Handbook of Research on the Efficacy of Training Programs and Systems in Medical Education

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Chapter 22
Expect What You Inspect:
A Worked Example of Dashboards That Support Continuous Quality Improvement in Medical Education

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ABSTRACT

The Liaison Committee on Medical Education (LCME) requires that medical schools track compliance and continuous quality improvement (CQI) efforts across a broad range of LCME standards. However, LCME does not state what form these tracking efforts should take, or how medical schools should represent this information to the Committee or internally. This chapter provides an overview of the Keck School of Medicine of the University of Southern California's (KSOM) new approach to CQI tracking using an online dashboard. The project resulted in an online platform that represents the CQI project progress across a range of elements, maintains visual consistency across a range of data sources and file types, and is easily accessible by relevant stakeholders. This innovation from KSOM illustrates how a web-based platform supports CQI efforts, and how this design can be translated to other contexts. The design presented in this chapter provides guidelines for the development and innovation of CQI tracking initiatives at other schools.

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INTRODUCTION

The Liaison Committee on Medical Education (LCME) requires that medical schools in the United States and Canada track compliance and continuous quality improvement (CQI) efforts across a broad range of LCME standards, as specified in Element 1.1 of the standards (LCME, 2017). However, the LCME does not specifically state what form these tracking efforts should take, or how medical schools should represent this information to the Committee or internally. The Keck School of Medicine of the University of Southern California (KSOM) has designed a new CQI tracking tool to address LCME's directive. Built in a commonly available online platform, the KSOM tracking platform serves as a starting template for use and adaptation by other schools and institutions who strive to monitor their ongoing efforts. This worked example provides an overview of the system developed at KSOM, the rationale and theoretical framework for the design, and lessons learned from the development of the system in KSOM's local context. This chapter presents the results of the development of the CQI tracking platform that began in October of 2017 and concluded in November of 2017, when administrators presented the dashboard during the LCME accreditation visit. Participants in the design and development processes included the Vice Dean for Medical Education, the Director of Educational Technology, two learning scientists, the CQI accreditation administrator, and the support of a medical illustrator. Total development time amounted to approximately 50 hours for all parties over the course of that month.

The platform described in this case was developed to serve as a central location for the multiple activities and parties that surround compliance and CQI tracking. KSOM's Vice Dean for Medical Education initiated the request for better CQI tracking tools during the school's Fall 2017 LCME accreditation cycle. As the Vice Dean noted in interviews following the accreditation process:

Our formal tracking of CQI initiatives began with the LCME process. Prior to that, there was not a central mechanism to track [improvement initiatives] from the various areas across the medical school. We maintained this data, but it was in the form of program evaluation data, and it was located in various offices. The information was brought together from those various sources and reviewed it at the appropriate meetings and gatherings, so it was not centralized. And as we learned going through the LCME process, we needed to capture all the relevant information and bring it together in one location. (2018)

For this reason, many schools of medicine have turned to the use of 'data dashboards' or data display systems to represent their CQI efforts in easy-to-consume formats. While information and analytics representation systems have existed for decades in business and information technology, recent advances in computer and network technologies have made it easier than ever to implement these systems in the context of academic medicine.

In developing this CQI tracking platform, the authors observed that few resources exist to guide the design of compliance and CQI tracking systems for LCME standards and elements. Searches in peer-reviewed literature found few contemporary studies that provide administrators with details about how to create tracking systems that conform to LCME's compliance and CQI tracking expectations. This constitutes a problem with severe consequences, as-without consistent guidelines to produce tools to serve that purpose, medical schools may fail to develop these systems and fail to fulfill the expectations of the LCME standards and suffer consequences such as probation (e.g., Miller, Dzowonek, McGuffin & Shapiro, 2014). Further, a disparity may emerge between large and well-resourced institutions that can invest resources in developing CQI tracking tools and smaller schools of medicine that cannot invest

human resource time in the prolonged development of such a system. Finally, these systems can also support the tracking of CQI initiatives beyond the requirements of LCME, thus improving outcomes for endeavors beyond accreditation. KSOM would like to share its response to the challenge of creating CQI tracking systems to help other institutions avoid the pitfalls associated with this issue, along with a theory-driven approach to dashboard development. The components presented in this chapter may help to speed other schools' advances in CQI tracking and promote an ongoing dialog about how best to achieve the creation of a standardized yet flexible approach to developing these platforms.

