The impact of adopting EHRs: how losing connectivity affects clinical reasoning

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CONTEXT As electronic health records (EHRs) are adopted by teaching hospitals, educators must examine how this change impacts trainee development.

OBJECTIVES We investigate this influence by studying clinician experiences of a hospital’s move from paper charts to an EHR. We ask: how does each chart modality present conceptions of time and data interconnections? How do these conceptions affect clinical reasoning?

METHODS This two-phase, longitudinal study employed constructivist grounded theory. Data were collected at a paediatric teaching hospital before (Phase 1), during and after (Phase 2) the transition from a paper chart to an EHR system. Data collection consisted of field observations (146 hours involving 300 health care providers, 22 patients and 32 patient family members), think-aloud (n = 13) and think-after (n = 11) sessions, interviews (n = 39) and document retrieval (n = 392). Theories of rhetorical genre studies and visual rhetoric informed analysis.

RESULTS In the paper flowsheet, clinicians recorded and viewed patient data in chronologically organised displays that emphasised data interconnections. In the EHR flowsheet, clinicians viewed and recorded individual data points that were largely chronologically and contextually isolated. Clinicians reported that this change resulted in: (i) not knowing the patient’s evolving status; (ii) increased cognitive workload, and (iii) loss of clinical reasoning support mechanisms.

CONCLUSIONS Understanding how patient data are interconnected is essential to clinical reasoning. The use of EHRs supports this goal because the EHR is a tool for collecting dispersed data; however, these collections often deconstruct data interconnections. Where the paper flowsheet emphasises chronology and interconnectedness, the EHR flowsheet emphasises individual data values that are largely independent of time and other patient data. To prepare trainees to work with EHRs, the ways of thinking and acting that were implicitly learned through the use of paper charts must be made explicit. To support clinical reasoning, medical educators should provide lessons in connectivity – the chronologically framed data interconnections upon which clinicians rely to provide patient care.
INTRODUCTION

Electronic health records (EHRs) are being adopted in health care centres around the world and are increasingly used by teaching hospitals (i.e. academic health centres [AHCs]).1–4 In fact, 69% of the EHRs used in the USA in 2011 were owned by AHCs.3 Given this prevalence, most medical trainees are likely to be educated in at least one setting in which an EHR is used. Research has established that learning how to communicate in a professional setting (e.g. learning to use an EHR) exerts a developmental, socialising force on novices.5–7 The impact of EHRs on trainee development must be critically examined, especially as EHR use has been shown to entail both beneficial8,9 and problematic consequences.10,11

Despite the pervasiveness of EHRs in AHCs, researchers have only begun to investigate the impact of EHRs on medical education. In each of three recent literature reviews, fewer than 50 publications addressing the effects of EHRs on medical education were identified (4712 in 2012, and 4213 and 4914 in 2013). In their review, Ellaway et al.13 warn that ‘EHR systems are not yet well integrated into mainstream medical education’. Tierney et al.14 report that, in relation to the Accreditation Council for Graduate Medical Education core competencies, EHR use has been associated with both educational benefits and challenges. Among the themes reported, these reviews suggest that trainees are not receiving sufficient guidance on how to use EHRs,13 that EHR use affects how trainees learn to care for patients,14 and that EHRs present an ever-expanding array of educational opportunities that medical educators must both consider and contend with (e.g. clinical decision support systems).13,14 One subset of this literature studies how EHRs impact trainees’ clinical reasoning skill acquisition, describing how the EHR can support15 but also detract16,17 from the development of these skills.

Scholars investigating the impact of EHRs on medical education commonly caution that more research is necessary for EHRs to be responsibly integrated into AHCs.13,14,18 As EHRs change AHCs’ environments, it stands to reason that our paper chart-oriented pedagogy must evolve.12 The question is: how?

