vSked: Evaluation of a System to Support Classroom Activities for Children with Autism

Sen H. Hirano[1], Michael T. Yeganyan[1], Gabriela Marcu[2], David H. Nguyen[1], Lou Anne Boyd[3], Gillian R. Hayes[1]

[1]Department of Informatics
University of California, Irvine
{shirano, myeganya, dhn
gillianrh}@ics.uci.edu

[2] HCI Institute
Carnegie Mellon University
gmarcu@cs.cmu.edu

[3]North Orange County Special
Education Local Plan Area
lboyd@ocde.us

ABSTRACT

Visual schedules—the use of symbols to represent a series of activities or steps—have been successfully used by caregivers to help children with autism to understand, structure, and predict activities in their daily lives. Building from in-depth fieldwork and participatory design sessions, we developed vSked, an interactive and collaborative visual scheduling system designed for elementary school classrooms. We evaluated vSked *in situ* in one autism-specific classroom over three weeks. In this paper, we present the design principles, technical solution, and results from this successful deployment. Use of vSked resulted in reductions in staff effort required to use visual supports. vSked also resulted in improvements in the perceived quality and quantity of communication and social interactions in the classroom.

Author Keywords

Visual supports, autism, education, assistive technology

ACM Classification Keywords

K.3.1 Computers and Education: Computer Uses in Education; K.4.2 Computers and Society: Social Issues, Assistive technologies.

General Terms

Design, Human Factors

INTRODUCTION

Interventions to support individuals with Autism Spectrum Disorder (ASD) often include the use of a wide variety of visual tools. These artifacts draw on words, images, and tangible objects to represent concrete and abstract real world concepts. Use of these visual artifacts, in particular for individuals with ASD, has been shown to reduce the symptoms associated with cognitive, communication, and social disabilities [3, 6].

A visual schedule is "a set of pictures or words that cues someone to engage in a sequence of activities" [11] (see, for example, Figure 1). They present the abstract concepts of activities and time in concrete forms by using pictures, words, and other visual elements to describe what will happen, in what order, and where. They have been used successfully in classrooms, homes, and private practices to lessen anxiety and to address difficulties with sequential memory, organization of time, and language comprehension [6, 12, 13]. In schools, visual schedules can assist students with transitioning independently between activities and environments.

Despite the benefits of visual schedules, certain limitations hinder their use and potential for improving classroom interactions. For example, creation and use of visual schedules can be demanding in terms of resources, especially time. Furthermore, it can be very difficult to record data for tracking student progress using traditional paper-based tools. Novel interactive computing systems are particularly promising for the development of advanced visual supports. Automated capture and access applications [1, 15] can enable monitoring of the effectiveness of interventions without significant caregiver effort. Health and behavioral data—captured, analyzed, and mined over time—can provide valuable evidence for tracking the progress of interventions [4]. Likewise, large group displays—particularly when integrated with smaller mobile displays—can be leveraged to augment and enhance current practices for displaying educational materials and engaging with students in classrooms [2].

In this paper, we first present the results of a qualitative study focused on visual supports in special education classrooms. Based on these results, we then describe the design of vSked, an interactive and collaborative visual scheduling system. Finally, we present results from a deployment of vSked in an autism-specific classroom.

This work has three contributions. First, although many other researchers have explored collaborative systems for use in classrooms, we focus on information about the particular needs of children with autism and their teachers. Second, these results led to a set of design principles that were used to develop vSked and will be useful to other researchers designing classroom systems for children with special needs. Third, the results of our deployment study of vSked indicate how these types of technologies can be successfully used in special education classrooms.

Figure 1: Paper-based visual schedules. (Left) Individual student schedules include representations for each activity of the day attached via Velcro. Students remove each item and place in the envelope to signify a start of an activity. (Right) Large cards representing activities to present to the class.

RELATED WORK

Children with special needs increasingly use computers for a variety of tasks and activities. However, designing for children, even those who are neurotypical, can be extremely challenging. Children develop and change—mentally, emotionally, and physically—at a rapid pace and are particularly vulnerable in terms of safety and ethical considerations. However, computational tools can also be significant enablers, particularly for children with special needs. Hourcade provides a thorough overview of the issues and theories surrounding design for children [7], a scope too large for this paper. Despite the interest by researchers and practitioners in visual schedules, little attention has been given to replacing these schedules with more high-tech solutions. Thus, in this section, we review some projects that are most closely related to this work.

Those few solutions that do attempt to use information technology for visual schedules do so with PowerPoint (*e.g.,* [9]). Similarly, for neurotypical students, researchers created Classroom Presenter, a PowerPoint plugin that adds multi-user inking functionality and the potential to insert "quiz" slides into presentations [2]. Although these systems are promising, they do not address many of the issues uncovered in our work, as we describe in the Design Principles section.