This chapter presents a worked example of a process that medical schools can use to construct functional CQI dashboards in their own contexts. As described by James Gee (2010), worked examples provide readers with a deeper understanding of the learning potential of digital media through the analysis of media artifacts from both theoretical and technological lenses. As such, this chapter includes both the theoretical underpinnings and a practical process for developing a high-quality dashboard. The worked example is organized into two sections: 1) *Background on LCME Accreditation, CQI Tracking, and Data Dashboards*, and 2*) an Activity Theory Approach to the Development of CQI Data Dashboards*. In the first section, the chapter provides a review of research and theoretical frameworks from two key areas that inform the development of CQI initiatives and the dashboard technology to track them according to accreditation bodies' directives. In the second section, the authors draw on Cultural-Historical Activity Theory (Vygotsky, 1978; Leontiev, 1978; Luria, 1976; Engeström, 2000, 2001) to describe five steps that dashboard developers at other institutions can follow to develop a CQI data dashboard and support the development of new technological innovations. With both theoretical and practical frameworks at their disposal, the authors hope that readers will be able to adapt the design presented here to the needs of their local context in ways that draw from the best of current knowledge in CQI dashboard development.

BACKGROUND ON LCME ACCREDITATION, CQI TRACKING, AND DATA DASHBOARDS

While the emergence of new data display technologies has made the creation of online dashboards easier than ever, the creation of dashboards that effectively scaffold the work of CQI administrators and accreditation specialists requires some background in two key areas of research. To help provide context for KSOM's approach to the development of a CQI dashboard, this worked example briefly reviews the current research on LCME accreditation standards and CQI tracking practices. Second, it will examine current thinking on the role of data dashboards as powerful information technologies and as a CQI tool in medical education. These areas of research provide a sound knowledge base for administrators and developers who wish to adopt, localize, or innovate the design presented later in the chapter.

LCME Accreditation and CQI Tracking

Researchers in medical education have described the role of continuous quality improvement initiatives since the mid-1990s (Buchanan, 1995). Despite this long-term interest in CQI in medical education, the LCME only adopted standards that require medical schools to track their CQI efforts in 2015 (Barzansky et al., 2015). As of 2019, the LCME accreditation Standard 1, Element 1, contains key mandates related to the implementation of CQI processes in each medical school:

A medical school engages in ongoing strategic planning and continuous quality improvement processes that establish its short and long-term programmatic goals, result in the achievement of measurable outcomes that are used to improve educational program quality, and ensure effective monitoring of the medical education program's compliance with accreditation standards.

(LCME, 2017, p.1)

To explain the emergence of this new standard in 2015, Stratton (2019) notes that the growth of the importance of CQI efforts in medical schools has closely paralleled medical education's goals of rendering the activities of medical school 'rationalized,' or measurable, operational, and transparent to the various stakeholders who are invested in school performance.

While the LCME's CQI standard covers a broad range of accreditation expectations related to CQI processes, it does not provide guidance as to how medical schools should enact the standard in their local context. For this reason, schools have been left to their own devices to develop these processes and negotiate the implementation on their own. This lack of specificity has created opportunities for schools to develop innovative processes for CQI tracking but has also left schools to manage challenges with little guidance. Further, without consistent guidelines that produce tools to facilitate CQI tracking, it is possible that smaller medical schools with fewer financial and human resources may fail to develop these systems and maybe unable to fulfill all of the expectations of the LCME standards. For example, Barzansky et al. (2015), identified the labor-intensive nature of managing the data produced for periodic reviews among the challenges faced by schools that implement CQI processes, as well as the difficulty of developing solutions to these data management challenges.

Since the adoption of Standard 1.1, scholars such as Blouin, Tekian, Kamin, & Harris (2018) have begun new research on the role of accreditation standards and CQI initiatives in creating institutional change through the allocation of resources, engagement of multiple stakeholders in institutional self-assessment, and changes in the business processes of the school. Blouin & Tekian (2018) also note that accreditation processes may play a reciprocal role in causing these changes, as accreditation pressures reinforce the importance of CQI initiatives between cycles of LCME evaluation. In their review of 10 U.S. medical schools' approaches to CQI processes, Hedrick et al. (2019) provided further evidence for the role of the LCME CQI standard in facilitating a range of changes in schools' business processes. This included the creation of officers and committees to manage CQI projects, the promotion of accountability for initiatives, and shifts in culture that reframed accreditation as a process that must be maintained through constant improvement and accountability.