As part of a larger study aimed at understanding how EHRs impact health professionals’ interprofessional communication and collaboration, we explored the emerging finding of how changing from a paper chart to an EHR can impact clinician reasoning. In this paper, we report on the analysis of one chart communication tool that lucidly illustrates a set of themes that emerged during our investigation. Participants from all disciplines and across all participating units relied heavily on flowsheets in their clinical work (including, for example, a respiratory assessment flowsheet, a pain assessment flowsheet and a complex care monitoring flowsheet) – a practice that is congruent with other research findings.19,20 We report our analysis of health professionals’ use of flowsheets using the paediatric intensive care unit (PICU) flowsheet to illustrate clinicians’ interactions with and responses to flowsheets in paper and EHR formats. This analysis examines: (i) how each chart modality presents conceptions of time and data interconnections, and (ii) how these conceptions impact clinicians’ clinical reasoning. This analysis led our team to identify and explore a phenomenon we call ‘connectivity’.

METHODS

This qualitative study was conducted at a paediatric AHC from June 2009 to December 2011. Ethics approval was obtained from the AHC’s and its affiliated university’s research ethics boards.

Setting and study design

In June 2010, the participating AHC implemented an EHR (Sunrise Clinical Manager Version 5.0; AllScripts Healthcare Solutions, Inc., Chicago, IL, USA). During this longitudinal, two-phase study, we collected and analysed data when a paper patient chart was used by health care teams (Phase 1: 11 months) and when the EHR was launched and adopted by these same teams (Phase 2: 18 months). Based on constructivist grounded theory21,22 and employing an approach similar to that used by Lingard et al.23 we tracked individual patients (22 in total: 10 in Phase 1; 12 in Phase 2) from the PICU to an in-patient unit and through to hospital discharge. We collected all patient-related communications as clinicians responded to patient needs. We purposefully recruited patients whose treatment required collaboration from at least three health care professions over extended periods of time to maximise the range of communications employed. We did not sample patients for disease category or any other patient population criteria.
Data collection

We used four data collection techniques, conducted concurrently and integrated with analysis (Table 1). Data collection involved 354 participants, including 22 patients, 32 parents, 40 staff physicians, 66 residents, 11 medical students, 121 nurses and 62 allied health professionals. We employed a passive consent with active dissent process in the observational data collection component of the study. Only one clinician declined to participate. Patients and their parents participated in single phases of the study and so were not tracked across EHR implementation. By contrast, many care providers participated in both phases, including 14 staff physicians (35.0%), 12 fellows and residents (18.2%), 23 nurses (19.0%), and 11 allied health professionals (17.7%). We conducted non-participant field observations24 (146 hours) of all intra- and interprofessional patient care-related interactions. We conducted 39 semi-structured interviews25 with patients and their family members and clinicians, using purposive sampling26 to ensure broad representation of professions and levels of experience. We collected 392 paper and electronic documents that were formally and informally used to support care delivery. We conducted 13 think-aloud27,28 and 11 think-after29 sessions on clinicians’ EHR use.

Data analysis

Data analysis was conducted in an iterative and constant comparison manner.22 All authors participated in three iterative coding cycles: open; axial, and theoretical.22 During open coding, we generated descriptive codes, clustered by similarity into categories that represented concepts common across the dataset. In axial coding, we explored patterns and interconnections among categories, and reviewed a range of literatures (both theoretically and research topic-oriented) to see how they might inform our understanding of emerging themes. During axial coding, we generated additional analysis questions. We collected additional data to vet these emerging questions until no new insights were generated. During theoretical coding, we finalised the interconnections between the coding levels and the literature reviewed. Across these coding phases, we developed and iteratively refined the concept of connectivity presented in this paper. The final coding structure was applied to the entire dataset using NVivo Version 9 (QSR International Pty Ltd, Doncaster, Vic, Australia). Across all cycles, 135 hours of team meetings were held to complete analysis activities. We maintained an audit trail of all study processes using the Study CV20 format. In January 2012, we shared a summary of study findings with approximately 35 employees of the AHC (including staff physicians, nurses and members of the AHC administration) in an interactive workshop setting as a member checking activity. These strategies supported methodological trustworthiness.31

