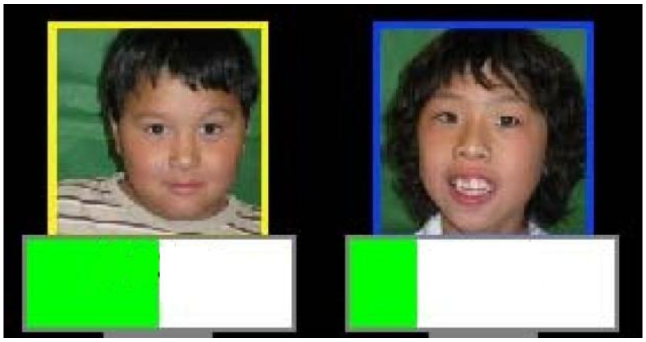

Fig 5. The green bar represents how far a student has progressed in an activity.

> *A1: ... taking the children up there, I'm always using it…Jeffery, today, he was kind of having a little meltdown and I took him up there and I showed him his little stars, and I'm like ... 'Look! Look how many you have. Do you want to lose them?' You know, he's [says], 'Noo noo noo'.*

In addition to the inherent visibility of the items on the large monitor, we observed students actively sharing items on their handheld display with teaching staff. Additionally, students showed interest in other student's devices.

> *A2: When the kids are using it, they are checking to see what their friends are doing.*
> *A1: They are kinda looking to see who is choosing what; they want to know what the other person is doing.*
> *A5:I think they also want to know what reinforcers they have. [The other students] have something they might want.*

Over the course of our deployments, the large screen became a focal point for the classroom. The size of the screen and colorful, bright images drew the students' interest. Additionally, the large screen allowed the students to have a shared experience with one another. Specifically, they were encouraged by and encouraging to one another because of the token system.

> *A1: When we say "Ohh right, look, so and so is getting a star." The other ones is kind of like "Ohhh"… looking out like I'm going to get a star too … and it's not just one piece of paper in front them … it's this huge… TV and the colors and everything it just really like makes them like "WOW" …[sic]*

Previously, the practice of checking schedules was a collection of asynchronous, singular tasks. With vSked, this now became an activity the class could do together. In our observations, checking vSked involved students each returning to their own desks and then transitioning to the next activity as a class. In the interviews, the teaching staff noted the importance of this procedure that took place often in conjunction with recess, bathroom time, and lunch.

> *T1: I think it's nice that the kids can come to their desks… which is like a natural transition for kids that are in typical classrooms you know… like everybody meets at their desk and then the teacher tells them what to do… [We] kind of reunite and then it's like "ok so we just finished this and you know, get all your reinforcers… get some tokens for the people that did really good during that work session.*

These community-building and sharing practices notably arose in an environment that is by nature highly individualized. Furthermore, assistive technologies tend to be programmed and deployed with only the needs of an individual student in mind. Each student in the classroom has an Individual Education Plan (IEP) and works toward unique goals at his or her own pace. Aides lower the student-staff ratio, ensuring personalized instruction for each student. The emphasis on individual goals and instruction facilitates the unique needs of children with autism. As such, group activities in autism classrooms are often not prioritized. However, this lack of emphasis does not mean that group activities and socialization are not also important goals. On the contrary, despite heavily individualized instruction, even prior to vSked, teaching staff would facilitate activities for the group to do together when possible and appropriate. The teaching staff found value in the experience of looking and feeling like a "regular classroom." Instantiating group transitions or work time provided students with the opportunity to practice some of the behaviors expected of their neurotypical peers, as well as chances for socialization. The teaching staff described repeatedly using vSked to enhance these kinds of group activities and noting how much easier the activities were with the system.

In one poignant example, a completely new practice emerged around administering a student's final token before receiving a reward. During class time, as students earned tokens for good work or behavior, the teaching staff tracked the progress of every student with a glance at the large monitor. When doling out the tokens, the teacher made a mental note of students only one star away from the reward. Before a student's final token, the teacher led the student to the front of the class, and made an announcement. Administering the final token initiated the fireworks simulation on the large screen. The teaching staff would then lead the class in collective cheering. The event concluded with the student receiving the tangible reward.

Certain aspects of vSked functionality supported this new practice, but it emerged from the desire to provide opportunities for the students to participate as a community. Despite the focus on individual education, in practice, the teaching staff strove to balance individual needs and the possibilities for group learning. vSked helped to realize some of these goals that we would characterize as community-building. One of the teaching staff concluded:

> *T1: [vSked] will definitely change the way we do whole group. And hopefully increase their independence during other work times.*

Within individual work time, students carried out activities with fewer prompts from the teaching staff, in exchange for the scaffolding on the system itself. The system allowed the students to work on their tasks with automatic positive feedback and consistency in the daily structure and reward mechanisms. However, facilitating completely independent work sessions in the classroom was not the only experience the teaching staff strove to create. For example, this new practice of group recognition demonstrated the importance of working together as a group towards common goals in a classroom setting. The students expressed awareness and interest in each other's activities. By presenting a student's accomplishments to the class as a whole, opportunities arose for socialization as well as extrinsic motivation. The emergent community-based practices came about through the digital scheduling system, but were shaped by the desires, norms, and culture of the classroom that had been developing over time.

