Designing for Collaborative Reflection

Gabriela Marcu, Anind K. Dey, Sara Kiesler
Human-Computer Interaction Institute
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA, USA
{gmarcu, anind, kiesler}@cs.cmu.edu

ABSTRACT
A significant problem with electronic health records (EHRs) has been their failure to fit into existing workflows because they do not support informal documentation and communication. We used qualitative fieldwork and participatory design to investigate how EHRs could be designed to meet these needs. The contributions of this work are twofold: we identified and described the informal processes of documentation and communication that we refer to as collaborative reflection, and then developed design recommendations for EHRs to support these existing workflows. We studied treatment teams providing behavioral and mental health services as part of integrated school programs for children with special needs. To make ongoing treatment decisions, team members document progress daily and communicate frequently with one another. Based on our fieldwork findings, we describe this process of collaborative reflection as (1) unstructured, (2) mobile, (3) reciprocally interdependent, and (4) long-term. We engaged the treatment teams in a participatory design process to understand how EHRs could be designed to fit this process, culminating in seven design recommendations. Our work suggests that by supporting the process of collaborative reflection, EHR-related information technology could significantly improve the efficiency and effectiveness of treatment teams.

Categories and Subject Descriptors
H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *computer-supported collaborative work*.

General Terms
Design, Human Factors.

Keywords
Health Informatics, Collaboration, Fieldwork.

1. INTRODUCTION
Two problems with the adoption of electronic health records (EHRs) and other health information technologies that are well documented in the literature [8][21] are their failure to support informal documentation [23] and communication [30]. Mentis [19] concluded from her review that problems with transitioning health services from paper to EHRs are "primarily due to a rash of unintended consequences from a lack of understanding how medical workers realistically coordinate and share information" (p. 3). She asserts that new technologies in healthcare "will inevitably overlook aspects of coordination that are less formal (and thus difficult to represent as part of a persistent and far-reaching digital record), but are just as important as the more objective elements of patient care" (p.5).

One reason current EHR development lacks support for informal coordination and information sharing is its heavy emphasis on practice in hospitals and, especially, critical care. Most of the literature on health service collaboration has been drawn from studies of hospital environments, for example, [1][2][19][22][23][27]. Health services in hospitals involve a large number of protocols and structured workflows to drive informed decision-making. Formalized structure governs the coordination of schedules, staff, patients, space, and equipment [1], computerized physician order entry systems [21], and protocol-based diagnosis and treatment aided by decision support systems [11][12]. Hospitals and critical care environments also require much time-critical decision-making. For example, activities like scheduling and coordinating diagnosis and treatment may require a decision to be made in the moment. Time- and safety-critical collaboration has been studied in-depth in trauma resuscitation [27] and emergency rooms [22]. In these high-risk environments, information sharing is focused and fast, supporting mutual awareness and distributed cognition.

In this work, we argue that EHR-related pervasive information systems should be designed with a broader scope, one that not only supports time-critical care but also supports coordination and information sharing for long-term and chronic care services. EHRs are also needed in such environments as exam rooms [25][30], outpatient psychiatric treatment [17], home-based therapy [12], and school-based health services [18][24]. These contexts require different kind of decision-making that involves ongoing information sharing and coordination. Outside of crisis decision-making, there is a collaborative middle ground of informal communication and information sharing that coexists with the protocols necessary in health services.

Another reason current EHR development lacks support for informal coordination and information sharing is that the tools are often designed to support on-the-spot decision-making and protocols used in time-critical situations. To support information sharing in these contexts, researchers have designed shared displays [27] and input through digital pens on paper for digital displays [28]. Stationary displays have been a popular solution for supporting collaborative work among health service teams.

PervasiveHealth'14, May 20–23, 2014, Oldenburg, Germany.

Shared displays have been used to support protocol-based decision-making [12], distributed cognition [27], temporal and spatial awareness [3], creation of a communication record [11], and conversations between patients and clinicians [25]. However, we argue that not all collaborative work is stationary. Even in time-critical decision-making people rely on workarounds, informal documentation, and spontaneous communication [8][18]. In these cases, EHRs have been supplemented by paper-based documentation and face-to-face communication [2][23][28][30]. Some researchers have addressed the inadequacy of tools that aim to increase structured protocol (*e.g.,* handoffs in hospitals [6]).

The literature suggests that paper-based tools persist because they are flexible enough to support mobility. Bardram and Bossen [2] have called collaboration within a hospital "mobility work". They assert that recent trends toward EHRs have introduced new challenges because the point of access to the EHRs is typically a stationary PC. To support mobility work, they recommend "systems architectures for more *ad hoc*, peer-to-peer based interaction" (p. 157).

