

TITLE PAGE

Computerized Provider Order Entry and Residency Education in an Academic Medical Centre

Wong B, Kuper A, Robinson N, Morra D, Etchells E, Wu R, Shojania K. Computerized provider order entry systems and medical education: Balancing educational opportunities with the safety of the training experience. Med Educ 46 (8): 795-806, August 2012.

Running title: Computerized Provider Order Entry and Medical Education

Word count: 4,797 words

ABSTRACT

Background: Many academic medical centers have introduced institutional policies, changed processes of care, and implemented new technologies to improve healthcare quality. The impact of such changes on medical education has received little attention. We examine the impact of computerized provider order entry (CPOE) on the educational experience of medical trainees that work and train in academic medical centers.

Methods: We conducted semi-structured interviews of postgraduate trainees and attending physicians in internal medicine at 5 academic medical centers (2 with CPOE, 3 without CPOE). Trainees routinely rotate from CPOE to non-CPOE academic medical centers, while some attending physicians work at both types of academic medical centers, making them well positioned to reflect on differences between CPOE and non-CPOE learning environments. Data collection and analysis used Grounded Theory methods. We sampled purposively until we reached theoretical saturation.

Results: Our study included 11 residents and 6 attending physicians. CPOE had both positive and negative impacts on five aspects of postgraduate training: 1) learning (better for medication interactions and availability of learning resources, worse for learning medication doses), 2) teaching (more medication information available to enhance case discussions, fewer face-to-face teaching opportunities), 3) feedback (improved ability to observe medication ordering behaviours to inform feedback, less provision of direct feedback), 4) clinical supervision (facilitates efficient and safe supervision from a distance, may impede trainee independence), and 5) trainee assessment (increased opportunity to assess clinical decision-making and organizational skills).

Conclusions: We identify 5 key educational themes that are positively and negatively impacted by CPOE. These themes form a conceptual framework that could be applied to define the educational impact of other healthcare quality and patient safety practices. This will help educators to identify educational opportunities and protect the safety of the training experience of residents in academic medical centers.

INTRODUCTION

Computerized provider order entry (CPOE) systems are regarded as having the potential to reduce medication errors (1). This has led to organizations such as the Institute of Medicine (2) and the Joint Commission (3) to recommend its widespread implementation. The reductions in medication errors may translate into improved patient outcomes and costs, but the data is contradictory (4, 5). Notwithstanding the potential benefits, there are emerging concerns regarding the unintended negative consequences associated with these systems (6-8), including new work, changes to workflow (9), altered communication patterns (10), creation of new errors (11), and overdependence on technology (12).

Trainees, including students and residents, play an integral role in the delivery of care in academic medical centres (AMCs). While these system-wide initiatives within AMCs primarily aim to enhance healthcare quality and safety, they may have positive and/or negative impacts on trainees' educational experiences. Yet the educational impact of quality improvement (QI) initiatives such as CPOE has received little attention, unlike other types of unintended consequences. The few studies that have attempted to address this issue in the context of CPOE have yielded mixed and inconclusive results (12-17). Several studies suggest that trainees perceive medication ordering using CPOE systems as “cookbook” medicine (12, 13), while

others do not (17). One study found that trainees learned how to write orders better as a result of CPOE (16), while another found no difference (15).

As part of our ongoing program of research intended to understand the intersection between healthcare quality and medical education in general, we chose to examine the impact of the use of CPOE, a prominent patient safety practice, on the educational experience of medical trainees that work in AMCs.

METHODS

Our research approach in this study was based in constructivist grounded theory, a qualitative research methodology that is intended to develop a theoretical framework to describe a social phenomenon that is derived primarily from empirical data (18-20). We conducted our study in March to September 2009. The [*insert institution here*] Research Ethics Board (*City, Country*) approved this study and were satisfied with the safeguards in place to mitigate against inevitable power dynamics and to protect the participants' anonymity.

Educational Setting and Context

Postgraduate Internal Medicine trainees rotate through the five affiliated teaching hospitals of the Faculty of Medicine, *University Name (City, Country)*, two of which have implemented the same CPOE system. The general internal medicine (GIM) service is structured similarly at all 5 teaching hospitals. Each hospital has 4 physician teams, each with one attending physician (similar to a consultant in the United Kingdom (UK)), one senior resident (similar to registrars in the UK), 2-3 junior residents (similar to foundation doctors in the UK),

and 3-4 medical students. Many GIM services in North American AMCs adopt a similar physician team structure.