In the domain of technologies for autism, Hayes *et al.* described social and technical considerations in the design of three capture and access technologies for children with autism [4]. The social issues included: the cyclical nature of caring for a child with a chronic condition, the need for rich data to document progress, the requirement to collect these data through minimal effort on the part of caregivers, and concerns about privacy as well as the financial cost of new systems. In our work, we considered these issues and ensured that all of the tools we developed could adapt over time and provide feedback in a cyclical manner. Furthermore, we designed vSked to collect rich data with minimal user intervention and respect for the privacy and control of data considerations of users. Finally, throughout our design activities, we primarily used off the shelf, low-cost components that could be available to schools within their educational and assistive technologies budgets.

Additionally, this same research group described four design challenges for creating ubicomp technologies for children with autism [8]. They noted the importance of four practices: understanding the domain, making system installation and changes invisible, keeping the technology simple and straightforward, and enabling customization and personalization of interfaces. In our work, we were also concerned with these issues, spending substantial time in classrooms to understand current visual schedule practices. Furthermore, the concept of integrating data already in existence figured tightly into our participatory design process, in which we used the images and activities currently used in classrooms to seed the design of the technological artifacts. Finally, we considered issues of customizability and personalization, as are described further in both the descriptions of vSked and in the Results section.

DESIGN METHODS

We used multiple design methods to uncover the requirements for and begin designing our novel interactive visual scheduling system. Our approach was highly participatory, involving stakeholders of all kinds (*e.g.,* teachers, neuroscientists, autism specialists, and parents) across all phases of the iterative design process. Building on our initial literature review, we conducted fieldwork to delve specifically into the challenges of visual scheduling and communication tools in classrooms for children with autism. During this work, we interviewed teachers, staff members, and autism specialists from three sites in the same area. These sites included:

- an Interagency Assessment Center for children from 18 months to three years old;
- a special education pre-school for children two years to five years of age; and
- an integrated elementary school that hosts regular education classrooms, general special education classrooms, and autism-specific classrooms.

Over the course of approximately nine months from October 2007 to July 2008, we conducted several visits to each site, taking field notes and photographs, interviewing educators (n=10) and therapists (n=3), and observing interactions among students, teachers, and other classroom staff members. During this time, we also conducted observations at nine special education classrooms across these schools. Specifically, we were focused on understanding the types of activities in which the students participated, paying special attention to understand the ways in which they transitioned between activities. Furthermore, we also focused particular attention to the artifacts—typically created by hand by teachers and other classroom staff—used in general classroom facilitation and during specific activities.

Building on the relationships developed during our initial fieldwork, we began to conduct participatory design

sessions in the fall of 2008. Our design team expanded to include an autism specialist and a classroom teacher. We explicitly chose not to include the children in the design sessions directly, focusing instead on using participant observation in our work with them. The burden of involvement was deemed too high for these children by the researchers, teachers, and IRB to include them directly. Domain experts engaged in the iterative participatory design process proxies for the children.

We then presented a functional prototype during two focus group demonstration sessions (n=13 and n=8) that included two other prototype systems in addition to our prototype. Participants in these focus group discussions included neuroscientists, special educators, assistive technology specialists, and private therapists. During these sessions, participants first joined in a general group discussion about the technologies and their accompanying interventions. Then they were encouraged to interact with the vSked prototype directly. Finally, participants joined again for a group discussion. These sessions lasted 120 and 150 minutes respectively. The themes that emerged from the focus group discussions were merged with data from the previous studies and analyzed collectively. Although we do not here discuss the details of the results of the focus groups, using those results, we extracted a set of core design principles described in the following section that led to the final design of the vSked system.

DESIGN PRINCIPLES
Based on our literature review, fieldwork, interviews, and participatory design sessions, we determined four design principles for interactive visual supports, specifically, for use in classrooms for children with autism. The design principles presented here represent common concerns for teachers and caregivers with whom we were working.

Ease the transition to new tools by mimicking old ones
Current analog visual schedules have several qualities that help teachers and students communicate effectively. Qualities such as the use of images to represent real world objects or events, the arrangement of images to convey sequences in schedules and within activities, and the physical interaction required to make selections all contribute to successful classroom facilitation. For example, students commonly communicate using paper-based "choice boards," a visual display of possible choices expressed as pictures or text through the use of objects or tangible symbols. To ease the transition to digital tools, user interfaces should match these designs. For example, in many autism classrooms, substantial effort goes into teaching students "token systems" through which they can be rewarded for appropriate behavior (*e.g.,* a student may earn a token for each activity successfully completed and get a bigger reward, such as time jumping on a trampoline, after earning a set number of tokens). Thus, our solution needed to support the use of token systems, which should be flexible enough to be customized for any classroom.

Teachers and staff members create highly personalized visual supports, because *"in Special Ed, everything is individualized"* (T[1]). Thus, to be incorporated successfully into classroom activities, new tools must also include elements of personalization, such as names, photos, and particular choices for activities. Likewise, the size and appearance of interface elements must be customizable to handle the particular concerns of students with fine motor skill difficulties and other disabilities.

