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Knowledge systems, health care teams, and clinical practice: a study of successful change

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Abstract

Clinical teams are of growing importance to healthcare delivery, but little is known about how teams learn and change their clinical practice. We examined how teams in three US hospitals succeeded in making significant practice improvements in the area of antimicrobial resistance. This was a qualitative cross-case study employing Soft Knowledge Systems as a conceptual framework. The purpose was to describe how teams produced, obtained, and used knowledge and information to bring about successful change. A purposeful sampling strategy was used to maximize variation between cases. Data were collected through interviews, archival document review, and direct observation. Individual case data were analyzed through a two-phase coding process followed by the cross-case analysis. Project teams varied in size and were multidisciplinary. Each project had more than one champion, only some of whom were physicians. Team members obtained relevant knowledge and information from multiple sources including the scientific literature, experts, external organizations, and their own experience. The success of these projects hinged on the teams' ability to blend scientific evidence, practical knowledge, and clinical data. Practice change was a longitudinal, iterative learning process during which teams continued to acquire, produce, and synthesize relevant knowledge and information and test different strategies until they found a workable solution to their problem. This study adds to our understanding of how teams learn and change, showing that innovation can take the form of an iterative, ongoing process in which bits of K&I are assembled from multiple sources into potential solutions that are then tested. It suggests that existing approaches to assessing the impact of continuing education activities may overlook significant contributions and more attention should be given to the role that practical knowledge plays in the change process in addition to scientific knowledge.

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Keywords

Antimicrobial resistance; Antimicrobial Resistance Educational Alliance; Case study; Knowledge translation; Practical knowledge; Practice change; Soft Knowledge Systems; Team learning

> Effective practice utilizes different forms of knowledge. Understanding professional practice requires an awareness of the ways in which knowledge informs practice and is developed from practice.
>
> —Joy Higgs and Angie Titchen in *Practice, Knowledge and Expertise in the Health Professions* (Higgs and Titchen 2001, p. 5)

Background/problem

As a field, continuing medical education has been called to move beyond dissemination of information and reorient its activities around improving clinical practice. One important reason is the well-documented gap between evidence-based practices and current clinical practice (Davis 2006; McGlynn et al. 2003). In this study we examined three instances in which healthcare teams found ways to successfully traverse the gap. Our purpose was to describe how groups in the hospital setting, hereafter called *project teams*, produced, obtained, and used knowledge and information (K&I) to bring about successful change in their practices related to a specific clinical area: reducing antimicrobial resistance.

The KT perspective on practice change

Knowledge translation (KT) has emerged as a potential response to closing the gap between actual and desired practices (Straus and Mazmanian 2006). Although there is no agreed-upon definition of KT, it is usually concerned with how the results of scientific inquiry can be employed to improve clinical practice and patient outcomes (Davis 2006; Estabrook et al. 2006; Graham et al. 2006). This view of practice change is built on the assumption that formal scientific knowledge is the most (if not only) relevant form of knowledge, that knowledge can be directly transmitted from one actor to another, and clinicians are users but not producers of relevant knowledge. Some of the limitations of this perspective have recently been acknowledged (Davies et al. 2008; McWilliam 2007).

An in-depth critique of prevailing views of KT is beyond the scope of this paper; however, we want to note that, drawing on the work of Schön (1983), Wenger (1998), Huberman (1994), and Brown and Duguid (2002), we grounded our study on three main assumptions: there are multiple ways of producing knowledge; health care providers are both consumers and producers of knowledge and information in the change process; and knowledge is not a commodity that can be detached from the knower. These assumptions transform the way we conceptualize the nature and role of continuing education for health care professionals and modify our expectations of its impact on professional practice. Seen from this perspective, practitioners no longer appear as “empty vessels waiting to be filled with the wisdom of research. Like the researchers, they have a coherent cognitive structure against which new information is actively tested” (Huberman 1994, p. 28). They become active, knowing agents who conduct their own “experiments,” develop hypotheses, act on the world, and observe the results (see, for example, Kolb and Fry 1975; Schön 1983). In short, it shifts our view away from professionals as consumers of scientific knowledge toward professionals as active, knowing agents whose learning is intimately bound up with their daily practice and practical experience.

A focus on teams

To the extent that CME is concerned to improve clinical practice, it cannot focus solely on individual physician learning, but must instead address the physician in a larger context. Although the practice environment is complex and multidimensional (Cabana et al. 1999; Eve et al. 1996; Grol 2001), we focused on clinical teams as a key variable. Borrowing from Guzzo and Dickson (1996, pp. 308–309), we define team as “individuals who see themselves and who are seen by others as a social entity, who are interdependent because of the tasks they perform as members of a group, who are embedded in one or more larger social systems (e.g., community, organization), and who perform tasks that affect others (such as customers or coworkers).”

There are several reasons to place clinical teams at the center of our thinking about improving practice. First, care is increasingly being provided in teams (Boaden and Leaviss 2000; Institute of Medicine 2001), a trend that is almost a necessary outcome of the rate of change in medical knowledge and the increasing specialization of health care professionals (Edmondson 2006). As a result, changes in clinical practice can rarely be accomplished by a single individual (Smith and Schmitz 2004). Second, the quality of health care is highly dependent upon the collective practice of teams (Donaldson and Mohr 2000; Salas et al. 2008). It has been documented that up to 80% of medical errors are related to interactions within the health care team (Schaefer et al. 1994). Finally, most previous studies of physician learning and change have taken the physician as the unit of analysis and given us insight into how individual physicians successfully learn and change (Fox et al. 1989; Geertsma et al. 1982; Slotnick 1999). Much less attention has been given to looking at change through the group-level lens, despite the promise it has shown in organization studies (Edmondson et al. 2001).

Team learning

The current study is located at the intersection of the constructs of team, learning, and clinical practice. We define team learning using an adaptation of the definition offered by Sole and Edmonson (2002) as the acquisition, production, and application of knowledge and information that enables members of a team to collectively address team tasks and issues for which solutions were not previously obvious. We also posit a direct link between *team* learning and clinical practice change, embracing Fiol and Lyles’s (1985) view that evidence of team learning can be found when teams have changed their work practices to reflect new knowledge and information.

There is a growing literature on team learning, much of which is written from an organization perspective (see, for example, Argote 1999; Argote et al. 2001) that has focused on how groups establish themselves, how they do their work, and the processes by which groups change themselves (Argote et al. 2001). Few studies have examined how teams change their practice in a naturalistic setting (Guzzo and Dickson 1996) but they do show a significant potential for adaptive learning and change at the level of the team across several professional domains (Brown and Duguid 1991; Horbar et al. 2001; Hutchins 1991; Weick and Roberts 1993).