Similarly, we argue that EHRs should include tools for informal mobile coordination and information sharing. In this paper we address the design of such a system, taking into account the challenges of designing for the collaborative middle ground between protocol and *ad hoc* interaction:

> *"For two reasons mobility work is constantly needed: firstly, even with routine mobility work and [protocol] there still is a need to establish ad hoc configurations of people, places, resources and knowledge since the routines and [protocols] do not cover all needs for the exchange of for example information and resources. Secondly, contingencies often arise that require unforeseen configurations"* [2], p. 151

Like Park *et al.* [23], we were interested in what the appropriation of paper-based tools could tell us about information and communication needs not being met by EHRs. We investigated the less traditional but no less clinical context of behavioral and mental health services for children with special needs. We frame clinical teamwork in schools for children with special needs as another type of health services, to contribute a new perspective of the role of EHRs in collaborative work. The context of special education provided a perspective on formal and informal, objective and subjective aspects of work with EHRs.

We emphasize coordination and information sharing that is part of long-term treatment. This type of collaboration is becoming more common due to a rise in the prevalence and impact of chronic conditions such as autism, asthma, and diabetes [14]. This context gave us a new perspective on problems with EHRs, and more freedom to explore the use of EHRs in an environment that is not time-critical. We contribute to an understanding of collaboration and coordination in health services by building on sociotechnical analyses such as [8] and [19].

We studied collocated team members who provide behavioral and mental health services in two special education programs. These programs integrate treatment typical of psychiatric clinics within the school day, enabling a child to live at home and attend school while receiving support to address behavioral, emotional, or social challenges on a daily basis. Children in these programs have diagnoses such as autism spectrum disorders, neurological impairments, and emotional disturbance. Symptoms and behaviors of these disorders vary and change over time, making it important to document behavior and progress (or lack of progress) from treatment interventions. Decision-making is complex due to the long-term nature of treatment and the invisibility of underlying conditions. Teams rely on manually recorded behavioral data (*e.g.,* social behaviors, aggressive behaviors, behaviors related to skills for independent living) for evidence of progress.

Contrasting the more rigid and standardized use of EHRs in hospitals, in our context EHR use and protocols are only partially standardized and require a significant amount of flexibility [18]. Treatment teams subjectively interpret long-term behavioral data. Behavioral data are formally and informally recorded to evaluate the effectiveness of behavioral interventions and psychiatric medications. However, behavioral data are difficult to both record and interpret. These types of EHRs require subjective manual entry by behavioral specialists. Objective and automated measures cannot be used, though research in computational behavioral science aims to make this possible in the future.

In the first stage of this work, we used qualitative fieldwork to identify and investigate informal processes of documentation and communication, which we call collaborative reflection. In the second stage, we used participatory design to determine how EHR systems could meet the needs of collaborative reflection. We present seven design recommendations for information technology that emerged from this process. Our work suggests that information technology could improve reliability of data recorded by multiple providers, improve availability and access for all team members to reflect on data, and help teams more frequently corroborate interpretations of data.

2. METHODS

To understand the collaborative reflection process in health service teams, we observed practices and interviewed employees in two schools for children with special needs in the United States. We documented collaborations in treatment teams that provide behavioral and mental health services in the schools. The teams are comprised of behavioral specialists, educators, personal aides, psychiatrists, mental health therapists, speech therapists, occupational therapists, supervisors, and administrators.

The research team consisted of 15 researchers, led by the first author. Fieldwork included 71 person-hours of observation and 67 interviews with staff. The research team interviewed 14 teachers responsible for collecting and managing data on a daily basis. In one school, we surveyed 130 of 150 staff, with 49 of the staff also participating in two focus groups.

Our approach to collecting and analyzing data during and after fieldwork was based on constructivist grounded theory [5]. In particular, we focused on gathering rich data using theoretical sampling across team members and contexts, constant comparison with data previously collected, as well as opinions of domain experts at our field sites, and inductive thematic analysis. We visited sites at least once a week, sometimes several times a week. During fieldwork, members of the research team took detailed notes and photographs of the artifacts and environments. We used affinity analysis [15] to identify themes inductively. We used an iterative process to discuss themes while continuing to gather field data. The research team met several times a week to analyze and compare fieldwork data. Using a collaborative approach grounded in data from field sites, models of knowledge sharing and implications of work practices were iteratively developed based on inductive themes.

In the second part of our study we focused on designing for the practices we had identified as collaborative reflection. In the spirit of action research [9], we collaborated with our field sites to define the problem (collection and use of data for collaborative decision making) and decide on an iPad solution. We conducted contextual inquiries with school staff to understand their workflow and use of artifacts, and studied work practices using aspects of contextual design [4]. We used naturalistic observation [16] in combination with interviews and focus groups to understand workflow in detail. Applying the participatory design framework outlined in [18], which is tailored to mental health systems, we involved providers in designing a system that could meet their needs. We used interviews and focus groups with a variety of users, and iteratively showed design mockups to users for feedback. We report on the design recommendations that emerged from this process.

3. FINDINGS

The documentation and communication practices we observed, which we call "collaborative reflection", had four characteristics: they were (1) unstructured, (2) mobile, (3) reciprocally interdependent, and (4) long-term.