Finally, teachers currently use a combination of visual supports of all sizes and shapes, positioned throughout the classroom. Thus, any solution must similarly include an assemblage of technologies all working together to support both individual and classroom wide work.

Reduce teacher burden
One of the biggest challenges described during our formative work was dealing with the arduous tasks associated with using traditional analog visual schedules. Not only do teachers dedicate entire days creating the small cards used in most paper-based scheduling systems, but hours after school are spent preparing the schedules for the following day. Multiple sets of these cards must be maintained, because it is easy to lose small square pieces of laminated paper. To address these issues, classroom systems need to have fast, intuitive, and simple tools to allow teachers to create schedules in less time and with less effort. Systems should also support the ability to export or print images and data, allowing the teacher to easily transfer data or be able to create paper-based artifacts.

Additionally, teachers and classroom staff currently spend significant time and energy prompting every student about daily activities, rewards, and socially accepted behavior. Current paper-based visual schedules are limited in their ability to support awareness of these classroom activities. Thus, some students may be neglected unintentionally and as a result lose focus. To reduce stress and fatigue on the teacher while keeping the students engaged and focused, classroom technologies should distribute activities and provide some automatic prompting and reinforcing for students to support their continued engagement.

One goal in many autism classrooms is to teach the students to help one another in addition to getting help from classroom staff. However, current paper-based tools are limited in their ability to provide awareness of other students. The awareness of each other tends to be centered on observing a single student, who has volunteered to complete the task at the front of the room while the others follow at their desks. Thus, to support peer interaction more fully, classroom technologies should include real-time updates visible to students in addition to awareness tools for staff.

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[1] All research participants are listed by anonymous code. T = primary classroom teacher. A1, A2, A3 = classroom aides. Students are identified by Student and a letter.

Automatically generate records and reports

The ability to capture usage data and access it afterwards with current tools can be arduous and time consuming, and in some cases infeasible. Individual and group progress data must be recorded and managed by hand, a process so burdensome that many teachers simply avoid recording data beyond their legal obligations. This minimal documentation can make it difficult to share student progress with parents.

Frequently, progress against set goals are thus only measured once per year, at an often contentious discussion around the development and satisfaction of Individual Education Plan (IEP) goals. These goals are negotiated by parents, teachers, and other specialists, with the resultant IEP representing a contract against which the school can be judged. Some of these goals can be complicated to achieve and to track. Progress on goals at these meetings can be refuted due to lack of evidence supporting their completion.

To address this challenge, data should be recorded accurately and continually throughout system use. Data visualization must also be accessible in multiple views, such as bar graphs or pie charts, to make the analysis more feasible. The ability to retrieve these data will enable teachers to provide evidence for satisfied IEP goals as well as hard proof to disbelieving parents. Through data analysis, teachers can identify trends, which may help create new activities, important interventions, or provide more insight in their student's behavior.

Design for flexibility and robustness

Teachers regularly face the challenge of developing new and creative activities to help teach concepts in class. Although they are often limited by resources, tools, and time, the special educators with whom we worked are incredibly creative designers and continually work to create new successful approaches and tools for their classrooms. Furthermore, equipment in public schools tends to be purchased infrequently and intended for multiple uses over many years. Notably, many assistive technologies are not customizable for multiple uses, a significant problem

brought up frequently in our early interviews. Thus, new classroom systems should use modular components that can be augmented, altered, and exchanged over time. Modular components—both in hardware and software—allow for the addition of new features or classroom activities.

Modularity not only supports flexibility but also robustness. For example, by separating data from the devices enables immediate replacement of broken hardware without substantially disrupting classroom activities. Similarly, the destruction of one piece of the system must not hinder the ability for the rest of the system to continue working.

"The throwing of [assistive technologies] and the fact that they are expensive… that would be my only concern…Once [current technologies are] broken you're like okay now we gotta' wait until it gets fixed." – A2

Software modularity is as important as hardware. Solutions must enable flexibility and allow for customization by teachers and other stakeholders. Robust, modular systems can support exploration of a wide range of activities and approaches without interruption from the loss or changing of portions of the system.

THE VSKED SYSTEM

vSked is an interactive and collaborative visual scheduling system for autism classrooms. vSked provides interfaces for creating, facilitating, and viewing progress of classroom activities based around an interactive visual schedule. The system includes three interfaces: a large touch screen display viewable by the entire classroom, a teacher–centric personal display for administrative control, and a hand-held touch screen device for each student (see Figure 2).