In the health care field, there is evidence to suggest that the collective learning process at the team level can be a critical component of successful practice change (Edmondson et al. 2001). Factors shown to promote successful learning and change are (a) a high level of scientific evidence supporting the recommended practice changes (Dopson and Fitzgerald 2005; Tucker et al. 2007), (b) a psychologically safe team environment (Edmondson 2003; Tucker et al. 2007), (c) rich social linkages between teams and relevant actors in their community of practice (Dopson and Fitzgerald 2005; Edmondson 2003) and (d) experience in three areas: the team’s level of experience using the new practices, the team’s level of experience working together as a team, and the length of time team members have been in the health care organization (Dopson and Fitzgerald 2005; Reagans et al. 2005).

Our definition of team learning makes the acquisition and use of knowledge and information central to the process of successful practice change. However this dimension of team learning has not been explored, leaving unanswered some key questions: How do teams of healthcare professionals acquire and use knowledge and information to improve their practice? What roles do various forms of knowledge play? The current study is intended as an investigation into these questions.

Methods

This study was part of a larger initiative: the Antimicrobial Resistance Educational Alliance (AREA), a nationwide collaborative in the US that sought to provide continuing education to health care providers in 2006–2007 (www.areainitiatives.org) and encourage adoption of the Centers for Disease Control's 12 Step Program for Reducing Antimicrobial Resistance in Hospitalized Adults (Brinsley et al. 2005). The key components of the CDC's program are summarized in Table 1. As noted earlier, the purpose of this research was to describe how project teams in the hospital setting produced, obtained, and used knowledge and information (K&I) to bring about successful change in their practices related to reducing antimicrobial resistance. To achieve this purpose we focused on three key questions:

1. How did actors organize themselves to achieve change?
2. What knowledge and information did actors use?
3. From what sources did they obtain relevant K&I and how did they obtain it?

We used Soft Knowledge Systems (SKS) theory (Engel 1997) as a conceptual framework (Table 2) to formulate research questions, inform development of the interview questions, and conduct the first level of data analysis. An underlying assumption of SKS is that knowledge and information are central to innovation, which is the term Engel uses for any purposeful change in practice.[1] Individuals and organizations both use and create knowledge and information to solve problems, adapt to changes in the environment, and enact goals. SKS was chosen because it was developed explicitly to explore ways to facilitate innovation; gives a central role to knowledge, information, and networks (and hence to learning and education) in the innovation process; and recognizes multiple forms of knowledge making actors involved in innovating both 'source' and 'users' of knowledge and information. Although it was developed to understand and facilitate innovation in agriculture, Engel has demonstrated its applicability to other fields (Röling and Engel 1990) and we believe it brings a valuable perspective to the health care field as well.

This was a qualitative comparative case study. The aim was not to generalize to a larger population but to come to an in-depth understanding of selected instances of successful innovation. We empirically examined hospitals in the US that demonstrated success in implementing at least one component of the CDC's 12 Steps for Reducing Antimicrobial Resistance in Hospitalized Adults. Success was defined as change in practice leading to a subsequent improvement in a clinical outcome. We used a purposeful sampling strategy (Patton 1980), seeking to maximize variation between cases.

Sites were nominated by experts in the field and screened by the research team in a preliminary telephone contact. Screening criteria required that the project addressed one or more clinical issues addressed by the CDC's 12 Step initiative, used pre- and post-outcomes measures,

[1]Hereafter we use the terms innovation and practice change interchangeably.

involved one or more physicians, was completed within the past 2 years, and took place in the absence of extraordinary circumstances (e.g., significant grant funding). Cases meeting our criteria were asked to provide an abstract describing the project, which was then sent to a panel of three nationally-recognized experts in antimicrobial resistance—an infectious disease specialist, infection control specialist, and pharmacist—for validation as an instance of a successful project. Using a rating form, experts were asked to determine using a five-point Likert-type scale ranging from “criterion not met” to “criterion fully met” if the project addressed an important health care problem, made a significant contribution to the overall goal of reducing antimicrobial resistance, used outcome measures that were appropriate given the goals of the project, measured improvement in patient/clinical outcomes, and demonstrated significant improvement in outcome measures. They were also asked whether they would consider the project to be an example of a successful initiative to reduce nosocomial infection (or as appropriate, antimicrobial resistance) using a binary yes-no scale.

Table 3 summarizes characteristics of the cases. Case 1, an academic medical center in the western US addressed a marked increase in resistance in *Pseudomonas aeruginosa* through the implementation of a hospital-wide policy restricting use of selected antimicrobials. Case 2 centered around an intensive care unit in a medium-sized community hospital in the Midwest. The goal was to eliminate ventilator-associated pneumonias (VAP) using a variety of strategies including implementation of a modified version of the Institute for Healthcare Improvement’s VAP bundle.[2] Finally in Case 3, a small community hospital on the Atlantic coast sought to reduce the number of new hospital-acquired methicillin-resistant *Staphlococcus aureus* (MRSA) infections. To achieve this goal, the hospital implemented surveillance screening of patients on admission, isolation procedures, and a strict hand hygiene policy. The outcomes of these successful efforts at change are also described in Table 3.

Informants in each case were selected on the basis of other informants’ descriptions of who was involved in the project. The initial contact person, themselves a key actor, was asked to provide a preliminary list of individuals involved in the project. We interviewed all persons on that list. From these interviews we learned of additional actors who would then be contacted, a ‘snowball’ approach to sampling (Patton 1990). In the case of collective actors (e.g., a committee or ICU nurses), we requested the names of individuals who were part of that collective and could provide a representative perspective.

Five trained field researchers collected data through semi-structured interviews, document review, and direct observation. Interviews were conducted on-site or by telephone and were transcribed verbatim. Data were analyzed using NVivo software. At the individual case level, primary coding was done using a coding dictionary. Secondary coding focused on emergent themes.

The unit of analysis for this study was the knowledge network specific to each case. As defined by Engel (1997), a knowledge network is “the more or less formalized, relatively stable pattern of communication and interaction among social actors who share a common concern” (p. 37). We constructed diagrams of the knowledge network for each case showing the individual and collective actors relevant to the case and the communication linkages between them. From a Soft Knowledge Systems perspective, knowledge network diagrams are not considered models of a real, independently existing world; instead they are constructs developed to facilitate inquiry and discussion. Ultimately, the research team had to determine how the network diagram was constructed through a process of data and researcher triangulation. We examined

[2]The IHI VAP Bundle included elevation of head of the bed to 45°, daily sedation vacations and assessment of readiness to extubate, peptic ulcer disease prophylaxis, and deep venous thrombosis prophylaxis. The head of bed guideline was adjusted by the project team to 30° due to problems they encountered with the steeper angle.

and compared the accounts of our informants and information from archival documents to construct each diagram. Any differences among research team members were discussed and resolved.

Cross case analysis followed completion of the individual case analyses and employed a modification of Stake's (2006) protocol. To enhance the trustworthiness of our findings, we used data triangulation, investigator triangulation (Patton 1987), and member checks (Lincoln and Guba 1985). The protocol for this study was approved by the University of Wisconsin-Madison Health Sciences Institutional Review Board.