DISCUSSION

The deployment and evaluation of vSked exposed tensions around its use in a classroom, and holds implications for further work and future design processes for assistive technologies and classroom design in general. In particular, vSked was developed for use by an entire classroom of students. Classroom educational technologies (*e.g., [1, 4, 31]*) are common, however, classroom-level approaches to assistive technology are unique, even among those devices and systems deployed within classrooms already. Furthermore, examination of the issues of classroom management, sociality, and communication among students and staff reveal considerations, opportunities, and challenges for assistive technologies different from those that focus on individual student learners.

Classrooms have inherently limited resources, particularly in relation to student-staff ratios. While reliance on human prompting is generally considered undesirable, the use of technological prompts and scaffolding can be acceptable and is encouraged in special education. The vSked handhelds can be seen as an extension of the capacities of the student and thought of as personal resources for accomplishing tasks, not unlike the use of calculators or PowerPoint™ in neurotypical classrooms. The design of scaffolding and feedback within assistive technology is a critical factor in the usability, adoption and, ultimately, the success of the device as an intervention.

Furthermore, consistent, shared, and networked systems can encourage more reaching out within a classroom space. We have found that individualization is not the only goal for assistive technology in classroom settings. In fact, emergent classroom practices provided evidence that teaching staff structured segments of the daily routines around activities designed for a group of students. Gathering students before recess or bringing a student up to the front of the classroom for recognition are examples of how community practices materialize within an individualized education model. These community practices are highly valued in the classroom setting, both to facilitate organization and to provide new opportunities for students to engage with each other and socialize. vSked supported new practices, such as synchronous transitions and public acknowledgement, previously uncommon to the classrooms of our study.

Despite the benefits of vSked, there were also some challenges, particularly when considering its role in the entire classroom, not just for individual students. In particular, vSked may have less flexibility for *ad hoc* customization than the paper-based schedules. Whereas a teacher can quickly use a marker to add text or change a detail on an individual paper schedule, she would have to use the programming interface to swap out the image for vSked. Limitations on this kind of *ad hoc* customization can conflict individualized student learning. If a student needs a schedule that is out of sync with the rest of the class, the current design of vSked does not necessarily accommodate that change. Furthermore, while vSked allows for more exact representation in the system, the overhead to update and manage a library of visual-graphic images can be a barrier to using exact representation. This suggests future work to examine the ways in which image search and retrieval technologies can be better incorporated into vSked.

In our studies, freeing the staff from specific individual prompting enabled them to be more flexible in moving from student to student but overall providing the same amount of attention as before. Future research should examine whether use of these technologies might become an excuse to lower teacher-student ratios. Also, many researchers have argued whether assistive technologies might create more dependence for individuals with disabilities over time (*e.g.*, McMillen & Soderberg 2002), an issue of relevance to long-term vSked use.

Although most assistive technology is designed to help with individual student's needs, we have found that designing a system explicitly for a classroom or a group of students creates opportunities for new practices. While the individual learning goals for each child may be paramount, assistive technology can, and arguably should, support both individualized work time and group practices. Designers creating new assistive technologies should thus consider how they might connect to one another, be used in concert, and be centrally coordinated. Achieving a balance between the needs of individual learners and those of the entire classroom—including both students and staff—is an open research question that warrants substantial further inquiry.

The resulting practices from these deployments are a reflection not only of vSked's functionality, but also a melding with existing social and educative trends. In our study, staff and students together established new practices around the system that incorporated previously defined parameters for school, classroom, and student success. In this work, we examined the classroom itself as the unit of analysis rather than just the individual student users. This approach contributes important implications for both the design and evaluation of assistive technologies in the future, especially those destined for classroom use. The deployment of vSked allowed the surfacing of issues that reflect school culture and norms related to the use of assistive technologies in classroom environments.

CONCLUSION AND FUTURE WORK

In this paper, we described the results of an empirical study of three deployments of vSked, a classroom intervention for students with autism, across two classrooms over the course of a year. In this work, we set out to understand the challenges and opportunities for a classroom-based assistive technology. Findings from this study indicate that use of these kinds of technologies can reduced the number of prompts given by teachers and aides and improve transition time. New community practices also emerged around the use of the system, such as collective cheering and general social awareness. The study also revealed some interesting tensions between facilitating a group of students (for example in the form of efficient transitions and predictable schedules) and individual students (by allowing for customized visual graphics and prompt variance). This results of this study contribute to the research on assistive technology by suggesting design recommendations that place classrooms and groups of students at the forefront.

This work exposes future research questions for classroom-based assistive technologies. First, the preliminary quantitative results we observed should be investigated with a larger controlled sample. Second, the impact of these kinds of technologies and designing assistive technologies for the classroom rather than just the individual should be considered for populations other than autism.

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