The large touch screen, placed at the front of the classroom, acts as a master timetable showing individual schedules for all students for the current day. The current task is denoted by being in the top position vertically on the large screen. The teacher touches it to invoke any animations appropriate for the large screen as well as to activate the activity on the wirelessly networked student devices. Each student's device then shows a prompt, the location of the task—if the task is at another location, and a virtual "choice board" with responses during those activities in which the students are expected to make a choice. Students choosing incorrectly or not choosing at all receive prompting to help them identify the correct response, including the removal of incorrect answers and the shaking or coloring of correct answers. Upon successful completion of a task, students are individually presented with a reward chosen specifically for them, such as an animation of fireworks traveling across the screen. The teacher can also provide tokens to the students by touching the "star" reward area by each student's name on the large screen. The number of earned tokens is echoed on the student's individual display, and as in their paper-based system, students receive a bigger reward of their choice after earning five tokens.
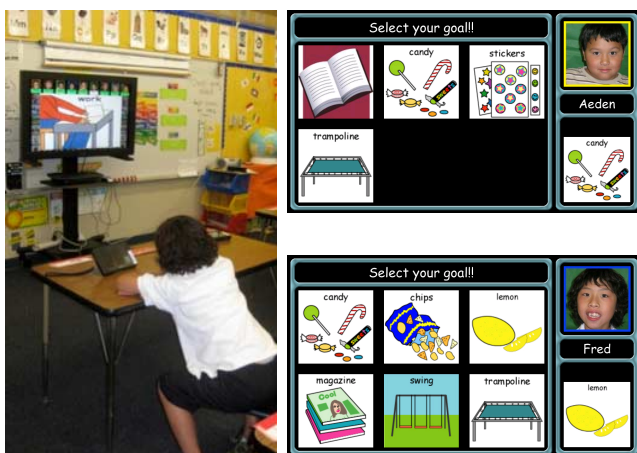

Figure 2: The large display at the front of the room (left) is controlled by the teacher and synchronized with individual schedules for each student (right).
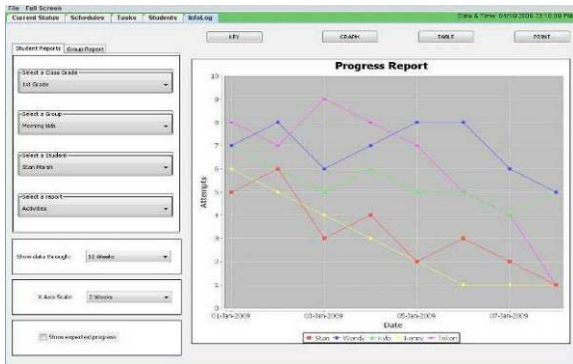
Figure 3: A sample progress report showing incorrect attempts for a prompt over time.

The progress of each student working through an activity is shown through a progress bar below each student's picture on the large display. Once all students have completed a task, the schedule automatically advances. If the students have not all completed the activity, but its scheduled completion time is drawing near, the teacher can configure the system to provide a prompt to her either on the large shared display or on her own private display.

Every interaction in vSked is logged and mineable. Thus, staff can generate reports on individual student progress or the entire class across individual activities or days and weeks (see Figure 3). These reports can be generated and printed daily, weekly, monthly, or yearly, and different templates are supplied for each of these potential lengths of time. Printed records are easy to file in school records or sent home to parents and caregivers.

EVALUATION METHODS

We deployed vSked in a classroom for children with autism over a three-week period to investigate three specific research questions:

- To what degree and how will users adopt and accept vSked? How will they integrate this novel system into their daily classroom activities?
- To what degree and how will vSked impact communication amongst the various stakeholders?
- In what ways does the use of vSked impact student behavior and learning outcomes both as individuals and as a classroom?

We deployed vSked in a classroom that included nine students between the ages of eight and ten with diagnoses of mild to moderate autism. One teacher developed the curriculum and facilitated class activities, assisted by three teaching aides who provided hands-on assistance and discipline for each child. vSked was used daily by all students and teaching staff to facilitate classroom activities.

After installing and configuring vSked, we trained the teaching staff to use the system and were available for troubleshooting assistance during the first week. In the following two weeks, the classroom staff operated the system independently without technical support. One to three researchers observed classroom activities from the back of the classroom almost every day of the deployment,

for a total of 97 hours of observation. We took extensive field notes, sometimes supplemented by photographs and videos. Student interactions with the system were logged.

Each member of the teaching staff was interviewed 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 half an hour and were recorded and transcribed. All members of the teaching staff participated in a post-deployment 1.5 hour group interview.

All field notes, interview transcripts, images, and videos were inspected together. We first analyzed the data for evidence of the efficacy of our decision in relation to the three primary research questions laid out. We also used open coding and multi-phased affinity analysis to uncover emergent themes from the empirical data.