During the first postgraduate year of training (PGY-1), residents typically spend four months on the GIM service at one of the five teaching hospitals. As junior residents on the team, they provide direct patient care and are largely responsible for the day-to-day medication ordering for admitted patients. During the PGY-2 year, residents move to a different hospital and spend another four months as the senior resident on the GIM service. Senior residents are primarily responsible for supervising junior residents and medical students, with much less direct patient care and therefore, less direct medication order entry. Medical students also provide direct care for patients and can order medications, but these orders need to be countersigned by a resident or attending physician. Attending physicians provided the highest level of oversight for all residents (including the senior resident), and typically perform very little direct medication ordering.

In non-CPOE hospitals, medication orders are either written directly in the patient chart, or given as a verbal order over the phone to the patient's nurse. In CPOE hospitals, medication orders are entered directly into any computer connected to the hospital's internal network. Since computers are located throughout the hospital, verbal orders are rarely used. Countersigning is done electronically in the CPOE hospitals, where orders entered by a medical student appear in a supervising resident's medication ordering queue, which need to be approved before the medication can be dispensed and administered.

Medication Ordering Practices

We focused our attention on three aspects of medication ordering and their associated educational activities during our data collection and analysis to establish the educational impact of CPOE.

1) In the emergency department when the patient is being admitted to the hospital: Both chronic medications and new medications intended to treat the acute illness are ordered by the resident (e.g., ordering chronic diabetes medications while initiating a new anti-platelet medication to treat an acute myocardial infarction);

2) Day-to-day management of admitted patients: Residents may adjust, discontinue, or order new medications as part of a patient's routine care (e.g., increasing the diuretic medication dose for a patient admitted with heart failure); and

3) On-call management of admitted patients: Residents need to provide *ad hoc* medication orders for patient issues that arise on call (e.g., pain medications, potassium supplementation for patients with hypokalemia).

Study Participants

No trainee in our program spends both of his or her first two years in a CPOE hospital, although some will spend both their first two years in non-CPOE hospitals. Therefore, we included only trainees who had trained at teaching hospitals both with and without implemented CPOE systems. As most attending staff are primarily affiliated with one teaching hospital, we included only those attending staff who had worked at CPOE hospitals before and after the implementation of CPOE (or attending staff who happen to work at hospitals both CPOE and non-CPOE hospitals).

For residents, we purposively sampled to include a balance of: (a) residents from various training levels; (b) residents who had attended medical school at institutions with or without established CPOE systems, and (c) male and female residents. For attending staff, we purposively sampled individuals whom we believed would represent different points of view based on our prior knowledge of them. We then used a confirming/disconfirming snowball sampling strategy and asked interviewed residents and staff to recommend other potential study subjects who might: (a) have a similar experience/viewpoint to their own; and (b) have a divergent experience/viewpoint from their own.

Data Collection and Analysis

We conducted semi-structured one-on-one interviews to gather our data. Each study subject was interviewed once for the study for 45 – 60 minutes. We audiotaped and transcribed interviews verbatim. The initial interview guides for these semi-structured interviews were based on our synthesis of what is known about the impact of CPOE systems on resident education and in our contextual knowledge of the functioning of the GIM services at the various hospitals. We analyzed the interview transcripts to identify key themes concurrently with data gathering (as part of our Grounded Theory methodology), informing iterative adjustments to the interview script as well as informing decisions with respect to saturation.

The analysis was reflexively mindful of the researchers' own subject-positions in the research context and of potential power dynamics between the research team and study participants. Six of the seven study investigators are attending physicians on GIM at one of the AMCs studied in this paper with different types of exposure to CPOE as users and researchers (as faculty or during training) both during transition and stable periods; all six are colleagues to

the attending physicians in this study and could potentially have supervised the residents in this study. Great care was thus taken to anonymize the study data. In particular, a research assistant (the seventh investigator on this study) conducted all resident interviews. The concurrent analysis was carried out primarily by one study investigator (*initials*), an attending physician at a non-CPOE hospital who trained in part at a CPOE hospital, and further refined by other members of the research team (*initials of 4 study investigators*) who read transcripts, met to discuss coding schemes, and suggested ongoing changes to the interview guides. Together we developed a model for analyzing the educational impact of patient safety interventions.

RESULTS

Study Participants

Our study included 17 participants, including 11 Internal Medicine residents, and 6 attending staff. Five of the residents worked at a CPOE hospital as a junior and then a non-CPOE hospital as a senior resident, whereas 6 started in a non-CPOE hospital and then switched to a CPOE hospital. Two of the 6 attending staff spend time working at both CPOE and non-CPOE hospitals.

The Educational Impact of CPOE

Five major themes emerged describing educational areas affected by CPOE: 1) learning; 2) teaching; 3) supervision; 4) feedback; and 5) assessment. We identified both positive and negative impacts on each of these educational areas (Table 1).