Prior use of the term collaborative reflection by Prilla *et al.* [26] describes people's reflections on their experiences and memories to aid learning. In this paper, we use the term differently, to mean pooling and reflecting on patient data to aid decision-making. In the sense that it emphasizes collaborative information sharing and decision making, our use of the term is similar to what has been called collaborative sensemaking, *e.g.,* [22]. However, the sensemaking concept has often been used to describe information seeking, time-critical decision-making, and the input of individuals who are not reciprocally interdependent—aspects that were not part of the collaboration we observed. Prior work on collaborative sensemaking within the domain of children with special needs has focused largely on information sharing practices (e.g., [24]), especially to increase the accuracy of data collection (e.g., [12]). In contrast, we are concerned with supporting communication and collaboration for interpreting and using the subjective data that are collected in this domain.

The teams we studied reflected on data to monitor students' long-term behavioral change and treatment. As change occurred, the teams retrospectively re-interpreted data. They were reciprocally interdependent in decision-making, meaning that each depended on others to do their work, and decisions were often jointly made. Thus our use of the term reflection rather than sensemaking. Our idea of reflection draws from personal informatics, where the same process has been studied within an individual [15].

3.1 Unstructured

Treatment teams used face-to-face communication and paper records in unstructured ways for virtually all of their collaborative work. We observed many informal interactions during which critical information and expertise were being transferred informally among team members. Therapists used the few minutes they were physically in the classroom to check in with a child's classroom staff, consisting of a teacher and several teaching aides. For example, an occupational therapist took a child from his classroom twice a week for a one-on-one therapy session. The therapist picked up the student from his classroom, walked him to her office for the session, and then escorted him back to his classroom afterwards.

In one instance of the brief interaction when an occupational therapist brought a student back to his classroom, there was a discussion about generalizing the skills learned in therapy. The therapist had used the day's session to work on the task of the child putting on his jacket independently. She asked the classroom staff what they typically do with his jacket at the end of every school day; do they hand it to him or put it on for him? She suggested they hand it to him, since he had shown enough progress that he should be able to put his jacket on by himself. Practicing everyday when he left school would help him to continue making progress. This informal communication based on the therapist's observations was one example of how unstructured practices were more effective for treatment team collaboration than structured records and practices.

The flexibility and adaptability of paper records accorded staff the ability to more easily coordinate their unstructured work. Staff considered paper-based notes, charts, and to-do lists flexible and easy to use. For example, jotting something on a post-it note reminded a team member to share some information with someone else on the team. Paper data sheets and reports, although they typically comprised a form or template for tracking children's behavior and problems over time, also offered the opportunity for unstructured communication. Our observations of the appropriations of paper and frequency of *ad hoc* interactions helps to explain the ways in which information technology failed to meet the team's needs, as similarly reported in [18], [23], and [30]. In our study, we saw that the process of reflecting involves unstructured and informal work that cannot be formalized.

3.2 Mobile

Team members exchanged information and knowledge in multiple places: meeting rooms for formal meetings, and informal interactions in hallways, classrooms, and the cafeteria. They used multiple resources, not just word of mouth, but also paper data collected in different ways by different people. Spontaneous informal meetings among team members happened everywhere. Team members might be in a formal meeting reviewing a child's case, they might be engaging with a child together, or they might run into one another in the hallway and have something to discuss about a child.

In their study of collaboration in hospitals, Bardram and Bossen [2] identified four aspects of what they call mobility work: resources, persons, places, and knowledge. These observations resonate with ours. We found that paper records were critical resources that were shared and discussed within teams; the persons involved in reflecting on the data were a variety of specialists that make up a treatment team; the places where interaction takes place ranged from conference rooms (formal) to hallways (informal) to classrooms (at times chaotic); and finally, that reciprocal interdependence drove exchange of knowledge.

3.2.1 Resources

Behavioral data were recorded on a regular basis to evaluate and support a child's unique needs with customized interventions. Behaviors were recorded in two ways: positive behaviors that interventions aimed to increase (*e.g.*, following directions, appropriate social interactions) or negative behaviors that interventions aimed to decrease (*e.g.*, verbal or physical aggression, anxiety-induced avoidance of social situations).

Teams implemented a token economy—a type of psychotherapy typically used for behavioral intervention, which reinforces desired behavior through the tracking of tokens (or points) that

can be exchanged for rewards. The token economy was the main part of their data collection, and together with some free form note taking, formed the records used to regularly assess and make decisions about the individualized support provided to each child.

The teams struggled to find appropriate computer-based tools to support recording and use of data [18]. Much of their process was paper-based and cumbersome. Records were paper data sheets and paper scatter plots. Data were frequently transferred among various forms and reports. Summaries were overly abstracted, and human errors were difficult to avoid. Data were ultimately stored in binders, where they were not easily reviewed or shared.

3.2.2 Persons

Both programs had psychiatrists, mental health therapists, behavioral specialists, educators, personal aides, speech therapists, and occupational therapists. Each child was assigned a treatment team consisting of a subset of these specialists, based on the unique behavioral and mental health needs of that child.