Theoretical frameworks

During axial and theoretical coding processes, we determined that rhetorical genre studies (RGS) and visual rhetoric could usefully inform our understanding of the data. We analysed paper- and EHR-based flowsheets as genres. Historically, genres have been defined and used as a means of classifying texts. More recently and across many fields, including RGS, genres have been acknowledged as powerful ideological shapers of meanings and social actions.3,32 Scholars of RGS examine genres as embodiments of cultural knowledge that structure and inform the way people think and act.5 Research in RGS examines how genres shape our understandings and actions in a range of professional settings, including health care.6,33-35 When recognised as manifestations of situated cognition,36 genres are understood as shaping cognition through the information conveyed (content) and the organisational features that structure the conveyed information (form). In communicating through a genre, users participate in and reproduce a community’s epistemologies, norms and ideologies.36 In these ways, the genre exerts influence over the user’s understanding, expectations and social actions. Although the communicator is not considered an entirely passive absorber of genre-based influences, RGS critically examines how genres influence understanding.

Visual rhetoric asserts that a genre’s visual elements are value-laden constructs that convey ideological messages.37-39 Scholars in medical education have applied the theories of visual rhetoric to study how visual forms influence trainee attitudes and actions.30,41 For instance, Zibrowski et al.42 used visual rhetoric to explore the relationship between residents’ perceptions of the CanMEDS roles and their in-training assessments. These authors found that the visual layout of the in-training assessments reinforced a hierarchy and a segregation of the roles, and factored into the trainees’ distortion of the CanMEDS construct.42

Taken together, RGS and visual rhetoric posit that attention should be paid to a genre’s content and form because they do more than allow users to communicate. Genres teach users how to think and how to
In specific situations. In this paper, we analyse how one genre – the PICU flowsheet – changed as it moved from a paper- to an EHR-based format. We examine how these two modalities of the same genre required users to engage with and reproduce specific conceptions of time and data interconnections. We examine how clinicians engage in the work of clinical reasoning through these conceptions embodied in these genres, and how these genres in turn work through them.

RESULTS

Echoing the order of our research questions, we first describe how each modality presents conceptions of time and data interconnections, and then present how these conceptions impacted clinicians’ clinical reasoning.

The paper flowsheet

The PICU paper flowsheet was a double-sided document measuring 25.5 \times 11.0\ inc\ inches. Using a landscape orientation, the flowsheet organised most numeric patient data in a grid wherein hourly time (24 hours) was listed along the $x$-axis and data categories along the $y$-axis. Examples of the data categories presented in the flowsheet’s grid include vital signs, respiratory therapy measures, and intake and output measures (Fig. S1). Data were manually entered in numeric form in each cell except for data for vital signs, which were entered as colour-coded graph lines (e.g. respirations in red, pulse in black, etc.). The flowsheet included an 8.0 \times 10.0-inch blank, lined note space for narrative entries – defined as free-text notations – titled ‘Progress Notes’. If more text space was required, clinicians stapled additional progress note pages on top of the flowsheet’s narrative text space.

Rhetorical genre studies and visual rhetorical analyses suggest that chronology and data interconnections were the dominant organising features of the paper flowsheet. Numeric patient data were visually presented by category and by hour. When a clinician manually entered or viewed data, he was required by the genre’s structures to work with the data in chronological relation to all data of (i) that category and (ii) all other data categories in the genre’s grids, as well as with the free-text information found in the progress note section of the flowsheet. For example, data for blood pressure readings were organised horizontally in line with all other blood pressure rates reported by hour – or more frequently as necessary – in the flowsheet. Simultaneously, those blood pressure data were placed vertically in line with other data collected across categories at that hour. In this way, time was used to arrange patient data from the multiple categories in visual and textual relation to one another.

The EHR flowsheet

Although patient data were available for entering and viewing in a genre also referred to as a flowsheet in the EHR, the processes for doing this work were unlike those in the paper-based genre.