Results

Actor organization: the knowledge networks

Diagrams showing selected features of the knowledge network for each case are displayed in Fig. 1, Fig. 2, and Fig. 3. The key actors, core project teams,[3] and external linkages are shown, however, for clarity, we have omitted secondary (i.e., 'non-key') internal actors and the linkages between all internal actors regardless of role.

The networks exhibit some similarities but also some major differences. In each case the relevant knowledge network consisted of both individuals and collectives. *Individual actors* included persons internal and external to the hospital in which the projects took place. *Collective actors* included internal committees and external organizations. An important collective actor in each case was the *research communit*y. Within this community we distinguished between researchers and the scientific literature produced by researchers. This allowed us to differentiate between direct communication with persons comprising this community and indirect communication through their published works.

The composition, configuration and history of these knowledge networks varied across cases. In Case 1, the network was relatively simple (Fig. 1). The core project team consisted of two pharmacists and an infectious disease specialist who together comprised the Antimicrobial Subcommittee of the hospital's Pharmacy and Therapeutics Committee. As members of this standing subcommittee they had a history of working together on a variety of projects, including previous attempts to solve their *Pseudomonas* resistance problem. We considered them to be the core project team because of their critical role in defining the problem, developing hypotheses about its causes, constructing a potential solution to the problem and providing leadership to its implementation. One important function of this team was providing linkages to important K&I resources external to the hospital organization. They obtained relevant K&I, primarily in the form of scientific evidence, through two processes: monitoring key journals in their field and actively searching the scientific literature to find information that might be helpful.

The knowledge network for Case 2 is more complex (Fig. 2). The core project team was larger and more interdisciplinary, consisting of a standing group, the ICU's Respiratory Clinical Action Team (RCAT) (which included a clinical nurse specialist, a lead respiratory therapist, and two staff nurses who volunteered to represent their peers), the ICU medical director, and a newly-hired hospital infection control professional (ICP). The network diagram shows that three individuals provided important linkages to external resources. The ICP obtained information through existing relationships with the Centers for Disease Control, a sister hospital (that also had a VAP project underway), the Association for Professionals in Infection Control & Epidemiology (APIC), and a nationally-recognized infection control expert that she

[3]The project teams were somewhat fluid in their makeup, with individuals moving in and out in response to project requirements. To be considered a core project member, an individual had to be an active member during most or all of the project term.

had met through her involvement in APIC. The Respiratory Therapist drew on existing connections with the research community evidenced by regularly searching and reading journal articles, and ongoing discussions with medical device sales representatives. She established a new linkage with an RT in the ICU at a sister hospital. ICU clinical nurse specialist, the project leader, also provided key linkages to the research community through journal searching and reading and through participation in an Institute for Healthcare Improvement (IHI) Breakthrough Collaborative Program for ICU teams. The IHI program provided an important link to the research community (e.g., by giving participants highly relevant, targeted journal articles) and the practitioner community (e.g., by creating opportunities for teams from different hospitals to share their knowledge and experience). The ICU Medical Director provided important ties to the research community through journal reading and regular participation in seminars and other activities offered by the medical professional societies of which he was a member, as well as the IHI program.

The knowledge system for Case 3 (Fig. 3) was the most complex in terms of the number of actors involved and linkages between actors, although the core project team was smaller, consisting only of the ICP and an internist who chaired the Infection Control Committee. The physician drew on several existing connections with key external resources. As a regular reader of medical journals and attendee at seminars and other activities sponsored by professional societies, he provided important linkages, direct and indirect, with the research community. Also important were his existing relationships with colleagues at other institutions, established through his involvement in professional society activities and his experience as a resident physician. However, the ICP provided a bridge to a larger number of external resources including the scientific literature, a regional program for training infection control (IC) staff, a regional collaborative for reducing infection, the regional APIC, the CDC, and key individuals associated with two of these organizations (the IC training program and the regional collaborative).

Multiple champions—There were several individuals identified as champions in each of the cases. As champions, they demonstrated commitment to the endeavor, giving time and energy to the innovation, and serving as advocates and messengers regarding the change. There was a high level of agreement among our informants on who these champions were. All champions were members of the project team; however, not all project team members were identified as champions.

As the literature would predict, a physician champion was identified in each case (Ryan et al. 2002). Although their role varied, they served as a liaison with other physicians in order to obtain approval and advocate throughout the organization for the innovation, and actively supported the implementation process (Tooman 2007). Interestingly, we observed that while having a physician champion appeared to be a key component in the success of each project, other healthcare professionals also served as champions and were viewed as having a major influence on the success of the projects. Others who served as champions were a pharmacist (Case 1), a clinical nurse specialist and respiratory therapist (Case 2), and an infection control professional (Case 3).

Professional symmetry in relationships seemed to be an important reason for the involvement of multiple champions, given their roles as messengers and change agents, as the following quote suggests.

> NURSE CHAMPION, CASE 2: So nursing knows how to talk nursing language. Physicians talk physician language. Even though you could be well respected… I think they tend to want to learn and hear from their peers. Just like I wouldn't want an aide or somebody else talking to me about nursing things.

Project teams—In each case there was an identifiable project team ranging in size from 2 to 6 members. Table 4 lists by profession the members of the project team for each case. Composed of individuals occupying mid-level positions in their organization, these teams were multidisciplinary work groups of key stakeholders in the innovation, cutting across organizational and professional boundaries to include persons considered to possess relevant information or other resources needed for the project.

In each case the multidisciplinary nature of the project team was described as being critical to success. The following quote is illustrative:

> INFECTIOUS DISEASE/CRITICAL CARE PHARMACIST, CASE 1: It really is a team effort, and it really does have to be multidisciplinary, so you can't be a bunch of physicians forcing it down pharmacy or vice versa. I think what's made our effort fairly successful up to this point is just the fact that it has been multidisciplinary in terms of pharmacists, physicians, nurses, everybody kind of working together, and it's not being driven just purely from the ID service.

Although the role and degree of autonomy (which we define as the ability to make significant decisions without the consent of others [Brock 2003]) the teams varied, they were instrumental in identifying and framing the problem, generating a solution, compiling relevant data to build their case, and reaching out to diverse groups of stakeholders in order to get their buy-in. Teams also played a key role in implementation, providing leadership to individuals and groups charged with putting changes in place.