RESULTS

The vSked system was received positively by the teachers, aides, administrators, and students at our experimental classroom site. In addition to these general positive responses, we uncovered a variety of interesting phenomena through the experimental deployment of this system in a real classroom environment. In this section, we describe first the levels of user adoption and acceptance of vSked and the ways in which the various stakeholders were able to weave use of the system into their daily lives. We then discuss the changes in information sharing and communication that we hypothesized we might observe going into the study. Finally, we describe the impact use of this system had on student behavior and performance and what these results indicate about the potential for future novel technological interventions to support children with autism and other developmental disabilities.

User adoption and acceptance

Before our deployment, our experimental classroom had three nine-year-old iMacs and one six-year-old iBook. New equipment is very hard to obtain in this classroom, and almost no IT training exists for teachers and staff members. Thus, one significant research question for us was whether and how students and staff might adopt and accept a novel technological solution that includes multiple mobile devices and a large touch screen all connected via wireless network.

Student use
In any classroom, tools are selected primarily based on student ability to use them and to learn from and through them. Thus, we were particularly concerned with student ability to use the interactive touch screens and understand the invisible connection between activities on their local devices and what was being shown on the large screen. Initially, the teaching staff was nervous about how, or even if, the students would be able to use the system. Thus, when the students were all able to use the devices successfully in the first day, the educators were particularly pleased:

"We were really scared when you first came here. We were like 'will they get it?'... they do get it [after a few days]it's not limiting them in any way. It's helping them to better themselves and to be more independent." – A3

*"...people tend to overlook [our kids] ... that they couldn't do it, but yet they pick it up so fast and they **do** understand it."* – A1

Over the three weeks of the deployment, student use and understanding of vSked grew from a novel artifact or even toy in their lives to a true support and means for communicating and learning.

"They're being more patient. I think before they just tried to touch it, touch it, touch it, to see what was going to happen…they're growing in the correct usage of it." – A1

One particularly remarkable interaction with vSked occurred during the second week of use. Student R noticed that the device belonging to another student had gone to "sleep" (turned to a black screen). He woke up the device, returned to the Windows menu—which is normally hidden from student use and had only accidentally been enabled during sleep—and then launched vSked. Describing this incident, the lead teacher stated:

"So not only [was Student R] able to work everything else like this, he's able to see…her's doesn't look right, and I don't know if he overheard, because we never taught them how to do it… so he saw it on the bottom [of the main Windows screen] and he just…looked at it, and he touched it, and then the screen came up…. It was amazing." – T

An aide was equally excited by Student R's progress and looked forward to what else he might do with the system:

"He found the vSked at the very bottom of the minimizer, touched it and up it came ... I mean, how much prouder can you get, because again, it's something we never taught him." The aide went on to describe how she had tried to fix the same issue earlier that week and failed. *"Here's this kid… he's only had it for the same amount of time, and he figured it out. So, that's my 'awe' story this week… we'll see what happens next."* – A1

Classroom staff burden
As previously mentioned, any new tools must reduce teacher and staff burden—or at least not increase it—to be accepted. Learning any new system can increase cognitive burden, and in our case, there was the added overhead of moving the mobile devices from their chargers against the wall to the desks and starting them each morning. Towards the end of the three week deployment study, however, the aides reported being comfortable with these tasks:

"I'm kind of getting more comfortable with the system. Like, Okay, got to get them out, got to have them set up…" – A2

Additionally, the teacher and aides reported that use of vSked reduced overall "prep time." In particular, the creation and management of analog visual schedules was reported to be more time consuming and burdensome than setup and use of vSked. For example, one aide noted:

"... we right now have to setup a schedule every afternoon ... with the [cards], and we have constantly ... probably 50 [cards] on the table trying to sort it out and create for each kid individualized schedules. So, this is really good. We were able to make that process a lot easier." – A3

Finally, the classroom educators reported being concerned about waste of materials. In an incredibly budget constrained environment, like the public school system in the US, losing or throwing away outdated materials can be very costly. Additionally, due to recent emphasis on environmental impact in schools staff are increasingly concerned with how much they are using—and wasting—in terms of paper, lamination, and other materials. The ability to configure and reuse vSked was seen then as an appealing way to reduce waste, both financially and environmentally:

"... we have all these materials that we have to make. So, that helps…not having to worry about wasting a lot of material." – A3

Notably, although participants were concerned about waste, they only discussed their own personal contact with materials and the cost to themselves in time and resources for creating them. They did not discuss electricity, infrastructure, and other significant up-front costs associated with high technology manufacture and use.

Information sharing and communication
In this work, we were interested in four types of information sharing and communication. First, given that the use of visual supports in classrooms is largely about helping students and specialists[2] to communicate with one another, changes to their communication patterns was paramount to our research. Second, we were interested in how communication amongst students themselves might be influenced by changing from a largely analog one-on-one interaction model to something networked and shared. Third, we were similarly interested in exploring how the work and communication patterns amongst the school staff might be changed by large and small networked visual tools. Finally, the logging and record keeping functionality of vSked was explicitly designed in consideration of communication among classroom staff, administrators, and parents. Over the course of our three-week deployment, we observed changes and the potential for change for all four types of communication. Furthermore, the findings from our observations were supported by the perceptions of the specialists whom we interviewed.