All EHR flowsheet data were manually entered. To create a data entry, the clinician opened the EHR flowsheet and then opened a separate pop-up window in which to enter the data value. The clinician either typed in the data value or electronically...
accessed patient monitors to auto-populate the data fields. By entering data in the pop-up window, the data value was documented in isolation from (i) data of the same category, (ii) data of other categories, (iii) timelines, and (iv) narrative entries. For example, when a clinician entered hourly intake via an intravenous infusion, she worked only with that specific data point (Fig. S2). She did not see: (i) other input readings; (ii) data from any other category; (iii) the chronological organisation of any data categories, or (iv) narrative entries. Similarly, to add narrative content, a pop-up window for free-text data would appear in which the clinician could add narrative notes. The note allowed for limited character entry and was virtually ‘attached’ to individual data cells in the flowsheet (e.g. a short narrative note could be attached to a single blood pressure value). Consequently, narrative content was fragmented and spread across flowsheet values. As these two examples illustrate, when entering data, the EHR flowsheet textually and visually detached the data from the continuity of the patient’s timeline and the context of all other patient data.

To view the numeric data entered in the EHR flowsheet, a clinician selected one data category. That selection opened a spreadsheet that numerically displayed data from the selected category in an hourly timeline (Fig. S3). For instance, to view blood pressure data, a clinician accessed the vital signs category of the flowsheet. This selection would change the display to present the spreadsheet of numeric vital sign data, including blood pressure. The EHR flowsheet displayed as many hourly fields as could fit on the computer, laptop or tablet screen. Numeric patient data could thus be viewed in a limited chronological display and in relation to a single category of patient information.

To view a line graph display of a numeric data category, the clinician navigated within the genre to a different data presentation view. For example, to view blood pressure data, the clinician selected the graph viewing option within this category of the flowsheet. At the bottom of the screen, the clinician could select between different views (e.g. flowsheet, graph and summaries) (Fig. S4). Vital sign data were visualised in the graph view as individual graphs, with one graph for each parameter such as temperature, heart rate, respiratory rate and blood pressure. Because these individual graphs were displayed beside or below one another, data were not necessarily visually aligned. This impeded the clinician’s ability to see connections across all data elements. Furthermore, only the data from a single category were graphically displayed at one time; thus data for vital signs could not be visually graphed adjacent to data for intravenous infusions, respiratory therapy measures, etc. In these ways, the EHR flowsheet visually and textually limited the chronological and contextual connections that a clinician could view across data categories.

As for narrative content, it was impossible to collect the free-text notes into a single whole. They remained fragmented and distributed across flowsheet data points in viewing modes.

The EHR did contain numeric data retrieval visualisation genres more closely aligned with the paper flowsheet’s chronological and data-interconnected structures. For instance, a graphical overview of the patient’s condition was available in the Clinical Data Viewer (Fig. S5). However, these genres existed beyond the EHR flowsheet. To see these visualisations, the clinician was required to access another part of the EHR external to the EHR flowsheet genre.

Impact on clinicians

Clinicians described several effects resulting from the change from paper flowsheet to EHR flowsheet, but chief among these were: (i) not knowing the patient; (ii) increased cognitive workload, and (iii) loss of clinical reasoning support mechanisms. We illustrate these effects with participant quotes labelled with the professional participant’s number (e.g. Physician 4) and data collection type (e.g. observation).

Not knowing the patient

Clinicians of all professions were frustrated that the EHR flowsheet impeded their ability to know a patient’s evolving status and how the patient data linked together to inform the care plan. Clinicians had difficulty familiarising themselves with the patient’s data in the EHR flowsheet’s textual and visual layout, a data retrieval process:

Instead of looking at a complete picture, it [the EHR] forces me to separate it. Instead of putting it on one page, it’s separating all my information, everywhere.(Nurse 39, interview)

Clinicians perceived that knowing the patient became problematic because the EHR flowsheet layout required them to adopt new ways of thinking and working:
I felt, some days [when using the EHR flow-sheet], “Did I really know what was going on with my patients?” because it was a new way of working and thinking and the data was presented differently. It looks so different on the computer than it did on the handwritten sheets. (Paediatrician 7, interview)

Although clinicians recognised that the EHR provided them with access to more patient data, they reported that this massive amount of data did not enable them to know their patients in more depth. In fact, they lamented the loss of the paper flow-sheet’s comprehensive data assemblage:

We have a huge amount of information but there is nowhere it’s truly collected. (Physiotherapist 1, interview)

Furthermore, the EHR interface presented all data points and displayed each point as equally important. This created an overwhelming display of undifferentiated data, forcing clinicians to spend excessive amounts of time sifting through the data in order to ascertain the patient’s particular situation. Participants did not have time for this sifting work, which resulted in a sincere concern that clinicians did not comprehensively know their patients.