Learning

A number of residents reported that it was easier to remember specific medication doses after ordering medications on paper as compared to using CPOE: “I didn’t learn doses as much in my first year because [of] the...multiple-choice dosing on CPOE” (resident 4). There were divergent views about the importance of being able to recall medication doses from memory. Some felt that it was still important to memorize medication doses during specific clinical contexts such as medical emergencies. Others believed that it is unrealistic, unnecessary and unsafe to try to commit medication doses to memory. However, when it came to learning the rationale of medication use in specific clinical situations, most trainees felt that the mode of medication ordering had little influence: “I think knowing doses for medications is not nearly as important as knowing when to use...medications, which the computer doesn’t teach you. That, you learn by taking care of patients” (resident 4).

Several aspects of CPOE systems potentially enhance learning. Clinical decision support systems (CDSS) linked to CPOE help to enhance learning with respect to medication interactions: “The interactions with other medications are built in [the CPOE system] and it’s something that you might not have thought of when you’re writing [medication orders] on paper” (resident 1). Furthermore, accessing online medication dosing information is more efficient because the CPOE system links directly to these resources, making it easier to look up medication information to support medication ordering: “The more complex things where you’d be more likely to look up dosages or contraindications...it’s faster at the computer for me personally because I tend to look it up on-line. You just open up a separate window and have the drug reference there as well as the ordering” (resident 3).

Teaching

Senior residents (and sometimes attending staff) need to review and countersign medication orders written by medical students before they can be carried out. In non-CPOE hospitals, there is a greater tendency for students and residents to come together and discuss written orders in person, which creates opportunities for teaching. However, when using CPOE, countersigning medication orders is done electronically and can be carried out remotely, and may result in lost opportunities for teaching. One senior resident commented: “In a paper system, you’d have to physically co-sign whatever orders someone wanted so there’s a lot more teaching and interaction that would happen in a paper system” (resident 9).

On the other hand, CPOE systems display the medication orders, medication administration record, and electronic patient record all in one place, and supplement case discussions with real patient information. “I tend to do global med reviews with [clinical] clerks more and what’s really nice is then you can see the pattern of Lasix dosing in a congestive heart failure patient...over the past week and you can discuss why we gave 80 mg that day and we’re only giving 40 mg now...You can put it up nicely in parallel quickly with the creatinine and discuss it in that context and think about what the potassium is doing...It’s much nicer to have that all there in front of you and to teach from that” (attending staff 1).

Supervision

Both attending staff and senior residents consistently identified that CPOE improved their ability to supervise from a distance by making medication orders easily available on any computer workstation. This was identified as a major benefit of CPOE, and felt to help to make the role of supervisor easier and more efficient while promoting safe patient care. One senior

resident recalled: “I had an Intern who ordered an extremely high dose of insulin on somebody [that] wasn’t out of the range where you could order it on the computer...because some patients need that high a dose but...it was ten times what the patient should have gotten...Even though it was an Intern and I didn’t need to co-sign anything, I still went through the orders that person had done, picked it up and the patient never got [the insulin]. Whereas, in a paper system, I probably wouldn’t have gone over his paper orders...because I’d have to go to find the chart...I probably wouldn’t have picked it up and the patient might have gotten ten times the dose of insulin they were supposed to” (resident 6).

However, because CPOE makes it easier to order medications remotely, it creates the potential for junior members of the team to have their clinical work done for them. While this was not felt to be a universal risk, most acknowledged that CPOE facilitates this concern: “Maybe I’ve done it before as a supervising physician where I go ahead and co-sign the [medical student’s] orders and the Resident feels their toes are being stepped on” (attending 2).

Feedback

Respondents felt that CPOE makes it easier to observe trainee medication-ordering behaviors and provide feedback. While this is also possible with paper-based ordering, there are many logistical barriers (physically locating a chart, medication orders and medication administration records located in different places) that made this more challenging. Some attending staff even used CPOE as a tool that could be used to provide indirect feedback to trainees. “The nice thing about the system is that...right there, staring you in the face, is who wrote the orders. So if all of a sudden a Resident is seeing a lot of Staff orders on the basic meds that were maybe ordered incorrectly, that’s a more direct way to show that there’s been a change

and that I've had to change it as Staff and so I think that's a good way [to provide feedback]" (attending staff 1).

Interestingly, this same practice, which is viewed by attending staff as providing feedback, might be viewed by trainees as being afforded less independence with respect to patient care: "The residents have felt...disenfranchised, that someone else is ordering things on the patients and they don't know what's going on...the residents just felt like they probably should stop ordering things because they knew the attending was going to do it...it created a lot of problems with patient care and the residents were unhappy about it" (attending 3).