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[2] For simplicity in reading, in this section we refer to all classroom staff as specialists. This group includes teachers, aides, administrative staff (*e.g.,* the principal), and therapists (*e.g.,* speech and language pathologists) who sometimes work with the students.

Student-specialist communication
Visual supports for children with autism are inherently about communication through visual means, in particular for children who have difficulties with verbal communication. Of course, both paper-based and computational supports should not replace, nor interfere with, human interaction in the classroom. Children with autism in particular require frequent specialized interaction to improve their face-to-face social skills.

"We are not using it during [activities in a] small group, because that's where we are still doing the human interaction…what it doesn't give is that human interaction. It's a computer…we still need a body here, because we still have to teach them these other skills that the computer can't do… how to play games… how to socialize." – A1

It is possible that computer-based agents might serve these roles in the future (*e.g.,* [14]), but such an idea was not considered by the participants in this study.

Traditional paper-based supports, however, can only support communication when the two individuals attempting to communicate are attending to one another. Using vSked, however, we observed improvements in student-specialist communication, particularly asynchronous. For nearly every student in class, at some point during the study, we observed a teacher, aide, or other specialist learning something they had not known about that student. For example, the classroom staff had believed one student preferred a particular item as a reward. Rewards are items (candy, toys, books) or activities (trampoline, swings) used to motivate students. Students each select a reward, and after earning the required number of tokens for good behavior, they receive the reward and are able to choose the next one they would like to work towards. Given a broader set of choices on vSked than this student typically received on paper, he consistently chose to work for a different reward.

One concern with use of a mobile interactive system with this population is the potential for inappropriately intense interest in the mobile devices in the place of engagement in group discussions or listening to the teacher. In our deployment, however, the classroom staff reported that the children learned quickly about appropriate times to use vSked or not.

"They are not becoming obsessed with it. They are using it when it's appropriate, and leaving it alone when it's appropriate. So, I don't see them being distracted, because sometimes they can get obsessed with items." – A1

Student-student interaction
A concern arose repeatedly in our early fieldwork, focus groups, and even initial interviews at the beginning of the deployment: Would the students lose something in terms of human interaction and peer socialization by using vSked?

"I think it might take away from the socialization a little bit, because obviously the kids have autism and the kids want to be by themselves anyways." – A2 (first week)

Results from our deployment, however, indicate that the introduction of computing technology did not decrease social interaction. As already described in the previous section, student-specialist interactions were reported to improve in quality, and we observed more shared understanding between the specialists and students. Perhaps both more surprising and more interesting, however, we also observed students interacting with each other in relation to or prompted by the system.

First, students began to cooperate and help one another with challenging tasks. The task progress bar at the top of the large screen as well as the visual cues of seeing the state of neighboring student devices prompted some students to help their peers. Students even supported one another in recognizing when they had received a reward. For example, we would frequently hear a student exclaim, "look, you got fireworks!" indicating to another student that the indicator for earning five tokens and receiving a reward had appeared on his or her individual screen. This kind of interaction is consistently a goal in working with children with autism, but one that can be incredibly difficult to address and accomplish.

At the same time, the students also appeared to behave somewhat competitively in their understanding and awareness of each other's progress. Again, the progress bars on the large screen and fireworks on the small screens were powerful indicators of the classroom wide activities, and students would speed up in responding to questions after seeing other students make progress.

"…they look to see if the next person picked [completed the task by choosing a correct answer using the interface]…they see the fireworks on everybody else's screens…it's motivating them a bit more." –A1

This kind of peer awareness is challenging for children with autism and thus was a remarkable effect of using vSked.

Intra-specialist information sharing and communication
The dynamic environment of schools, including the movement of specialists and students in and out of rooms throughout the day, can make communication difficult. Although many special education teachers plan team meetings for the end of each day, exhaustion and an hourly pay plan for aides that does not include time outside of class for aides make these meetings rare and difficult. Thus, teachers and their staff must frequently coordinate schedules dynamically and in the presence of the students. During our deployment, vSked supported this dynamic coordination by providing visual support not only to the students but also to the classroom staff. As the teacher noted:

"I'm kind of the brains behind the whole thing … I know like tomorrow…I have my whole day planned in my head…My aides don't … So, I think it's great that with vSked, they can totally see what we are doing today, what's planned on our schedule, and then they know exactly what activities to do within that time period." – T

Likewise, one of the aides commented on duplicating work:

"...before we would kind of be like, 'oh you did a good job at recess.' So we would give them a token and then somebody else would come over and…give them a token because they did a…great job doing something else. This way, we all were on the same page, not just the kids, us as staff were on the same page, looking at the same token board …" – A1

Similarly, we frequently observed visitors to the classroom (*e.g.,* the principal, therapists, parents) quietly looking at vSked from the door and then commenting—either to the observing researcher or to someone else in the classroom—that the individual for whom they were looking was elsewhere and they would either find that person at the location indicated by vSked or come back at a time that vSked indicated that individual would be back in the room.