Due to the difficulty of reviewing and sharing data, teams most often made decisions based on anecdotes, intuition, and highly abstracted data. While teams were able to achieve positive outcomes using these methods because they primarily needed to rely on human intuition and expertise, they recognized that significant untapped potential lay in the data, which was not used enough in determining trends and evaluating interventions.

3.2.3 Places

Team members were collocated within the school building. Their work practices were both synchronous and asynchronous. Teaching staff stayed mostly within the bounds of their classroom. Other staff, such as therapists and supervisors, worked across classrooms and moved throughout the school during the workday. Therapists moved between classrooms on a schedule, while supervisors were on call and moved between classrooms based on where they were needed.

Treatment team meetings, the only time team members were all in the same place at the same time, were held monthly. The long-term process of recording and using student data was therefore embedded in everyday practices that took place across different locations within the school building. Staff spent the majority of their time working directly with the children, leaving little time for formal collaboration. They most often discussed data when running into one another in the hallway; they discussed a child's case in detail once a month at the formal treatment team meeting.

3.2.4 Knowledge

An administrator described to us how she would like to use information technology to share knowledge:

> *"Data basically needs to be available to the rest of the team, parents, therapy providers, changes in staff, supervisors. It needs to be analyzed on many different dimensions: within classrooms, across the school, across gender."*

Her description reveals two aspects of how her program manages data and knowledge First, the entire treatment team (and ideally even stakeholders outside the team such as parents) is involved in analyzing the data to make sense of what it says about a child's progress with treatment. Second, the program is limited in how much it is able to analyze paper-based data for trends.

Team members contributed different types of knowledge, because they had different experiences with a child, and different perspectives and expertise based on their backgrounds. For example, a behavioral specialist depended on a therapist for direction in applying an intervention, and a therapist depended on a behavioral specialist for day-to-day information about how a child is responding to an intervention and progressing. We therefore found team members to be reciprocally interdependent.

3.3 Reciprocally interdependent

Reciprocal interdependence exists in a relationship in which both parties rely on one another for information to be able to complete their work [29]. Reciprocal interdependence requires more than information sharing, it involves frequent communication and knowledge sharing. The team members we studied were reciprocally interdependent for several reasons: data were collected by multiple staff members and later aggregated; staff had unique experiences and data about one child; and staff were drawing knowledge from different areas of expertise.

Team members were reciprocally interdependent because they each only knew part of the narrative making up a child's story and trajectory. Team members worked with the same child in different contexts, so they each developed unique knowledge based on different behaviors they were witness to in different situations. Treatment teams integrated all of these perspectives through collaborative reflection, to understand a child's progress and make treatment decisions over time.

Team members were distributed along a spectrum of specialized knowledge, illustrated in Figure 1. Those who spent most time with the children had detailed knowledge about their day-to-day life, behaviors, progress, personality, and needs. These individuals, represented by the bottom of the lower triangle in Figure 1, were parents and paraprofessionals (*e.g.*, teaching aides, personal care assistants). Some had formal training or expertise, and all applied practical knowledge from working hands-on with a focused caseload or loved one. Domain experts, represented by the top triangle in Figure 1, were clinical supervisors and psychiatrists. They managed a larger caseload, so they had a high-level understanding of each child without day-to-day details. These professionals used their expertise and knowledge of best practices to provide diagnosis, prescriptions, treatment plans, and other high-level direction.

Some team members, such as therapists, fell somewhere in the center of the spectrum. For example, speech therapists had expertise in speech-language pathology and applied it to their work with the same child once or twice a week. Although they had some regular contact with the child, outside of these one-on-one therapy sessions, speech therapists depended on other staff members for information about the child's regular progress.

Figure 1. Team members were distributed along a spectrum of knowledge, creating reciprocal interdependence.

3.4 Long-term

The safety-critical aspect of behavioral and mental health services is long-term rather than immediate. Teams tracked children's behaviors over time, and we heard references to concepts such as "predictors" of behaviors over time. One of the schools tracked treatment periods of 20 days, comparing the current treatment period with the previous treatment period to evaluate the effects of interventions. Treatment team meetings were for reflecting on a child's progress and making decisions about interventions for the next treatment period.

Our observations brought to light information practices that held long-term weight in two ways. First, a multitude of daily decisions could impact long-term outcomes for a child. Second, the focus on change over time required records of children's behavior over time that could be compared, not just for change but also for "predictors." With good, easily accessible information, providers would be able to review large amounts of information and corroborate interpretations and decisions with others. Unfortunately, the mass of paper data in pages of charts and notes were not as useful as they might be for this purpose, as the data could not be manipulated or viewed in different ways to answer questions about a child's progress and treatment.

Our findings demonstrate a need for information technology that can support an understanding of information over time; help users identify and explain trends over time; and even help to predict behaviors or outcomes into the future.