The problem framing function of project teams was especially important in two cases. In Case 1 the breakthrough came only after their high resistance rates were re-conceptualized as a fluoroquinolone overuse problem. In Case 2 the project team framed the VAP problem as a performance shortfall, mainly on the part of the ICU nursing staff. Although it focused on the negative and placed responsibility for any VAP cases squarely on the shoulders of the ICU team, the net result appeared to be positive. Many of the actors in Case 2 conveyed a strong sense of pride in their accomplishments, as exemplified in the following quote:

> ICU NURSE EDUCATOR, CASE 2: I think it gave us a sense of empowerment. We didn't have to rely on any physician to direct the care that we gave to that patient. We realized as nurses, we had the power and the ability to have an impact, and we didn't have to rely on an order from someone that says you have permission to raise the head of the bed, or you must, a physician order that this is the way you're going to suction because suctioning practices and patient positioning and oral cares, those are all things that are driven and guided by nurses. And we realize that, you know, we have a lot of power to influence and impact, and I think it was empowering for us.

It was within project teams that much of the relevant information was shared and transformed into workable knowledge. Potential solutions were conceptualized, designed, refined, tested, and then turned into standard operating procedures. They were sites at which performance data were collected and reviewed. Teams were organized to capitalize on general and local knowledge and information resources of their members. These teams were the focal point in terms of obtaining, producing, sharing, organizing, evaluating, adapting, and synthesizing knowledge, information, and data forging them into a well-defined set of practices adapted to their context and goals.

Knowledge and information used to innovate

We found that multiple forms of knowledge and information were used. To organize the discussion that follows, we will address three types of K&I: scientific knowledge, practical knowledge, and clinical data.

Scientific knowledge—Scientific knowledge played an integral role in these projects, although rarely were the actors involved able to identify specific articles, study results, or practice guidelines that they used; one notable exception was the use of the IHI VAP bundle in Case 2.

In each of the cases we studied, the scientific literature gave team members insight into the underlying causes of problems the teams were working on. For example, in Case 1, a key bit of information discovered in a peer-reviewed journal helped actors generate a new hypothesis to explain why their *Pseudomonas aeruginosa* resistance rates might be rising, suggesting a new strategy they might try and ultimately leading to a breakthrough.

> ID PHARMACIST CHAMPION, CASE 1:… there was a lot of literature that was coming out where fluoroquinolones seemed to be prevalent in terms of resistance rates going up. And we started looking at our own use, and it was the number one antibiotic used in our hospital.

Having the scientific backing provided the credible evidence needed to persuade key stakeholders that specific changes were required. The components of IHI's VAP bundle used in Case 2 were all based on Level 1 evidence (i.e., randomized controlled trials). The IHI program provided the team with journal articles describing the evidence behind the bundle and these materials were used by the team to facilitate acceptance of the proposed changes.

> INTERVIEWER: [W]ho was gathering the information, the journal articles?
>
> NURSE CHAMPION, CASE 2: [IHI] gave us all the references…the nursing staff is pretty happy just to know that if we have researched it, to take our word for it that that's the evidence. The physicians like to read it themselves, so if the physicians had questions, we would provide them with copies of whatever they wanted.

Practical knowledge—Gleaned from the personal experience of the actors, practical knowledge played a prominent role in each of the three cases and our data were rich with examples.

Prior to the start of the project in Case 2, the ICU project team had acquired valuable experience making improvements in patient care in the unit. In their earlier attempts to improve hand-washing and oral care they observed the impact of helping staff to 'see' the value of the changes they were being asked to make. They did this by making 'the invisible visible,' by first making explicit the rationale behind the changes, the connections between the change in practice and the desired patient outcome, and continuing to emphasize the logical connections between the two so that staff could understand how the change was supposed to contribute to the desired outcome. They also learned the value of continuous monitoring and frequent dissemination of patient outcomes as a means of letting the staff see for themselves the effects of the changes, motivating them to stick with it. Their earlier efforts also gave them experience with various strategies for effectively communicating with the staff when rolling out changes within the unit. They had used a number of communication strategies including signs, in-service education, posters, bulletin boards and vendor-led training sessions and they drew on this prior experience to develop their roll-out plan for this next phase of their efforts to reduce VAP.

Another example of prior experience contributing in meaningful ways to the project can be found in Case 1. One of the pharmacist champions drew on her residency training experience for the idea of a restriction policy and insight into key factors that might influence its success:

> PHARMACIST CHAMPION, CASE 1: My residency training at [State University], they had a pager that they restricted amphotericin products, the lipid pharmaphotericin products, mainly because of cost. And it was all pharmacist run, no physician was

> involved. But I think they had a physician overseer, who, if they had any difficult people, the physician would intervene. So I kind of modeled part of this on that. I wasn't directly involved in that, because I was never, as a resident, allowed to carry that pager, because it was an attending level, the pharmacist who carried it.
>
> INTERVIEWER: But you had seen this work in another instance, in another setting?
>
> PHARMACIST CHAMPION, CASE 1: Yeah. And again, with someone who has tremendous rapport in a university with a lot of respect.

A noteworthy dimension of practical knowledge that emerged in each case was associated with project team members' length of experience in their organizations. Key actors in each case cited the importance of long-standing relationships with others in the organization as one factor that contributed to the success of their project. Longevity gave actors the opportunity to know others and be known to them. They described knowing who the players were, how to work with them, who to trust, and also being known and respected by the other players as someone who is competent and trustworthy. Many credited their strong professional relationships throughout the organization and a climate of trust and respect as a critical component of their success.

> PHARMACIST CHAMPION, CASE 1: I believe a good reason why this worked in our institution is that we are known entities. So…the three of us have been here for a while… So, well-known to the department division heads, department heads, whatever you want to call it. You know, basically, we aren't a group of unknowns coming in saying, 'we need to do this.' So, you know, rapport is so important… that was key to this actually working.

The longevity of key actors also enabled them to gain practical knowledge specific to their organization, or what might be described as 'how things get done around here.' Because of their long tenure at their institutions, they came to understand the various stakeholders, the internal processes, the politics, procedures, history, and challenges of their hospital as an organization.

Practical knowledge gained from past experience also encompassed the handling of challenging interpersonal situations, for example, the sometimes delicate process of monitoring and giving performance feedback to a peer. In the conversation that follows from Case 2, one of the RCAT nurses explains how she knew to correct and coach her colleagues.

> INTERVIEWER: How did you handle the ones where, did you personally know, for instance, which nurses were not complying?
>
> CRITICAL CARE NURSE, CASE 2: You can see the nurse's initials, and then we were not being judgmental, but we would go up to them and 'Say, you know, it's the standard of care now. We've made this a standard of care that you do oral care on a vented patient every two hours. There were four hours that you didn't chart it. If you didn't chart it, it's not [done].' 'Well, I did it.' 'Well, it's not done.' Then you just tell them. They're pretty, like anybody else, they take it well. If you say it in a right tone of voice, they take it well.
>
> INTERVIEWER: [H]ow did you learn the right tone of voice?
>
> ICU LEAD NURSE: These are people we work with. These are our friends, so you don't want to come at them judgmentally… We say, 'You know what?'

Some aspects of practical knowledge used to make the project successful were more mundane. For example, in Case 3:

> NURSE MANAGER, CASE 3: We tried so many different things… The isolation equipment… seemed like such a small thing, but… that contributed to noncompliance sometimes because the staff was saying, oh gosh, I'm miserable in that. We had to go back and look at different gowns.