The problem of not knowing the patient was compounded by automatic data entry options. These automations distanced the clinicians from the very data they needed in order to know their patients:

In the old system I had one flow-sheet and I could see everything all at once. And it was in graphic form so with all my vital signs I could see trends. Now in [the EHR] I don’t see trends. I just see numbers... so it’s harder for me to recall them [the vital signs]. (Nurse 19, think aloud)

Increased cognitive workload

By making it difficult for clinicians to know the patient and by contributing to information overload, the EHR flow-sheet increased the cognitive work required of clinicians. Understanding the chronology and data interconnections within EHR flow-sheet data became a new, complex cognitive task for clinicians:

I like it better when it comes out in [the nurses’] story rather than reading the raw data in all those little boxes on a big [EHR-based spread] sheet and trying to figure out what’s going on. (Paediatrician 7, interview)

Clinicians warned that their workday schedules had not changed to accommodate this additional cognitive workload. Finding and constructing data connections required time that they did not consistently have available:

Before, we could really see the trending perspective at a glance on our old flow-sheets, [that is] how the child was doing; whereas now, you actually have to go in and look for it. And for some kids, when we’re busy, this is just another step that doesn’t happen. (Nurse 19, think aloud)

Loss of clinical reasoning support mechanisms

Medical students and junior residents generally expressed satisfaction with the EHR flow-sheet, describing it as a valuable central repository for patient data:

The [EHR] system – I love it! I’m just a medical student, not a resident, but I think it’s great. Everything is right here. Before, when I was on the floor [during Phase 1]... you had to go all over the place to find things. Now it’s all right there. (Medical student 4, observation)

Conversely, more experienced clinicians expressed frustration that the EHR flow-sheet was making it harder for expert clinicians to provide patient care:

It’s a bit of paradox in a way that the people who know the job very well are having trouble with the [EHR] system and the people who don’t know the job very well are fine with the [EHR] system. (Nurse 48, interview)

Participants acknowledged that the EHR’s structure supported less experienced clinicians by prompting the recording of specific patient data elements. For instance, dropdown menus acted as cues to remind clinicians to assess and note specific values. However, senior participants pointed out that knowing which data to record and knowing how to interpret those data are two different skills:

I’m an experienced nurse and I’ve seen the new grad inputting data, inputting data, inputting data, but not being able to take the data and form any kind of opinion based on it. It’s a very
conscious effort to put together what the assessment data means and form an action on it. For example, the auto-entering of vital signs; it is very easy to press that button “auto-enter”. You don’t have that graphic display in front of you that we used to have all the time. It’s like, “Woops! That blood pressure was 90 on 60 for the last four hours and now I’m sitting at 150 and it’s been rising every hour for the last two hours.” […] We have to remember to look at [the graphic display] because before when you penned in your actual vital signs you were thinking about what you were writing down. Now I have to make a conscious effort to look for information… The way we chart electronically does not enable us to put charting and analysis together. (Nurse 31, interview)

Although the EHR structures facilitated the recording of patient data, participants reported that this assistance entailed the loss of supports for more complex clinical reasoning:

It’s harder to put the story together, but it’s easier to actually chart. (Nurse 78, think aloud)

While the chronologically linked data interconnections of the paper flowsheet supported clinical reasoning by displaying the ‘patient’s story’, clinicians described having to reconstruct the patient’s story when working with the EHR flowsheet. Even its narrative content fragmented and distributed the patient’s story. In the paper flowsheet’s progress notes, an example of a typical entry read: ‘NG [nasogastric tube] blocked; tried to flush with ginger ale, met resistance, no success, left to sit for 10–15 minutes, reassessed, still blocked; removed. Reinserted and tolerated procedure well.’