Not everyone agrees that this process of changing medication orders *post hoc* is an effective form of feedback. Some residents stated that electronic countersigning of medical student orders using CPOE often goes unnoticed by students and can lead to modification of medication orders without any direct feedback provided. "I'll be going through what the medical students have ordered and something that's totally wrong, I just won't co-sign it. But if I'm busy, I won't get around to telling them why I didn't and so that's detrimental to their educational process because they're still likely to go and do the same mistake because they never really discussed why that was not the best choice" (resident 5). Many trainees therefore prefer a verbal discussion to accompany these types of medication changes to reinforce the feedback on their medication ordering practices.

Assessment

Attending physicians stated that CPOE allows supervisors to assess whether residents are responding to lab abnormalities appropriately or starting the appropriate medications (according to best evidence), which speaks to medical knowledge and clinical decision-making. Others also commented that the ability to observe how quickly trainees respond to certain lab abnormalities

(e.g., replacing electrolytes) provides insight into resident's managerial/organizational skills.

One attending staff recalled: "I see someone's electrolytes are abnormal, they should have had some intervention...I see, oh, look at that, they've already got their IV Magnesium, that resident's really on the job" (attending staff 5).

Learner and Supervisor Factors that Influence the Educational Impact of CPOE

Several factors modulate the type and degree of impact that CPOE has on the five main themes identified. These include factors related to the learner and the supervisor (Table 2).

Learner factors

The impact of CPOE on learning about medications (including doses, rationale for use, and interactions) depended in part on individual learning style. For some residents, the act of generating orders on paper reinforced learning medication doses because it requires actively thinking about which medication to order and how to order it. These residents often described ordering medications using CPOE as a passive process (e.g., "multiple-choice dosing"). On the other hand, other trainees are more visual and reflective learners and used the medication information displayed by CPOE systems as a springboard for learning about medications.

Some trainees highlighted the potential for CPOE to affect the time available for learning and teaching. This depended largely on the trainee's experience with CPOE and how easily he or she was able to adapt to its use for ordering medications. Residents at the early stages who were slow to adapt tended to report the greatest difficulty balancing the time required to carry out their clinical work and the time available for learning and teaching. However, once familiar with the system, with the added efficiencies that were identified with respect to medication review,

most residents felt that there was an overall time savings, which some devoted to learning and teaching.

Supervisor factors

The attending staff or senior resident's supervision style could either dampen or enhance the positive and negative aspects of CPOE on medical education. For example, a supervisor that tended to be more "hands-on" or controlling with respect to patient care would tend to undermine a junior trainee's autonomy in either system. CPOE served in this case to facilitate these behaviours by making it easier for the supervising physician to circumvent his/her trainees by making medication review and ordering possible from any location. On the other hand, supervisors who were diligent with the provision of feedback would also ensure that this occurs irrespective of the modality used to order medications. These supervisors would therefore tend to take advantage the added information available from CPOE systems to inform and enhance the type of feedback that they are able to provide trainees.

Another critical factor is the supervising physician or resident's commitment to teaching and education. Residents who were committed to ensuring that junior trainees were appropriately supervised and taught did so in either context. In the CPOE environment, this may require the use of specific strategies to ensure this occurs. This includes deliberately reviewing medical student orders in person (even if the possibility exists to do so remotely) and keeping a running tally of teaching points that are fed back to trainees when the opportunity arises. However, residents who were seen as having little interest in their role as teacher were no more likely to teach in a paper-based system than a CPOE-based system. CPOE may have served to facilitate their avoidance of teaching responsibilities, but did not establish this behaviour.

DISCUSSION

This study provides a contemporary, in-depth summary of the impact of CPOE, an emerging patient safety technology, on the educational experiences of postgraduate internal medicine trainees. We discovered that the use of CPOE for medication ordering broadly impacted five areas in medication education both positively and negatively. These educational areas include learning, teaching, supervision, feedback and assessment. The degree of impact depended in part on several learner and supervisor factors, including learning style, level of comfort with using CPOE, supervision style and commitment to teaching. Indeed, some of the purported positive and negative impacts of CPOE may in fact be underlying features of the professional and educational practices and organizational culture that CPOE reveals rather than directly causes.

The majority of the previous studies that examined the educational impact of CPOE focused primarily on the most obvious educational impact, namely learning medication doses (12, 13, 15, 16). While our study confirms prior concerns regarding the detrimental effects on learning medication doses, we discovered that trainees viewed learning specific doses as less important than learning indications and contraindications for medication use. The latter may actually be enhanced by the decision support systems that increase awareness of important drug interactions.