Clinical data—We found extensive use of data in these cases, primarily in the form of data on infection, resistance, and antibiotic utilization rates and the financial impact of the problem.[4] Most of these data were 'locally produced,' and use of these data was prominent in each of the three cases. In Case 3, it was internal hospital data that showed a problematic trend in their multi-drug resistant organism numbers:

> PHYSICIAN CHAMPION, CASE 3: And then as we saw our rates climb into 25% resistant organisms, and we saw pitch rates begin to climb to 35% to 40%, we began to realize that it's coming, and it was coming fast.

The champions used internal data to persuade their organizations to act and obtain support from key internal stakeholders as well.

> INFECTIOUS DISEASE/CRITICAL CARE PHARMACIST, CASE 1: Again, when we just present to them, here's what we've been doing over the last several years to try to influence resistance rates, show them the numbers continue to get worse. We developed data in terms of how much drugs we were actually using… So we had gone back and pulled all the data to find daily doses, and we had those numbers. We could show them that [despite the] restrictions, they actually were still going up. It was easy to point to the quinolones and say, here's all the other drugs down here. Here's the quinolones up here, and there were times when we were literally using twice as much fluoroquinolone as all the other major classes of drugs put together.

Case 2 provided a unique example of how what might be called 'naturally occurring data' helped the nursing staff see the effectiveness of a new endotracheal tube, which they had adopted as part of their approach to eliminating VAP, in removing secretions:

> RESPIRATORY THERAPIST, CASE 2: We had several RN's up in ICU that didn't buy into it… I think what finally got them to buy into it was… actually seeing these nasty secretions continuously coming through the line. I really think it opened everybody's eyes to go, 'I cannot believe there is that much down there.'

Local data were used as a 'key indicator' to monitor progress and provide valuable feedback to project leaders. In two of the cases, this information was shared with those charged with implementing the changes in order to make the benefits of the changes more observable.

In each case, the practice changes were generally implemented in a stepwise, iterative manner and were driven by data. The process of implementation stretched out over a year or more. It was an ongoing process of experimentation to see what worked in their hospital. For example, from Case 1:

> INFECTIOUS DISEASE/CRITICAL CARE PHARMACIST, CASE 1: We finally just came together one month in this committee, after the course of a couple months and several different meetings, and said, you know what, it's time to really address the fluoroquinolone issue. We've got to do something about this if we hope to ever make a significant dent in the resistance problems. And since we've tried all these other things, what we're really down to is a serious, pretty draconian restriction of the

[4]That these data were used is not in itself a finding—our case criteria mandated that pre- and post-outcome measures be available to provide evidence that these were successful projects. Instead, our findings relate to *how* the data were used and the *importance* the actors ascribed to having the data available.

> fluoroquinolones. We just arrived at the point where we tried everything else and that was the only thing that was really left to us. So we discussed the logistical issues of doing that. We knew that it was going to be hard. We knew that it would require a lot of manpower to do that. We knew that it would not necessarily save us money if we restricted the quinolones because they were relatively inexpensive drugs. If we tell them we can't use a quinolone, what else are they going to use, and whatever that alternative is may be more expensive than the quinolone, so we knew it might cost us some money in the long run. But the bottom line was, we've got a resistance problem that's so out of control. We've got to impact that somehow. We've tried everything else. This is what's left, and so that's when, again after discussions within the antibiotic subcommittee, finally we decided that's what we need to do.

Sources of K&I and linkages

A wide variety of K&I sources and linkage strategies were used. Many linkages were pre-existing. At the beginning of their projects, several actors had established communication linkages with information sources that would later be incorporated into the knowledge network for this project. These networks linked the actors to sources of ideas, information and options for improving care. Actors in these cases drew extensively on previously established relationships with various sources of information. Some of these linkages had a more formal, structured character. For example, presentations delivered at regularly attended professional meetings were a route by which scientific information flowed to actors. Regular reading and targeted searches for articles published in professional journals were another commonly identified means for obtaining relevant information. In Case 2, the Infection Control Professional obtained from the literature the CDC's newest criteria for VAP infection. This was a key input into the project that was used not only to standardize data collection internally but also to facilitate comparisons between their numbers with other facilities.

In other instances, pre-existing linkages were used for more informal communication. For example, in Case 3, the physician champion described using his collegial network to help plan their project:

> PHYSICIAN CHAMPION, CASE 3: And I know those people, and I know the people at [State College] because I did my residency through their program. So we just get on the phone and start calling and saying this is a problem we're running into, what are you all doing about it, and just made lists, and then came back, and [the ICP] and I, and a few others just compared lists about what people are doing, and how they're approaching it, and what do we think we could away with.

In Case 2, the ICP had previously established connections with national experts that she had come to know through her leadership activity in the APIC. This network was an important link to experts in the infection control area, yielding information that was not only highly relevant but also timely:

> INFECTION CONTROL PROFESSIONAL CHAMPION, CASE 2: Well, [a nationally known expert on infection control], of course… she's come to our meetings every year. I actually was the one that asked her to talk about pneumonia, and so whenever we had questions about it, I just called her up and got some advice. 'How would you do this?'

These relationships gave her access to information that helped her apply information already in the public domain. They also gave her access to information that was not yet widely available:

> INFECTION CONTROL CHAMPION, CASE 2: Other people then, people that have written the guidelines, now we get to know them and just e-mail them and say, what

> are you doing in this? [It's not addressed] in the guideline, so how are you managing it?

Existing linkages were not always sufficient to meet the K&I needs of project teams and new relationships had to be cultivated. For example, while attending a regional APIC meeting, the infection control professional from Case 3 had the opportunity to hear a nationally-known expert on infection control speak and learned that he was leading a collaborative effort to pool resources and data in her region. Afterward, she sought him out for a one-on-one conversation. She told this expert she thought she could make an impact in her hospital and the community it serves, and, she said:

> INFECTION CONTROL CHAMPION, CASE 3: 'I want you to help me.' And he gave me some very clear guidance, things he suggested, things to say to the physicians. It was a wonderful 30-minute conversation about what it took.

Most of the key linkages were developed for the purpose of innovation. Of these, some were established to facilitate learning and change generally; others were specific to the current project. However, some linkages were developed primarily to serve some other purpose or no specific purpose at all.

> PHYSICIAN CHAMPION, CASE 3: And it just so happens that the person who is now in charge of infection disease for the State Health Department was the physician who helped train me when I was a medical student at [State College].