In the EHR flowsheet, the same content was embedded as an asterisk in an Input/Output data cell and was typically reduced to ‘flushed with sterile water’. In discussing this example, one clinician explained that the EHR flowsheet notes are problematic because they no longer ‘flow as a story’ (Nurse 19, think aloud).

DISCUSSION

Making and understanding data interconnections are crucial elements of a clinician’s reasoning activity. In the paper flowsheet, data interconnections are realised through chronologically organised, textual and visual structures. By contrast, the EHR flowsheet textually and visually presents data in restricted chronological contexts that provide minimal additional data contexts. The theories of RGS and visual rhetoric tell us that the textual and visual structures in these genres shape how clinicians think and act. This argument is extended by scholars in science and technology studies, particularly those who use actor network theory. In other words, clinicians think and act through the tools they use, including paper charts and EHRs. Further, just as people have preferred ways of thinking and working, so too do our tools. Paper charts embody specific ways of thinking. The EHR embodies different ways of thinking. It is not surprising, then, that the experienced clinicians in our study identified the EHR flowsheet as imposing new ways of thinking and working — ways that generated obstacles to knowing a patient, increased their cognitive workload, and failed to support clinical reasoning. We sought to understand why this new way of thinking and working was so problematic for clinicians. Through our analyses, we came to understand that the EHR flowsheet deconstructed the data interconnections and chronology on which experienced clinicians relied to support their clinical work, leaving them with massive amounts of data fragments, but without an interconnected whole.

We suggest that clinicians’ reliance on interconnected wholes is an issue of something we label ‘connectivity’. Connectivity refers to the chronologically framed data interconnections that clinicians must make and understand in order to provide patient care. Connectivity is textually and visually embodied in the genres of patient care delivery that clinicians think with and act through. As our analyses of the paper and EHR flowsheets illustrate, the connectivity upon which clinicians rely in their clinical reasoning can conflict with the way EHRs amass data. In our setting, the loss of connectivity was evident across other genres including, for example, discharge notes and team transfer notes. Indeed, connectivity was embodied in all the paper-based genres we examined in this study, including, for instance, all flowsheets (from across all units and professions), and the physicians’ and nurses’ progress notes. However, the connectivity that once was constructed in the genres of the paper chart was minimised in many genres in the move to the EHR.
Recent research into clinical reasoning has investigated how context can influence reasoning processes. Working with theories of situated cognition and ecological psychology, Durning et al. posit that appreciating clinical reasoning requires examining it in relation to context because ‘reasoning is located in the details of the experience at hand (participants, setting and their interactions)’. Our research adds to this work by demonstrating how genres are part of the contextual factors that influence clinical reasoning. Others have suggested that clinical reasoning is intimately related to communication skills. We confirm and refine that assertion by suggesting that communication in general, and connectivity specifically are inextricably integrated with clinical reasoning. Genres embodying connectivity can support clinical reasoning (e.g. the paper flowsheet), but those that eschew connectivity can impede it (e.g. the EHR flowsheet).

We also suggest that recognising the loss of connectivity is a mark of clinical reasoning expertise. Novices in our study failed to notice diminished connectivity. This finding is similar to those of others who have found that inexperienced clinicians tend to be less aware of their clinical reasoning limitations. We posit that medical educators should consciously attend to the lessons of connectivity embedded in genres. The EHR is designed with multiple users and goals in mind. Focusing on individual data points enables the EHR to assemble information in different visual and textual structures that can support these multiple users and goals. However, clinical reasoning is fundamental to successful patient care. Fundamental to clinical reasoning is connectivity.