Several studies highlighted another negative impact in that trainees reported concerns that CPOE increased the time needed to order medications (13, 14, 17, 21), and that this might result in medical students losing opportunities to order medications (21). Trainees also resented the “clerical” nature of having to use computers in their work (13, 14). Given these findings, we

specifically looked for these effects and, despite asking directly about them, our respondents did not see time as an important issue related to the use of CPOE. There are several potential explanations. A systematic review of studies that have measured the impact of CPOE on physician time suggests that the increases in time vary significantly (22), with some sites being able to approach time neutrality because other tasks, such as locating charts, were made easier (23). Both residents and attending staff cited that, despite minor increases in the amount of time spent entering orders, there were significant time savings with respect to medication review due to the companion electronic medication administration record. So, on the balance, CPOE was seen to save time in our study. It is also conceivable that our contemporary CPOE system has a better user interface that makes medication ordering easier than the pioneering systems from the 1990s. Finally, with half of the prior studies published in the 1990s, their findings may have limited relevance to our current training environment given the considerable advances in technology and the now-ubiquitous use of computers, including in healthcare and in medical education.

We also identify additional threats to the educational experience, most notably in decreasing face-to-face encounters that may result in lost opportunities for teaching and facilitating unfavorable supervision practices that undermine trainee autonomy, and discovered a number of previously unrecognized advantages, including safer supervision of trainees and enhanced observation of medication-ordering behaviours to inform feedback. We speculate that one of the reasons that we uncovered these novel findings may be that, unlike previous studies, our trainees, and some attending staff, routinely rotate from hospitals with CPOE to those without CPOE, and vice versa, and are able to compare and contrast their experiences in real-

time to provide a much richer description of the various facets of the interaction between CPOE and education.

Conceptual Model for Evaluating the Educational Impact of Quality Improvement or Patient Safety Practices

A recent review of QI in medical education describes an emerging recognition that real-world QI initiatives have the potential to affect the educational experience in AMCs (24). Our case study uses CPOE as the context for studying the general phenomenon of the educational impact of QI and patient safety practices, and proposes a conceptual model that can be extended to assess how other QI initiatives affect medical education (Figure 1). This model's 5 key elements (learning, teaching, supervision, feedback and assessment) are mapped onto those aspects of clinical work that are directly affected by the QI intervention in question to determine the nature of the educational impact. This helps to direct our attention towards characterizing the educational advantages as well as unintended negative consequences that stem from specific aspects of a QI or patient safety intervention.

For example, with medication ordering, one type of clinical work that CPOE might affect relates to the countersigning of medical student orders. The *teaching* and *feedback* elements map naturally to this aspect of clinical work, since these encounters often create teaching opportunities for medical students and allow them to receive feedback on their medication ordering skills.

Other widely adopted QI and patient interventions likely have similar educational impacts that have yet to be fully characterized. The notable exception is the attention received by resident duty hours restrictions, primarily because this widespread policy change directly

affects trainees (25-28). Reductions in resident duty hours improved resident work-life balance and addressed concerns regarding the impact of sleep deprivation on resident performance (29). However, concerns have emerged regarding the potential threats to medical education (30-34). Attending physicians report spending less time teaching residents as a consequence of increased direct patient-care responsibilities (31), and decreased satisfaction with teaching activities as a result of duty hours reduction (30).

To illustrate how this conceptual model might be applied, we can hypothesize how other healthcare quality practices that less explicitly involve trainees, such as rapid response teams, might affect the educational experience. In AMCs, rapid response teams affect a trainee's clinical work surrounding critically ill patients. From an educational standpoint, these patient encounters are important for trainees to gain hands-on experiential *learning* to become competent in managing critically ill patients. However, having adequate levels of *supervision* is crucial for these precarious circumstances. Therefore, one could imagine that having this additional level of oversight might detract from experiential *learning*, but create new opportunities to improve *supervision* of trainees. Ultimately, this conceptual model helps to generate hypotheses surrounding the educational impacts of healthcare quality and patient safety practices, and promotes further learning about these unintended consequences.

Once we had created our empirically-derived conceptual model, we explored how it might relate to other frameworks that attempt to account for unintended consequences that result from the implementation of new health information technologies (HITs). One framework that has been used within the medical informatics community specifically in relation to CPOE is the Interactive Sociotechnical Analysis (ISTA) framework (35). We found that our empirical data appeared to support at least some of the features of this theoretically-derived framework.

The ISTA framework includes 4 elements, (the features of the HIT itself, the social system, the technical and physical infrastructure, and the real-world use of the HIT) and analyzes the interactions between these elements to understand why unintended consequences arise when new HITs are implemented. For example, the ISTA framework suggests that the features of the HIT can directly change the existing social system. Our data showed that CPOE created a mechanism for orders to be countersigned remotely, which changed the way senior residents and junior trainees review medication orders and potentially decreased opportunities for teaching and feedback. Another interaction suggested by the ISTA framework is one where the actual use of HIT affects the social system. In our study, we uncovered several empirical examples of such interactions. For example, using CPOE to order medications has both positive and negative impacts on learning about medications and their dosages. Furthermore, using CPOE to review medications enhances clinical supervision practices and makes them safer.