Continuing education activities in the form of seminars, presentations, and conferences played an important role, both directly and indirectly. In Case 3, for example, the infection control champion learned about the regional program that would later become a critical source of information during a presentation at a regional APIC meeting. Vital information on a strict but effective hand hygiene policy at another hospital, which in Case 3 was described as the piece of the puzzle that finally provided the breakthrough they were looking for, was obtained rather serendipitously from a didactic presentation. Similarly, in Case 2, while attending a society meeting the ICU Medical Director learned about improvements made in a new type of endotracheal tube that was eventually adopted and was identified as the breakthrough that finally brought the VAP rate to zero. Another example that illustrates the role of ongoing participation in CME activities was that the attendance at annual seminars led to development of linkages between the physician champion in Case 3 and expert resources:

> PHYSICIAN CHAMPION, CASE 3:… I had communication with the infectious doctors at all of the universities, and partly we know them, and we go to seminars with them. I go to the infection disease seminar every year that's held by [State College].

Typically, the linkages with information sources were provided by members of the project team. An interesting exception was reported in Case 3. A surgeon, who was not a member of the project team, was considered critical in obtaining physician approval of the changes being proposed to reduce MSRA. From a variety of sources, he had become aware of the emergence and growing prevalence of MRSA. When asked where he learned about the MRSA problem he cited the state chapter of the American College of Surgeons and professional journals.

> SURGEON CHAMPION, CASE 3: As you read and study, and you got to meetings and so forth, you become aware of this, you know, that MRSA, you start hearing [about] MRSA.

Through his participation in state meetings, he had heard of an operating room in Pennsylvania that had been shut down because of MRSA. He described this as the signal event that convinced him the changes being proposed in his hospital must be approved and he used this information to persuade his physician colleagues to support the changes during a meeting that was widely described as ‘the turning point’ in the approval process.

Discussion

This study consisted of an empirical investigation of three instances of successful change in clinical practice in the domain of antimicrobial resistance in the hospital setting. This narrow focus makes it impossible to generalize our findings to a larger population of cases. In the discussion that follows, we seek instead to generalize our results to selected points in current theory and research on facilitating change in clinical practice.

Actors and organization

In each case multiple actors were involved in the change process. At the core was a multidisciplinary project team supported by, and frequently overlapping with multiple champions. That we found multidisciplinary teams at the core of these successful projects and multiple champions is concordant with research findings in the practice change literature. The importance of champions is well-established in the diffusion of innovation literature (e.g., Rogers 2003), and the importance of a physician champion to successful change in the medical setting is widely accepted. In addition, multidisciplinary teams at the local level have been found to have an important role “in shaping or ‘mediating’ the flow of knowledge into practice” (Ferlie et al. 2000, p. 101).

Projects were initiated by project team members and champions who were mid-level in their organizations. This reflects what has been called a middle-up-down approach to change (Nonaka and Takeuchi 1995), as opposed to a bottom-up or top-down model. These actors saw a situation they felt was problematic and became advocates and agents for the changes they believed were important to make. Teams were largely self-directing: project teams assumed primary responsibility for initiating, planning, obtaining approval for, implementing, and evaluating practice changes, although in one case these functions were divided between two teams. The teams analyzed and framed the problems to be addressed, marshaled evidence to support the need for and direction of change, developed proposals, and secured approval from internal stakeholders. They oversaw implementation, monitored progress, and solved problems as they arose.

Project teams were linked through their members to individuals and groups, both within and outside of their organizations, who served as sources of knowledge and information that were used in the change process. Teams organized themselves to take advantage of these multiple sources, bringing the K&I obtained from them into the innovation arena where it could be evaluated in light of project needs and incorporated as appropriate. Teams were characterized as collaborations in which hierarchy and roles were downplayed, creating environments in which team members felt a high degree of freedom to share their knowledge and ideas, a factor that has previously been shown to positively influence team learning (Edmondson 2003).

We found it noteworthy that although physician champions were identified in each case, they were neither the sole nor always the primary change agents. A physician was identifiable as a primary champion only in Case 1. This finding may be due in part to a distinction that can be made between antibiotic management (Case 1), which in our experience is typically a physician-led function in hospitals, and infection control (Cases 2 and 3), which is usually a nursing-led function.

Multiple sources/multiple linkages

The project teams we studied made use of multiple and varied sources of knowledge and information in the process of making changes in their clinical practice. The research community was an important source of K&I, both directly and indirectly. However, it was but one of several sources that were identified as important to the success of the projects. Of particular interest was the number of interpersonal connections to colleagues, experts, coworkers, and others that served as conduits through which key bits of K&I were acquired. The picture that emerges is that of a social network that was mobilized, intensified, and elaborated to serve the specific purposes of the innovations the teams were working on, a phenomenon that Engel (1997) observed in the agricultural sector.

We were struck by the importance to the innovation process of social networks that were already in place at the time the projects had begun. These were relationships between team members and coworkers in their organizations, friends they met during residency training, experts recruited as presenters at professional meetings, colleagues at other hospitals, and the like. Existing relationships with professional societies and government agencies offering continuing education were also important. To the extent that these relationships crossed intra- and extra-organizational lines, they may be characterized as boundary spanning, which has been found to be important to the innovation process (Ferlie et al. 2000, p. 101). There is considerable evidence that such linkages promote innovation (Greenhalgh et al. 2005) and this was borne out by the cases we studied.

When existing networks could not deliver the K&I needed, new networks were cultivated, often opportunistically and aggressively. The key actors in these cases were thoroughly engaged in an active pursuit to solve the problem they had chosen to work on and they seemed to be in an ongoing state of alert for new K&I that could advance their efforts. This was an active, purposeful process for relevant resources, but not all linkages that yielded useful K&I were deliberately engaged. We observed a degree of chance and serendipity as well. Some important bits of K&I came at times and from sources that were unanticipated by the project teams. They were more ‘discovered’ than ‘acquired,’ suggesting that there is a certain amount of randomness or chance that can enter the change process.

The richness of the networks of interpersonal relationships available to project teams was likely facilitated by their multidisciplinarity. This is especially true with regard to those individuals who served as boundary spanners, linking the project team to resources outside of the hospital. Diversity in team membership gave project teams a rich network for exchanging information, both internally and externally.

Knowledge and information used

Scientific knowledge and evidence played an important role in the innovation process, providing insight into the causes of problems, suggesting strategies in the form of evidence-based practices or practice guidelines for addressing the problem, and legitimizing recommendations for specific practice changes. We found some evidence of adaptation of practice guidelines, lending support to Dopson and Fitzgerald’s (2005) observation that practitioners often adapt evidence-based practices as they enact them within their work settings. However, scientific knowledge and evidence-based practices account for only some of the K&I identified as essential to the success of these projects.