4. COLLABORATIVE REFLECTION

The workflow we observed was not adequately supported by information technology. Treatment teams had evaluated existing technologies, especially iPad apps. They told us that none were an improvement over their paper methods. The limitations of apps they had tried, documented in more detail in [18], included poor usability, lack of scalability for their number of students, and lack of flexibility for recording and sharing data in their distributed environment. Improving their paper methods remained an unsolved problem:

> *"We have [records] that have to be filled out every day. A ton of paper [is] being wasted. Can we do this electronically?. . . If you're looking for information on what's being done each and every day there should be somewhere you can go."*

The challenges our field sites faced with incorporating information technology to help them record and share their data were similar to those experienced in other settings [19][21][23], suggesting that the collaborative processes we focused on are relevant for a variety of domains and systems.

We named the process we observed collaborative reflection because team members were reciprocally interdependent on one another's knowledge and had to collaborate in interpreting data to make long-term treatment decisions. Further, making these ongoing decisions required retrospective reflection on the data as they changed over time. Figure 2 illustrates the collaborative reflection process, consisting of two iterative loops.

The long-term outer loop contains four collaboration points over time, where team members have reciprocal interdependence. First, staff reflect on a child's behavioral data to understand the needs of the child and determine an appropriate intervention. Second, multiple staff members may be involved with an intervention. Reflecting on child data together helps staff apply the intervention consistently, for example, by comparing child

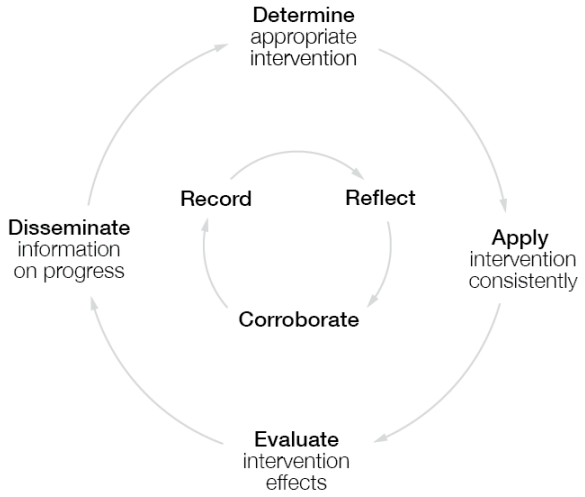

Figure 2. The collaborative reflection process, consisting of a short-term inner loop and a long-term outer loop.

responsiveness and immediate progress with different staff members, or by sharing successful strategies for applying the intervention and working with that child. Third, staff evaluate the effects of an intervention by reflecting on the child's data over time. Fourth, staff disseminate information on the child's progress to others on the team, to providers not on the team, or to caregivers or family members.

The short-term inner loop shows how interdependent team members work together everyday to develop a shared understanding, which they draw on to make ongoing treatment decisions. Team members record data, reflect on the data both individually and collaboratively, and corroborate interpretations of the data with others.

4.1 Interaction between loops

At each stage of the long-term outer loop, teams draw upon the collective knowledge they have developed within the inner loop. As team members contribute individual knowledge to recording and reflection, this integration of knowledge, and the process of corroborating knowledge and evidence (inner loop), enables the team to interpret data collaboratively and use their collective knowledge to make treatment decisions over time (outer loop).

The connection between the two loops represents a sociotechnical system because knowledge in organizations "often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices, and norms" [7], p. 5. Our findings suggest that this sociotechnical process has not been supported in full by information technologies such as EHRs.

4.2 The role of information technology

Scrutinizing the process of collaborative reflection, we can identify the overlooked dimensions of coordination discussed by Mentis [19]. For example, information technology must not only improve efficiency and reduce human error, but also support the informal social practices that surround collaborative reflection. The paper-based systems we observed did not adequately support these processes.

With existing paper-based systems for collecting data on a child, the data were stored in the form of hard-to-read scatter plots or

overly abstract monthly reports. Data stored in heavy binders were not easily accessed or shared. Sometimes one staff member would be the keeper of the data and responsible for transferring information from data sheets to graphs or reports for others to use, making human error difficult to avoid, and making staff dependent on one person's interpretation and handling of data. Similar findings have been reported in other settings, *e.g.*, [2][19], demonstrating that what we observed was not domain specific. In the following section, we discuss design recommendations to address these problems.

5. DESIGNING FOR COLLABORATIVE REFLECTION

Working together with the providers whose interactions we had studied, we used a participatory design process to explore the design of an information system that supports collaborative reflection. Seven design recommendations emerged for information systems to support the two iterative process loops of collaborative reflection.

5.1 Short-term loop: creating a shared understanding

Treatment teams record, reflect on, and corroborate their interpretations of data, and through this interdependent process they create a shared understanding of a child's progress that they rely on in their day-to-day collaboration. Teams with reciprocal interdependence need technology that supports frequent communication, information sharing, and knowledge sharing [29]. We describe design recommendations for supporting these short-term practices of collaborative reflection.