While the ISTA framework has previously been applied to study new errors, changes to workflow, and altered communication patterns caused by CPOE, it was not designed to consider the educational consequences of HITs. Our empirically-derived model highlights the important features of the educational experience of trainees in relation to a new HIT, which could be considered an element of the social system within the ISTA framework. Future studies that aim to expand on our current findings could attempt to incorporate the 5 key educational elements that we derived (ie. learning, teaching, supervision, feedback and assessment) within the ISTA framework and then empirically validate that modified framework; such work could both extend the theoretical power of the ISTA framework and encourage more frequent consideration of educational impact within the medical informatics community.

Limitations

Our study has several limitations. First, the issues identified were as much about how our specific CPOE system was implemented as opposed to the intrinsic design of CPOE itself. Also, we did not include medical students in our study. While we acknowledge that this is an important omission, we believe that the educational issues are sufficiently different for medical students and would consider their experience one that warrants separate attention. We also did not include specialties outside of internal medicine. Given the major differences both in clinical workflow as well as educational objectives that exist among specialties, our findings may not be entirely transferable. Finally, we gathered our data solely through interviews and not additionally through direct observation; such methodological triangulation might have enriched our study findings.

Conclusion

In this paper, we have provided a comprehensive summary of the impact of an emerging healthcare quality practice, CPOE, on the educational experience of postgraduate trainees. There were both positive and negative effects on five key areas of medical education. Educators situated in academic medical centres that have implemented CPOE systems should be familiar with and capitalize on the educational opportunities associated with CPOE, and mitigate those aspects of CPOE that potentially threaten the safety of the educational experience of postgraduate trainees.

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TABLE 1. Positive and Negative Impacts of CPOE on Five Aspects of Postgraduate Medical Education

Theme and Type of Impact	Area of Impact	Representative Transcript Excerpts
Learning		
Positive impact	Learning medication interactions	“The example I remember specifically was calcium channel blockers interacting with statins. I remember that popping up and...oh, I didn’t know that. With a paper-based system, I don’t think I ever would have identified that. That would have been something I would have had to happen upon by chance or have a pharmacist come up and say, did you think about this? [...] I don’t think I’d ever independently come across...this interaction” (resident 2).
	Availability of online learning resources	“We use the on-line references to look up medication dosages or anything about them. If you’re at a computer it’s very easy to look it up...whereas a paper-based system...[you have] to find a computer to look things up and then go back and find the paper chart...so it’s probably quicker and more efficient” (resident 3).
Negative impact	Learning medication doses	“I think electronic ordering, it makes people rely on the computers and sometimes automatically picking the doses or the orders without taking that extra thought about it, because it’s all just clicking. And you stop memorizing the doses... when you go back to the written it’s like, oh yeah, what was that dose again” (resident 1).
Teaching		
Positive impact	Availability of medication information to enhance	“The thing that I like is that I can sit down...to review something...[with] one of the residents or clinical clerks and

Theme and Type of Impact	Area of Impact	Representative Transcript Excerpts
	case discussions	say...let's just go through what you've done. And we sit down at the computer, and without spending 20 minutes trying to find the chart, the MAR (medication administration record)...and having paper all over the place, we sit down, there's one screen, we're viewing the same thing, same time, standardized format, and we can go through it" (attending staff 5).
Negative impact	Decreased opportunities for face-to-face teaching	"I think for the day-to-day issues that come up in the work, yeah it is an issue. You know, when I was a medical student and I was ordering things like potassium replacement or anti-coagulation orders and things like that, then I would have to show it to my senior resident. And they would teach me about those basic day-to-day things that most of us take for granted later on in residency but are a big part of medical student learning. And on the computer based system I think there was definitely much less of that interaction teaching" (resident 7).
Supervision		
Positive impact	Promotes efficient and safer supervision of junior trainees from a distance	"From the position of an attending physician who's supervising...it has made my job a lot easier, because I can quickly review from either my office or home exactly what my residents are ordering and how they're responding to abnormal results. I can see a low potassium, I can check to see if someone's ordered potassium and if they haven't I can follow that up. If they have, I can be reassured...so from that point of view it's been tremendously helpful" (attending staff 5).
Negative impact	Decreased autonomy and	"I know that there are staff who do things on their own and...link in