In addition to the added awareness that use of vSked enabled, the school professionals also found that they were able to document and share information with one another more formally through vSked. For example, each morning, the teacher takes attendance and asks the students whether they brought lunch from home or will be purchasing it. Both of these pieces of data must be communicated to the front office each morning, but the exercise of obtaining these data is also a taxing one for the group and can involve multiple prompts for individual children. By the end of the exercise in the traditional pen and paper system, the teacher sometimes forgot the responses of the students who had answered quickly. With vSked, she noted:

"...the attendance and the lunch count. I'm able to just… see from that chart… it's very very helpful." – T

As another example, vSked logs every action during a user's interaction with the system. Thus, educators can mine the logs for patterns that are difficult to discern in a paper-based system (*e.g.,* if the student always chooses the answer furthest to the left even when that answer changes). They can also recognize particular concepts with which particular students consistently struggle. For example:

"...the data will [help] us understand…if they are pressing the button multiple times, they are not getting it. We need to teach them these concepts … in a one on one setting." – T

Furthermore, in a fully connected system, these data could be automatically transferred to the administrative staff who need them for both daily reports and long-term goal tracking.

Parent-specialist cooperation

In special education, communication and cooperation between parents and the school system can be particularly important, and in some cases particularly contentious. As previously mentioned, this sensitive relationship includes an annual negotiation of progress and goals for each student: the IEP. During these discussions, goals are formally set for the upcoming year, and the previous year's goals and progress are assessed. Most teachers also send home daily notes describing each child's activities and progress. The content of those notes can be more or less descriptive and complete depending on the individual teacher, legal constraints, and other factors.

At times, even those parents with whom classroom staff have wonderful relationships are unaware of the progress their children are making. Students may behave differently at school than at home, and parents often have simply not seen a particular skill accomplished first hand.

"It's proof that they actually do it. Sometimes we feel like we want to record one-on-one sessions to show [the parents that] he can do it. He knows these things. So, this will prove to them and show them that your kids do know more than you think they know." – A3

Some parents may attribute the difference in performance at home as opposed to school to over prompting or support by classroom staff. Thus, one aide described wanting to defend against that concern using vSked:

"It would be really good for [the parents], because they would actually see that [the students] are doing it on their own. It's not us… prompting them…you're able to see… the progression from when maybe it wasn't really good to like how they just improved tremendously, and I think a lot of parents like to see that. They like to see growth." – A2

Certainly, teachers can use other methods to demonstrate progress to parents, including video recording or complex notes. However, the additional burden of creating these records can inhibit many educators [5]. Thus, the automated logging and data recording was seen as a huge benefit by the classroom staff.

"You're not having to video tape it. You're not having to write it down. The parents can be able to see it as it comes out…. 'This is what we did today.'" – A1

Impact on student behavior and performance

Use of vSked impacts students both while at their desks and during times of transition. Particularly interesting for students with autism who often struggle with group work and social interaction, we also uncovered the potential for these types of interactive classroom technologies to support these challenging focus areas. In this section, we describe the impacts on individual and group behavior and performance related to use of vSked.

Individual behavior

The automatic prompting and delivery of activities to individual student devices proved to be relatively simple for the students to understand. In fact, they were so successful on the first day that they completed the calendar activities that normally take more than half an hour in only a few minutes. The students had worked forward without waiting for the teacher in much the same way neurotypical students might proceed through a workbook without awaiting instructions. Working with the teacher, we modified the system to deliver activities in synch with her own delivery of information at the front of the classroom. This slower

pace of delivery of instruction allows the teacher to ensure comprehension in the students, but it also means that the students may have difficulty remaining in their seats. During the deployment, however, the students tended to remain seated, occasionally glancing at their devices in anticipation of the delivery of the next activity.

"They are at their seat. They are not rocking or shaking or running around." – A1

"[With the old system] we always have to constantly ask [Student R] to go check his schedule. He is not excited, but with this, he is constantly excited to check it. He just loves it." – A3

Although use of vSked does seem to be intrinsically motivating for some students, the combination of scheduling, choice, and rewards information all in one place appeared to be particularly successful in encouraging them to focus and stay "on task." The large screen shows an overview of all of the students and their tokens, but the small screens show individual students' tokens and the rewards for which they are working. This reminder encouraged the students, even without instructor intervention. In fact, some students would even remind the instructors instead of the other way around.