5.1.1 Record

There is significant opportunity to improve consistency in the recording of data. Existing paper-based data sheets are cumbersome, time-consuming, and at high risk for human error. Data reliability is also an issue due to data being collected separately, at different times, in different locations, by different staff members. Efforts to maintain reliability are limited to staff training once a year followed by occasional reliability checks. Others have also noted the challenges with the reliability of records over time when multiple providers contribute to the records (*e.g.*, [24]).

An information system with mobile devices as point of access to patient records could replace paper-based data sheets. Yuill, Rogers, and Rick's [31] work with iPads suggest such a transition could be made and could improve data reliability. However, to promote reliability, an information system cannot force structure and rigidity throughout the system. Our findings demonstrate the importance of unstructured practices. Therefore, whereas some structure can be used to support reliable records, significant flexibility should be maintained in other areas of the system, for example, requiring a form to be completed in a particular way but allowing subjective notes to be added.

Recording accurate data in the moment is challenging, and staff adopted unique practices to help them accomplish their work as conveniently as possible, in a way that worked for them. Freeform annotations and note taking, mimicking jotting down notes on the margins of a piece of paper or on a post-it note, exemplify the flexibility that could accommodate variance in personal practices.

Teams also require flexibility. Teams develop workarounds and routine practices based on their experience. An information system could support this process by enabling members of a team to compare and discuss how members are recording data. Teams could be encouraged to develop a common structure by providing the flexibility and communication tools for team members to become aware of which elements of their individual practices work best.

On multiple occasions we uncovered inconsistencies in the implementation of data recording practices. Most of the time we found contradictions between supervisors, who promulgated ideal recording practices, and behavioral specialists working in the classroom, who recorded data as they could in the moment. Sometimes our participants were unaware of their contradictions, and sometimes we acted as mediators to find a compromise between the ideal and the realistic. The process of designing a novel EHR system became a means for teams to discover and resolve these inconsistencies. We therefore saw a need for systems to have the flexibility to enable team members to record data in slightly different ways, so they could have the freedom to adjust their recording practices within the bounds of required data collection. We found that our emphasis on flexibility gave those recording the data more of a voice in their practices and lowered their feeling of being constrained by the paper forms provided by their supervisor for recording data.

5.1.2 Reflect

Flexibility and adaptation to practices are also important for reflection. One example of adaptation that we learned about from team members was their way of representing behavioral data by absolute points earned (20/40) versus percentage of points earned (50%). Different team members were reporting and discussing data based on their personal preference for one of the two representations. Over time, during the participatory design discussions, they realized that each of the two representations revealed different aspects of a child's progress. As a result, they began to change their recording and reflection practices. Percentages helped them review data long-term because percentages accounted for variations in points possible (for example, due to a half day or a student arriving late for school). Absolute points were harder to reflect on long-term because the denominator could change, but absolute points gave a more complete picture of a particular day or short-term period.

During reflection among team members, they shared knowledge by exchanging anecdotal accounts and second-hand evidence. Collaborative reflection took place primarily during everyday informal interactions, when data might not be at hand, as during a conversation between two teaching aides across the room while they were working with different children, or in a discussion when two staff members ran into one another in the hallway. We concluded that reflection could be improved by making data accessible in this kind of context so that data could be displayed and discussions could involve first-hand interpretations of data.

The teams we studied specifically and repeatedly requested that they have iPads for managing behavioral data. Although some of their opinions might have been influenced by the popularity of the iPad, we agreed that handheld tablets could enable the *ad hoc* peer-to-peer based interaction prescribed by Bardram and Bossen [2] for supporting mobility work. Yuill *et al.* argue that tablets could play the role of Weiser's scrap computers (similar to scrap paper) because they can "readily flip between being personal and being shared, potentially enabling more fluid transition between

individual and group working" [31], p. 949. Their aim of enabling fluid transition between individual and group work is similar to our ideas of supporting fluid interaction between individual and group reflection to inform treatment over time.

Yuill *et al.*'s study compared the use of paper and iPads for collaborative work (via a game of co-creation). They found that iPads afforded similar social behaviors and workflow as paper, and improved group creativity. These findings bode well for a transition from existing paper-based practices to information technology. If this transition could be as smooth as Yuill *et al.*'s findings suggest, then these devices could more effectively support collaborative reflection.

5.1.3 Corroborate

When team members have different areas of expertise and different perspectives, converging their interpretations of the same data can be challenging. By making it easier for teams to access and review data, information technology could increase opportunities for team members to share their interpretations of data. Because different expertise is likely to cause different interpretations of data, the more teams discuss and corroborate their interpretations, the higher the likelihood that they will able to integrate them and correct inaccuracies.

One way to support corroboration is to provide more ways for team members to communicate. We observed the use of email, cell phones, landline classroom phones, meetings, and *ad hoc* interactions in the hallway. An EHR system could provide additional means of reaching other team members, such as through group messages with links to data, discussion forums around visualizations of data, and notifications based on automated analyses of data as they are recorded and aggregated.