Theme and Type of Impact	Area of Impact	Representative Transcript Excerpts
	independence of junior trainees with respect to patient care	from home and order medications and respond to lab results in the middle of the night...even if you're not on site. And that can be very tempting to a staff person who sees a problem, maybe can't get in touch with the resident, wants to make sure that their patient gets an intervention right away. And I am aware of time when that has been a problem for teams where the attending staff has been too involved because it's so easy to do. You can be at home, your kids can be playing, and you can order potassium" (attending 3).
Feedback		
Positive impact	Facilitates observation of medication ordering behaviours to inform feedback	"If a patient's got vascular disease and diabetes and heart failure, there's certain evidence based interventions they should be on. I can quickly check and see if they're on them. If they're not, then I have a discussion point with my house staff: 'I noticed Mrs. So-and-so isn't on an ACE inhibitor, what's the reason you didn't [prescribe the medication]'" (attending staff 5).
Negative impact	Less direct feedback provided to trainees	"Everything comes into the senior resident's inbox and you just click, okay, okay, okay. There's no real one-on-one interacting with the individuals saying: why did you want this medication? Why did you do that?" (resident 9).
Assessment		
Positive Impact	Contributes to an improved ability to assess medical decision making and organizational skills	"We discussed this at 8:00 in the morning...and it's 3:00 and still we haven't put in the order for this particular medication, or you haven't changed the dose of Diltiazem that we discussed" (attending staff 2).

TABLE 2: Learner and Supervisor Factors that Influence the Educational Impact of Computerized Provider Order Entry

Factor		
Learner	Learning style	“Writing things out and repetition is certainly an effective way to [learn]. Some people do learn by looking at a screen...” (resident 5)
	Familiarity with CPOE system	“I think that anyone who starts with CPOE, it’s going to ... at first, you’re going to have a drop in your efficiency but then, once you’ve conquered that, you’re going to have an improvement in your efficiency...once you can improve your service efficiency, then you have more time for learning and you’re a more efficient learner as well” (resident 4)
	Clinical workload	“Your intentions are good as a senior resident and you want to follow-up on everything and provide some teaching but you’re spread in too many directions to actually follow through” (resident 5)
Supervisor	Supervision style	“It maybe facilitates for those Attendings...who don’t...quite trust even a very clever and successful Resident, and they’re doing the over-the-shoulder thing more than they should, or worse still, they’re coming in late and re-writing things, yikes. I’m not sure that maybe other than facilitating that bad behaviour in some Attendings, that [CPOE] is necessarily a culprit” (attending staff 4)
	Commitment to role as teacher	“Unless residents seek out their junior trainees, it’s very easy to get away without educating them on medication order entry or dosing of medications” (resident 9)

APPENDIX: Interview Guide with Prompts

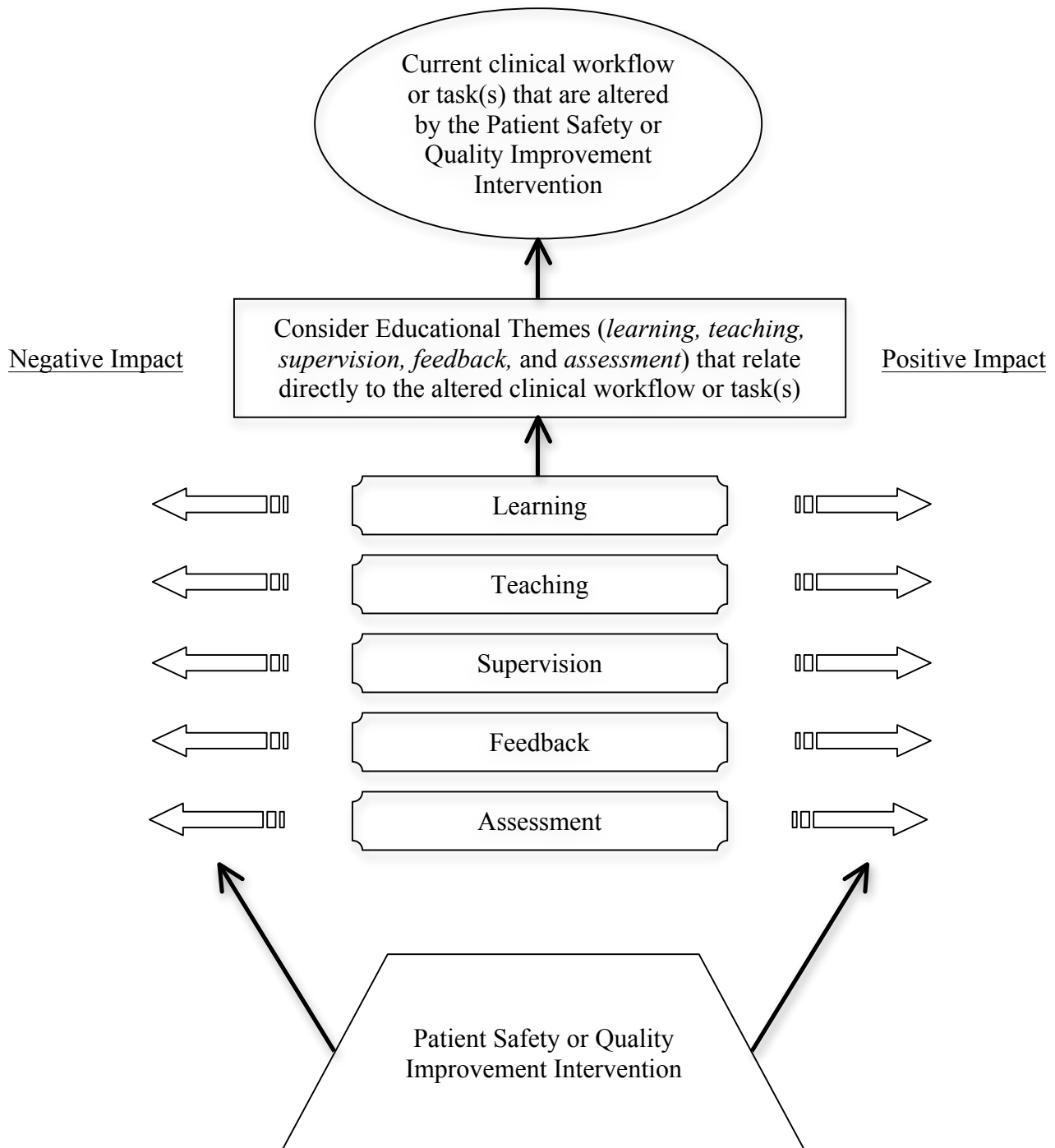
In answering the questions, the respondent should be encouraged to draw on their prior experiences using a paper-based ordering system.