The dominant theory of professional practice holds that “professional activity consists in instrumental problem solving made rigorous by the application of scientific knowledge and technique” (Schön 1983, p. 21). This theory has been challenged by studies of diffusion of innovations showing that formal scientific evidence is not the sole source of action; instead, diffusion is described as a complex interplay of explicit evidence and *practical knowledge*, gained from professional experience (Dopson and Fitzgerald 2005). Our findings support this view at the level of team learning as well. The distinction we wish to make is one that Ryle (1949) described as "knowing that" versus "knowing how." It is one thing to *know that* the evidence shows that improving hand hygiene reduces the transmission of infection but obviously quite another to *know how* to get a hospital staff to wash their hands more frequently. To know the details of a policy that another hospital implemented to make significant improvements in its hand hygiene rates is not the same as knowing how to successfully enact that policy in one's own setting.

When it came to the 'knowing how' aspect of practice change, the project teams made extensive use of their own and others' practical knowledge. An especially salient dimension of relevant practical knowledge was related to the length of time champions and other key actors had been members of their organizations. By contrast, practical knowledge borne of experience working within teams generally or within the project team specifically was not consistently mentioned as important. This finding suggests that under some circumstances, of the three levels of experience related to increased team learning (Reagans et al. 2005) experience with the organization may be more important than experience at the team level.

At key points in the process, locally-produced data or what might be called 'practice-based evidence' (PBE) served an important function. Project teams typically described their PBE as being both essential and highly effective for convincing stakeholders of the need to act and also for tracking and monitoring improvement; and, local data were a critical element of team learning process, a point we will return to later.

One way to appreciate the importance of these locally-produced data is to reflect on how these projects began. Given the enormous investment in guideline development and initiatives by government agencies, professional societies, academic medical centers and other third parties to promote change in clinical practice, it was of interest to us that none of the key actors attributed the start of their projects to a planned effort by external stakeholders to stimulate change. Instead, these projects began with clinical problem or an opportunity: the worsening of *Pseudomonas aeruginosa* resistance rates, recognition that MRSA was the predominant problem pathogen in the hospital and was a growing problem nationally, discovering that other ICUs had reduced their VAP rates to zero. They were not driven by "a decision by an individual or group that a new treatment should be disseminated in their organization" (Rosenheck 2001) or a perceived gap between a practice guideline and the existing clinical care process. None was undertaken as the result of a formal, organized initiative. Instead, *they originated in an observed gap between desired and actual clinical outcomes* at the level of the patient in two cases and resistance rates in the other. These were problems that health care professionals discovered, analyzed, and framed using a combination of locally-produced data, benchmark data from other sources, the scientific literature, and their own powers of reason. These were problems in search of solutions, not solutions in search of willing adopters. We find an intriguing parallel here with the findings of the physician learning and change study (Fox et al. 1989), Slotnick's (1999) research on physician learning, and research on adults' self-directed learning projects (Tough 1979), all of which describe a learning process that begins when an individual confronts a problem that he or she is motivated to do something about. The problem-oriented origins of these projects provides an interesting commentary on Ferlie et al.'s (2000, p. 101) suggestion that "Searches for discrete change levers may be less productive than identifying local contexts that are ripe for evidence-based change."

Practice change as team learning

In our introduction, we linked learning with change in practice. This study sheds light on some of the dynamics that connect the two. The dominant image that emerged from our informants' descriptions of their projects is that of 'learning-in-practice.' The change processes described to us were highly active and experimental in nature. A characteristic of all three cases was that key actors appeared to be continuously monitoring their environments for information and other resources that might support their efforts. To achieve change, these project teams engaged in a process of experiential learning that was continuous, stepwise, active, problem-oriented, and focused on a measurable outcome. From this perspective, the critical role that the ongoing production of practice-based evidence (i.e., outcome measures) is highly visible.

Learning through the use of practice-based evidence was at the core of the innovation process. It required repeated cycles of strategizing, implementing, assessing the results, and reflecting back on the process to see where additional changes might be needed. The processes described to us bore similarities to constructs such as the Plan-Do-Study-Act cycle associated with quality improvement and the IHI model (Institute for Healthcare Improvement 2003), Kolb's experiential learning model (Kolb and Fry 1975), or action research (Coghlan and Brannick 2004). On this point our study validates Brown and Duguid's observation that practice change often takes the form of "experiments that are simultaneously informed and checked by experience" (Brown and Duguid 1991, p. 50) and lends support to the central role given to outcomes measurement in the IHI's model for improving clinical practice (Institute for Healthcare Improvement 2003).

In our view, these teams used clinical data in a way that made the scientific evidence and evidence-based practice secondary to their practice-based evidence, with the result that the latter became the primary driver in the practice change process. The project teams we studied were empiricists in that they relied on experimentation and observation. The scientific evidence and the practices derived from it were, it might be said, a source of ideas about what changes in practice might make a difference, but their process was ultimately governed by the result of their experiments, whether or not the changes they had implemented 'moved the needle on the dial' (i.e., led to improvements in their measured outcomes). This eclipse of scientific evidence by practice-based evidence as the primary driver of practice change poses a challenge to models of change that place scientific research at the center of its universe, showing the limits of such a view in accounting for the full range of processes by which innovation takes place in hospitals. Science clearly plays a crucial role, but as an explanatory concept it has limited value when it comes to understanding how these teams went about improving their practice.

Another major theme that emerged across cases was the highly synthetic and sometimes improvisational process by which project teams developed, tested, and refined a solution to their clinical problem. As we searched for a word or metaphor to describe how the teams at the core of these cases acquired and used knowledge and information we arrived at *bricolage*, which we define as the ability to "make do with whatever is to hand" (Levi-Strauss 1974, p. 17). As the teams involved in these cases moved through the process they acted as bricoleurs, piecing together a solution using bits of K&I gleaned from several sources or manufactured in-house. The teams at the core of each project were, in effect, the 'intellectual workshops' in which knowledge, information and data were forged into solutions.

Conclusions

There is a growing body of evidence that teams can be effective agents of change in practice. This study provides some additional insight into how teams go about producing change, the learning activities that teams engage in and how they use knowledge, information, and data in the process. The project teams we studied were not passive receptors of knowledge and information but were actively engaged in seeking out, creating, synthesizing and deploying multiple forms of knowledge and information from a variety of sources. This dimension of the innovation process is not well-accounted for by approaches to change that make a sharp distinction between producers of knowledge (researchers) and users of knowledge (practitioners) and treat knowledge as a commodity. By their focus on the production, packaging, dissemination, and utilization of scientific knowledge, they tend to blind us to the multiple forms and sources of knowledge and information utilized in the innovation process, and obscure the challenges actors confront when they attempt to apply K&I in their own practice.

This study suggests that the underlying intellectual ground pattern of at least some instances of practice change can be understood as an iterative learning process. This stands in stark contrast with more linear models tracing the movement of scientific knowledge from researchers to practitioners. We believe it also shows the value of using a broader understanding of what counts as knowledge in the context of innovation in clinical practice and draws attention to teams not only as consumers but also as sources and producers of relevant knowledge and information.

Some instances of practice change grow out of a process that highly social. They simply cannot be well-accounted for by focusing on an individual. It also highlights the potential value to change efforts of rich interpersonal networks that span boundaries both within and across organizations.