Multiple representations of data also could help members of a treatment team discuss the data in different ways. For example, data can be shown in a scatter plot or a bar chart, and data can be shown by week or by month. Looking at the data in different ways could help teams broaden discussions and possibly share more varying interpretations. Multiple views could therefore aid corroboration by helping team members to identify where there are diverging interpretations, and what should be discussed in order to develop a shared understanding as a team.

Further research is required to investigate the effects of a significant change in the representation of data. Existing paper-based data management enables little more than scatter plots created by hand. The staff we observed did not have the means to perform statistical analysis even as simple as correlations, and few had appropriate training in data analysis. As a result, we expect new representations of their data to be a significant change in their practices. Understanding how this change will affect providers and their interpretations will inform the design of information systems for collaborative reflection.

5.2 Long-term loop: making treatment decisions over time

Treatment teams we observed drew upon their shared understanding of a child's progress to make decisions over time. The outer loop of our collaborative reflection model shows four long-term collaboration points at which team members were especially interdependent. An information system could provide the infrastructure to enable team members to connect at these points in time to make decisions for the course of treatment.

5.2.1 Determine appropriate intervention

Reflecting on a child's progress with treatment over time enabled staff to understand how a child responded to various interventions. Identifying and predicting trends over time could inform and empower decision-making about interventions going forward. Advanced visualizations and automated analytics could make the identification of trends much simpler, and allow team members to collaborate on assigning meaning to the trends.

5.2.2 Apply intervention consistently

With the ability to view aggregated data that have been collected by multiple team members, treatment teams could monitor the application of interventions and ensure consistency. The effects of an intervention are closely tied to providers' ability to apply it consistently across time and context. For example, behavioral interventions need to be generalized across contexts in order for a child with special needs to adhere to the new behavior consistently. Information technology could help all relevant team members reflect on the agreed-upon intervention, and could also be used to verify the consistency of its application.

5.2.3 Evaluate intervention effects

Staff often followed their intuition, based on their expertise and human judgment, to understand how a child was responding to an intervention and to adjust the intervention accordingly. This intuition is critical and cannot be mimicked or replaced, but it could be supported with data. A mobile system that made a child's data accessible anywhere and anytime could help team members test their intuition against data, and present them to others on the team for corroboration.

5.2.4 Disseminate information on progress

Team members we observed spent a lot of time updating one another on activities and progress someone may have missed, because everyone needed to be included before discussion and decision-making could happen. Some staff reported not learning about important updates or changes to treatment plans until weeks or months later. An information system that gave all team members access to the same data and intervention information and allowed them to easily connect with one another could help the teams disseminate information more effectively.

6. CONCLUSION

Team-based decision-making is becoming more common in health services, as evidenced by recent trends in both research and practice. Teams face increasingly complex decision-making due to a rise in the prevalence of chronic conditions that span time, organizations, and providers (*e.g.*, autism, asthma, diabetes). Providers have recognized the necessity of team-based medicine for meeting the needs of patients with complex and chronic conditions involving long-term treatment [14], p. 21. Researchers have focused on improving coordination and continuity of care over time and place [20]. Both providers and researchers assert the promise of information technologies to improve information exchange and communication among treatment teams [10][14], p. 71. This paper contributes to this literature by identifying and describing the informal documentation and communication practices that comprise the process of collaborative reflection, and providing design recommendations for EHRs to support these processes.

7. ACKNOWLEDGEMENTS

We are grateful to the teams and organizations we observed in our fieldwork. This research was supported by the National Science Foundation under Grant No. CCF-1029549, and by a National Science Foundation Graduate Research Fellowship to the first author under Grant No. 0750271.

8. REFERENCES

[1] Abraham, J. and Reddy, M.C. 2008. Moving patients around: a field study of coordination between clinical and non-clinical staff in hospitals. In *Proc CSCW* (2008), 225-228.

[2] Bardram, J.E. and Bossen, C. 2005. Mobility Work: The Spatial Dimension of Collaboration at a Hospital. *Computer Supported Cooperative Work* 14, 2 (2005), 131-160.

[3] Bardram, J.E., Hansen, T.R., and Soegaard, M. 2006. AwareMedia: a shared interactive display supporting social, temporal, and spatial awareness in surgery. In *Proc CSCW* (2006) 109-118.

[4] Beyer, H. and Holtzblatt, K. 1998. *Contextual Design: Defining Customer-Centered Systems*. Morgan Kaufmann Publishers, Inc., San Francisco, CA.

[5] Charmaz, K. 2006. *Constructing grounded theory: A practical guide through qualitative analysis*. Sage, London.

[6] Cohen, M.D. and Hilligoss, P.B. 2008. Handoffs in Hospitals: A review of the literature on information exchange while transferring patient responsibility or control [online]. Deep Blue.

[7] Davenport, T.H. and Prusak, L. 1998. *Working Knowledge: How Organizations Manage What They Know*. Harvard Business School Press, Cambridge, MA.