1. How have CPOE systems altered the way in which you work with respect to ordering and reviewing medications?
Prompts:
 - a. Do CPOE systems affect how, when and where you tend to order and review medications?
 - b. Does ordering and reviewing medications using CPOE systems affect how, when and where you tend to do other areas of your work?
 - c. What about the impact of your workflow on a typical workday versus on call?
 - d. How does it impact your daily workflow when you are on your home ward as opposed to off of it (e.g., off-service ward, rounds, clinic)?
2. How has CPOE affected the efficiency of your work?
 - a. Are there some tasks that take more or less time?
 - b. Are there new tasks you have to do you, or tasks you no longer have to do?
 - c. Are there differences in efficiency with respect to medication ordering?
 - d. Are there differences in efficiency with respect to medication reviewing (i.e., reviewing medication history etc.)
3. Has CPOE impacted the safety of medication ordering?
 - a. Are there certain types of mistakes in medication ordering that are facilitated by CPOE systems?
 - b. Are there certain types of mistakes in medication ordering that tend to occur less frequently with CPOE systems?
 - c. Are there any new types of mistakes or problems that are created through the use of CPOE systems?
4. Has CPOE altered the way in which you interact or communicate with other health care professionals on the healthcare team?
Prompts:
 - a. Have you noticed any differences in when or how often you speak with other team members (i.e., other physicians, nurses, pharmacists)? What about with whom you speak regularly? What about where these interactions occur? Any other changes in communication patterns that come to mind?
5. How does the presence of CPOE systems impact on resident education?
Prompts:
 - a. Some people have said that the changes to daily workflow that occur as a result of CPOE may impact on the time available for learning. What

impact, if any, have you noticed? Is there more or less time available for teaching and learning?

- b. It has been suggested that the increased availability of medical imaging has affected how we teach and learn about physical examination skills. Do you think that CPOE systems have affected teaching and learning about ordering medications in a similar way?
- c. CPOE systems make use of decision support to improve patient safety (i.e., allergy alerting for antibiotic ordering). Do you think this decision support influences what you learn about medicine? In what ways?
- d. Sometimes the introduction of new ways of doing things creates new learning opportunities. Does this statement apply to the use of CPOE? Can you provide examples of this?
- e. Does the use of CPOE systems affect the interaction between the teachers (i.e., attending staff and senior resident) and the “students” (junior residents and medical students)? **NEW** For example, does it affect the way you supervise the junior trainees (or the way you were supervised as an intern – depending on context) **NEW** CPOE systems eliminate for the most part the need to generate hand written orders. Does this fundamental change in practice affect your learning? In what ways?

Figure 1: Conceptual Model for Evaluating the Educational Impact of Quality Improvement or Patient Safety Practices



1) Define the clinical workflow or task(s) that are altered as a result of a patient safety or quality improvement initiative; 2) Determine the educational themes that map onto the clinical workflow or task(s) in question; 3) Assess the impact of the patient safety or

quality improvement initiative to identify educational opportunities and unintended negative educational consequences