The current study demonstrates the limitations of current approaches to assessing the impact, effectiveness, or value of CE activities. A comprehensive account of the impact of CME on clinical practice requires two perspectives. The first is what might be called an *activity-based strategy* that examines the impact of an educational intervention on practice. This is currently the dominant model in CME evaluation and research. Given that some practice change is the result of an ongoing, iterative, synthetic, and to some degree, serendipitous process and that not all changes have as their proximal cause an educational activity, studies of this sort are highly likely to underestimate the impact on practice. A fuller understanding requires a second, complementary approach, which we will call a *change-based strategy* that examines how CME activities contributed to practice change when change is found to occur. This turns the problem on its head by asking not *does change occur* as a result of an educational intervention, but instead *when change does occur*, what was the contribution that continuing education activities made? These cases demonstrate that although CME activities may not be the primary or proximal cause of change in practice, they may nonetheless make critically important contributions, directly or indirectly, to the innovation process. This finding suggests that prior investigations into the impact of continuing education have tended to overlook or perhaps under-appreciate some of the ways CE can contribute to innovation, both as a source of relevant information and as a mechanism for developing the knowledge networks needed to support current and future change initiatives. This phenomenon might be attributed in part to a view of continuing education programs as primary tools for producing short-term changes in clinical practice, a view that often leads to the conclusion that CE is not often very effective. Our study suggests an alternative perspective: continuing education as one dimension of the knowledge and information ecology (Malhotra 2002) that supports efforts to improve practice. Effectiveness of a CE program in this context would be based more on criteria such as timeliness, accessibility, relevance, and utility of the information provided in relation to the practice change goals of participants, the contribution made to participants' readiness to attempt to make a change, or the enrichment of social networks that can support current or future efforts at change.

Further studies examining the types and sources of knowledge and information used in the innovation process will enhance our understanding of how continuing education might support innovation more effectively. The dissemination of information and creation and recreation of knowledge are at the heart of the CE enterprise; accordingly, CE theory and practice will benefit from a better understanding of how knowledge and information are acquired, interpreted, and reconstructed by actors in health care settings to effect change.

Additional research is also needed on how to facilitate the process by which teams learn and transform this knowledge and information into practical 'know how,' the optimal personnel configurations for collecting and using the relevant information, and, given the central role learning can play in the innovation process, the role of continuing education in fostering innovation and improvements in patient care.

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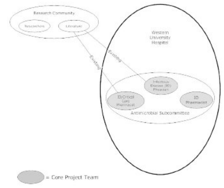

Fig. 1.
Case 1: knowledge network showing linkages with external resources

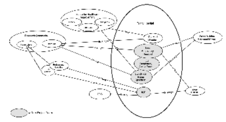

Fig. 2.
Case 2: knowledge network showing linkages with external resources

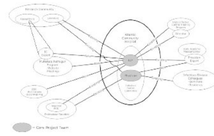

Fig. 3.
Case 3: knowledge network showing linkages with external resources

Table 1

CDC 12-steps to prevent antimicrobial resistance in the hospitalized setting

Strategy: prevent infection
Step 1: Vaccinate
Step 2: Get the catheters out
Strategy: diagnose and treat infection effectively
Step 3: Target the pathogen
Step 4: Access the experts
Strategy: use antimicrobials wisely
Step 5: Practice antimicrobial control
Step 6: Use local data
Step 7: Treat infection, not contamination
Step 8: Treat infection, not colonization
Step 9: Know when to say “no” to vanco
Step 10: Stop treatment when infection is cured or unlikely
Strategy: prevent transmission
Step 11: Isolate the pathogen
Step 12: Break the chain of contagion

The CDC campaign to prevent antimicrobial resistance in healthcare settings. Available at: http://www.cdc.gov/drugresistance/healthcare. Accessed May 25, 2009

Table 2

Key concepts from soft knowledge systems theory

Concept	Definition
Innovation	"'Change-on-purpose', propelled by individual and collective intentions" (Engel 1997, p. 11). Encompasses both the decision to make a change in practice and implementation
Knowledge	"Knowledge is taken very broadly to mean the concepts, ideas, insights and routines (including mental routines) people use to impute meaning to events and ideas" (Engel 1997, p. 32). A property of individuals, it cannot be observed or communicated directly, instead it is embodied in individual and social actions
Information	"A pattern imposed on a carrier such as sound, radio waves, paper, diskettes, electronic cables and so forth" (Engel 1997, p. 32). Information is explicit and can contribute to the development of knowledge
Knowledge network	"The more or less formalized, relatively stable pattern of communication and interaction among social actors who share a common concern [such as improving clinical practice] … Such patterns emerge as a result of relation-building efforts among actors" (Engel 1997, p. 37). These networks may be found within organizations or extend across organizations and institutions; they "may be spontaneous and totally informal, or designed to serve a specific purpose" (Engel 1997, p. 37). Knowledge networks can be described only in relation to some purpose. Innovation is the desired outcome of a knowledge network, but in practice they are defined in relation to more specific goals
Actor	Individuals or collectivities involved directly or indirectly in an innovation. May be either internal or external to the innovating group or organization
Communication linkage	The formal or informal channels or networks through which information flows. Communication is "the production, exchange and processing of information (including symbolic information) between two or more social actors" (Engel 1997, p. 33)
Knowledge processes	A concept used to anticipate and identify the activities and division of labor among actors within a knowledge network. We employed Röling and Engel's (1991) approach of looking at the generation, acquisition, integration, distribution and utilization of knowledge and information

Table 3

Case characteristics

	Case 1	Case 2	Case 3
Location	West	Midwest	East
Pseudonym	Western University Hospital	Trinity Hospital	Atlantic Community Hospital
Size	Large	Midsize	Small
Type	Academic	Community	Community
Interviewees	13	18	18
General focus	Antibiotic Mgmt	Infection control	Antibiotic Mgmt and infection control
Specific clinical focus	*Pseudomonas aeruginosa* resistance	Ventilator-acquired pneumonia	Methicillin-resistant *Staphylococcus* aureus
Intervention	Fluoroquinolone restriction policy	IHI VAP bundle, new ET tube	Active surveillance cultures, isolation, hand hygiene
Results	Appropriate FQ use went from 68 to 92%	6.0/1000 vent-days to 0.0 over 18 months prior to study	Resistance went from 80 to 62%
	Resistance from 49 to 39%		Hand hygiene compliance rose from 45% to 89%
			HA-MRSA virtually eliminated

Table 4

Project team members

Case	Team member
1	Infectious disease physician
	Infectious disease pharmacist
	Infectious disease/critical care pharmacist
2	Clinical nurse specialist, critical care
	Respiratory therapist
	Infection control professional
	Critical care nurse (1)
	Critical care nurse (2)
	Critical care physician and medical director
3	Infection control professional
	Internal medicine physician