[8] Harrison, M.I., Koppel, R., and Bar-Lev, S. 2007. Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis. *JAMIA* 14, 5 (2007), 542-549.

[9] Hayes, G.R. The Relationship of Action Research to Human-Computer Interaction. *ToCHI* 18, 3 (2011), 15.

[10] Jee, S.H. and Cabana, M.D. 2006. Indices for Continuity of Care: A Systematic Review of the Literature. *Med Care Res Rev* 63 (2006), 158-188.

[11] Kane, B.T., Toussaint, P.J., and Luz, S. 2013. Shared decision making needs a communication record. In *Proc CSCW* (2013), 79-90.

[12] Kientz, J.A., Hayes, G.R., Abowd, G.D., and Grinter, R.E. 2006. From the War Room to the Living Room: Decision Support for Home-Based Therapy Teams. In *Proc CSCW* (2006), 209-218.

[13] Kolko, J. 2011. *Exposing the Magic of Design: A Practitioner's Guide to the Methods and Theory of Synthesis*. Oxford University Press.

[14] Lawrence, D. 2002. *From Chaos to Care: The Promise of Team-based Medicine*. De Capo Press.

[15] Li, I., Dey, A., and Forlizzi, J. 2010. A stage-based model of personal informatics systems. In *Proc CHI* (2010), 557-566.

[16] Lofland, J., Snow, D.A., Anderson, A., and Lofland, L.H. 2006. *Analyzing Social Settings: A Guide to Qualitative Observation and Analysis* (4th Ed), Thomson Wadsworth.

[17] Marcu, G., Bardram, J. E., and Gabrielli, S. A 2011. Framework for Overcoming Challenges in Designing Persuasive Monitoring Systems for Mental Illness. In *Proc PervasiveHealth* (2011), 1-8.

[18] Marcu, G., Tassini, K., Carlson, Q., Goodwyn, J., Rivkin, G., Schaefer, K., Dey, A. K., and Kiesler, S. 2014. Why Do They Still Use Paper? Understanding Data Collection and Use in Autism Education. In *Proc CHI* (2013), 3177-3186.

[19] Mentis, H.M. 2010. Emotion Awareness and Invisibility in an Emergency Room: A Socio-Technical Dilemma. Doctoral Dissertation. The Pennsylvania State University.

[20] Miller, A.R., Condin, C.J., McKellin, W.H., Shaw, N., Klassen, A.F., and Sheps, S. 2009. Continuity of care for children with complex chronic health conditions: parents' perspectives. *BMC Health Services Research* 9 (2009), 242.

[21] Niazkhani, N., Pirnejad, H., Berg, M., and Aarts, J. 2009. The Impact of Computerized Provider Order Entry Systems on Inpatient Clinical Workflow: A Literature Review. *JAMIA* 16 (2009), 539-549.

[22] Paul, S. and Reddy, M. 2010. Understanding Together: Sensemaking in Collaborative Information Seeking. In *Proc CSCW* (2010), 321-330.

[23] Park, S.Y., Pine, K., and Chen, Y. 2013. Local-universality: designing EMR to support localized information documentation practice. In *Proc CSCW* (2013), 55-66.

[24] Piper, A.M., D'Angelo, S., and Hollan, J.D. 2013. Going Digital: Understanding Paper and Photo Documentation Practices in Early Childhood Education. In *Proc CSCW* (2013), 1319-1328.

[25] Piper, A.M. and Hollan, J.D. 2008. Supporting medical conversations between deaf and hearing individuals with tabletop displays. In *Proc CSCW* (2008), 147-156.

[26] Prilla, M., Degeling, M., and Herrmann, T. 2012. Collaborative reflection at work: supporting informal learning at a healthcare workplace. In *Proc GROUP* (2012), 55-64.

[27] Sarcevic, A., Marsic, I., and Burd, R. S. 2012. Teamwork Errors in Trauma Resuscitation. *TOCHI* 19, 2 (2012), 13.

[28] Sarcevic, A., Weibel, N., Hollan, J.D., and Burd, R.S. 2012. A paper-digital interface for information capture and display in time-critical medical work. In *Proc PervasiveHealth* (2012), 17-24.

[29] Thompson, J.D. 2013 [1967]. *Organizations in Action: Social Science Bases of Administrative Theory* (With a new preface by Mayer N. Zald and a new introduction by W. Richard Scott ed.). New Brunswick, New Jersey: Transaction Publishers.

[30] Weibel, N., Emmenegger, C., Lyons, J.;,Dixit, R., Hill, L.L., and Hollan, J.D. 2013. Interpreter-mediated physician-patient communication: Opportunities for multimodal healthcare interfaces. In *Proc PervasiveHealth* (2013), 113-120.

[31] Yuill, N., Rogers, Y. and Rick, J. 2013. Pass the iPad: Collaborative creating and sharing in family groups. In *Proc CHI* (2013), 941-950.