Other research has examined connectivity, although it may not have labelled it as such. For example, investigators have examined how medical experts bring multiple data items into comprehensive and comprehensible ensembles called ‘bundles’. Bundles are actively created, involve an organised selection of information, comprise data of varying levels of granularity, are created to facilitate a specific task, and involve groupings of data based on criteria of relatedness. Bundles help clinicians identify chronologically organised data interconnections in order to move patient care forward. Paper flowsheets have been studied as examples of bundles, finding that ‘experts using flowsheets are able to determine at a glance the overall severity and stability of the patient’s condition as well as the major conditions that require attention at a given point in time’. The PICU flowsheet is an example of a bundle, or a tool that relies on and embodies connectivity to support clinical reasoning.

Another set of literature that examines issues of connectivity is that of research into the function of narrative in clinical reasoning. In this field, narrative is defined as a ‘set of events and the contextual details surrounding their occurrence’ that is meaningfully organised chronologically. Although narratives are usually communicated textually in prose format, in our data, narratives were evident both textually and numerically. Narrative relies on chronological continuity and event interconnections. Narrative allows clinicians to understand how events of the past unfolded chronologically and how that history connects with and informs present and future actions. The narrative of a patient’s care trajectory as it exists in genres enables clinicians to understand a patient’s case and to take appropriate actions. Thus, narrative thinking, which requires connectivity, is a prerequisite for clinical reasoning. Narratives, and the clinical reasoning they enable, require an understanding of interconnections between events, and between events and the contexts (including chronology) in which they unfold. Other research has also suggested that EHRs interrupt narrative connectivity. Patel et al. found that EHRs interrupted narrative continuity by organising patient data as ‘discrete units that were not linked by connecting narrative’. They concluded that these disconnections, which we call ‘missing connectivity’, profoundly influenced the cognitive behaviours of physicians.

The common thread that links theories of bundling, narrative, RGS and visual rhetoric in relation to clinical reasoning is connectivity. Connectivity is a foundational skill our trainees require. Connectivity education can explicitly focus, in part, on bundle-making and narrative-building skills. Connectivity can also be implicitly taught in the documentation systems used in AHCs. These skills would help trainees contend with the ‘data feast but a clinical thinking famine’ that EHRs present. We must emphasise here that connectivity should not be considered a paper-based phenomenon, nor is it a skill that can only be put into action on paper. Although we witnessed a highly evolved form of connectivity in the paper documents in our setting, connectivity can be created in electronic documents (e.g. in graphs and paragraphs written in e-mails or other electronic documents) and even in EHRs if the interface and coding structures enable users to manipulate displays. Connectivity-savvy trainees would be well-positioned to
work in any setting, including those that use predominantly paper documents and those that use EHRs. Connectivity helps learners to reason their way through the data feast, be it paper- or electronically based.

Vendors of EHRs can support connectivity by designing interfaces that present data as chronological interconnections. Some EHR designs do so already. However, EHRs vary widely between clinical settings, with designs reflecting the coding practices of individual vendors. They are all too often introduced in AHCs only to later be abandoned. This vendor factor means that educators cannot assume that all EHRs will embody connectivity. Indeed, our findings echo those of others,56 thus suggesting that the presence of connectivity in EHRs is an exception, not the norm. Furthermore, being a skilled genre user requires constant development because genres are dynamic and are continually undergoing gradual change to meet the needs of writers and readers.57 Genres necessarily evolve over time, including as they move from paper to electronic formats. Just as paper documents, like the PICU flowsheet, have evolved over time through community collaboration and consensus building, it is possible that EHRs will evolve to present connectivity to clinical users. However, until that time, we must equip our trainees with skills that transfer across iterations of a genre. We propose that one such skill is the ability to create connectivity.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

**Figure S1.** A portion of a completed paper-based flowsheet.

**Figure S2.** Electronic health record flowsheet data entry pop-up window (simulated patient data).

**Figure S3.** Electronic health record flowsheet default display of EHR (EHR) flowsheet vital sign data (spreadsheet format) (simulated patient data).

**Figure S4.** Line graph displays of electronic health record flowsheet vital sign data (simulated patient data).

**Figure S5.** Clinical data viewer in the electronic health record (simulated patient data).

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