"[Student F] loves to pick it up and show the teachers what he's working for and how many tokens he has." – T

Of course, there are some challenges to automated prompting and rewards. For example, the students quickly learned how they receive the tokens they earned (through touching their names on the large screen), and would

"try to give themselves their own tokens ...Nobody's ever taken any away from themselves. They're using it correctly." – A1

As another example, one student found the prompting itself to be reinforcing. He enjoyed watching the correct answer shake when he chose the wrong answer. During the first week, one aide commented, *"He's like 'Look, I'm touching the wrong answer. Oh I'm just going to touch this one, but I know that's shaking but I want that one.'"* (A3) Over time, the aides and teachers provided him additional reinforcement for choosing correct answers, and he stopped knowingly choosing the wrong answer, but this behavior speaks to the need to explore multiple types of prompting that may be less reinforcing to particular students.

Finally, one significant concern with any kind of prompting—manual or automatic, human or computational—is the potential for students to become dependent on the prompts and unable to perform independently. During our deployment, the aides and teacher reported not being any more concerned with this potential in vSked as opposed to any other tools. For example, one aide commented:

"I don't think its going to make them prompt dependent…it just shakes, and it just gives them a visual. 'Hey look I can do it on my own without you telling me to do it.' … it makes them more independent." – A3

Transitioning

Transitioning between activities is typically a time of great stress in special education classrooms. Moving from place to place and activity to activity can be challenging for children with autism. Furthermore, keeping track of all of the students during these times of transition can be difficult for the classroom staff members.

Certainly, one benefit to transitioning using vSked is simply the physical location of the schedules. In the paper-based system, individual schedules are displayed on the wall. Using vSked they are replicated on both the large screen and the individual devices at the students' desks. Thus, the students do not have to get up from their desks to see and interact with their schedules at close range.

"[Using vSked] makes the transition a lot smoother, because the schedules are at their desks…instead of being across the room….and within the time of moving from their desk to their schedule, a lot can happen." – A3

Finally, transitioning is a time when students in special education may feel particularly stigmatized—either in or outside of the classroom. Being required to be led by hand or to carry conspicuous assistive devices can identify students as obviously in need of special assistance. Thus, for many teachers, making transitions happen as independently as possible and as close to the processes of "regular" education classroom is often a goal. In keeping with this goal, the teacher in our experimental classroom commented that she appreciated the students learning to go straight to their desks after returning from an activity outside the classroom.

"I think it's nice that the kids can come to their desks, which is…a natural transition for kids that are in typical classrooms… everybody meets at their desk, and the teacher tells them what to do." – T

Group work

In the past, the emphasis on individual schedules made perceiving the group as a whole challenging for the students. For example, during a group activity (*e.g.,* story time), each student would be alerted to that activity by checking his or her individual schedule. With vSked, the centrality of a large screen showing images that indicated group activities supplemented the individual schedules and supported more social interaction and consideration of the group as a whole.

"the big screen is… telling you what we are doing. It's telling you where we are at. It's kind of like a magnet… and so I think it's helped them be more like a group." – T

The teacher went on to note that one student who previously never participated in group activities had begun doing so because of vSked's big screen. Through looking at

the big screen, the student participated for the first time in a music-focused activity, even if from a distance.

CONCLUSIONS AND FUTURE WORK

Visual schedules have been shown to have positive impacts on individuals with ASD. They provide additional structure and support, reduce anxiety, and improve classroom interactions and communication. However, these tools come with a heavy burden to special education teachers who spend much time and energy creating, maintaining, and using these tools. Furthermore, current tools lack necessary functionality, such as interactivity and automatic logging of data.

Through in-depth fieldwork and participatory design sessions, we uncovered a set of core design principles for technological interventions to be deployed in classrooms for children with autism. Incorporating these principles, we developed an interactive and collaborative visual scheduling system, vSked. We deployed vSked in a classroom for children with autism over a three-week period to explore the use and impacts of the system in a real world setting.

Classroom staff and students alike were generally positive in response to the system and requested to continue to use it throughout the school year. Additionally, we uncovered a variety of interesting phenomena regarding user adoption and acceptance, communication among various stakeholders, and the impact on student behavior and performance. We also uncovered some areas for improvement and future research. First, the results of the deployment study indicate the importance of dynamic flexibility in classroom systems for children with autism, such that the system can adjust for students experiencing particularly stressful days (*e.g.,* from a change in medication or diet).

Further exploration is needed to assess the potential for controlling system behavior more dynamically in response to student behaviors and mental states, to explore mechanisms for achieving student independence, such as fading of prompts over time [10], and to explore the resource trade-offs between vSked and traditional systems.

Likewise, daily schedule changes (*e.g.,* from a fire drill) can disrupt classroom activities. Thus, further investigation is needed into manual dynamic control of the schedule as well as the potential for machine learning and sensors to detect these shifts automatically.

The experiences reported here alongside the results will be of use to educators and autism specialists interested in exploring how interactive technologies can be used in these settings. These results will also be helpful to HCI designers and researchers interested in creating and studying technologies for this domain.

ACKNOWLEDGMENTS

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