CQI Tracking and Data Dashboards

To ensure compliance with Standard 1.1, schools across North America have begun to investigate the development of new kinds of data dashboard technologies to support their CQI tracking processes. In the context of this chapter, the term 'data dashboard' describes digital technologies that facilitate the visual representation and summary of quantitative and qualitative data in centralized systems. More specifically, Few (2006, p.12) notes that visualization technologies qualify as data dashboards when they provide "a visual display of the most important information needed to achieve one or more objectives consolidated on a single screen so it can be monitored and understood at a glance." Similar technologies have existed for many years in business contexts and have emerged in response to personnel and time

pressures faced by organizations in the private sector (Gemignani, Gemignani, Galentino, & Schuermann 2014; Rossett & Schaffer, 2012).

Power (2008) extends the definition of data dashboards by describing the function of a broad category of 'data-driven decision support systems' that exist in multiple business domains. This class of technologies support basic functions that include: 1) Ad-hoc data filtering and retrieval, 2) software-initiated alerts and triggers, 3) the capacity to create predefined data displays, 4) back-end software to support data aggregation and summarization for the visualization, and 5) the ability to interact with data warehousing and statistical analysis software. Evergreen & Metzner (2013) also identify several specific visual properties that make these systems effective, including the use of color, line weight, motion, and text and arrows. Evergreen & Metzner indicate that these graphic properties of information display play an important role in users' ability to make sense of data, particularly when these data are used to inform evaluation or call attention to important information represented by the data.

While Power's features of decision-support systems describe the technological aspects of the software and Evergreen & Metzner describe the relevant graphic properties, Smith (2013) identifies three main kinds of dashboards as defined by their purpose. These include data visualization tools that support humans in strategic, analytic, and operational domains. These dashboard types differ in how they combine system functions, graphics, and crucially, their role in the decision-support process. In this view, the purpose of the dashboard influences its form in ways that are unaccounted for in the technical and graphic properties examined in the research. Ongoing research on data dashboards in fields such as learning analytics (Verbert, Duval, Klerkx, Govaerts, & Santos, 2013) indicate that these dashboards can be designed in ways that support the effective use of data by educational leaders without imposing additional time burdens (Tyler, 2013; Wayman & Cho, 2008).

Due to the relative novelty of these dashboards in educational fields, current studies include only general guidelines for the designs of data visualization systems. For example, some researchers have suggested that practitioners may benefit from bringing together multiple forms of data from schools into units that facilitate analysis (Hernandez-Garcia & Conde, 2014; Knigge & Cope, 2006; Wayman, Stringfield, & Yakimowski, 2004). However, the design of dashboards that are useful in a particular setting may depend on various factors such as the kinds of data available in the system, the kinds of graphical representations available, and the kinds of analysis supported by the data system software (Verhaeghe, Schildkamp, Luyten, & Valcke, 2015). For this reason, medical education requires the application of a theory-grounded, generalizable approach to the development of medical education dashboards that specifically target the needs of CQI officers and data personnel in medical schools.

While the communications features of data dashboards have become clearer over time, the broad availability of data created by the automated collection of information via computer systems has simultaneously created an 'attention economy,' further complicating strategies for the tracking of CQI initiatives. Attention economies place pressure on humans to devote more of their cognitive resources to data analysis as human-machine systems routinely produce more data than they are able to consume and use (Simon, 1971). That is, even when medical schools develop the capacity to generate and access the right kinds of data, they are often unable to manage or make sense of this information because of a lack of available time for analysis.

Echoing the challenges faced by the abundance of data, Hedrick et al. (2019) found in their review of ten medical schools in the United States that the schools used a range of qualitative and quantitative data to provide the LCME with evidence of their CQI work. In describing the technological strategies used by these institutions, Hedrick et al. note that some institutions felt constrained by the limited spreadsheet

technologies that were available to track their CQI projects. While the use of spreadsheets to manage and analyze CQI efforts may seem to be a trivial issue, broader research on data dashboards in educational environments indicates that the choice of display technology can have a substantive impact on how these data are used to inform decisions about improvements to student outcomes and performance (Wayman, Stringfield, & Yakimowski, 2004). For this reason, Hedrick et al. note that while eight of their ten schools used standard spreadsheet software to manage their CQI data, "others noted that standard spreadsheet software was not specific to the CQI process, is not customizable, is not searchable, requires many sheets, and needs better dashboarding" (2019, p. 289). For this reason, many schools have turned to the use of data dashboards as a means of tracking and supporting their CQI projects.

Within medical education, Shroyer, Lu, & Chandran (2016) have provided the beginnings of a data dashboard development process that specifically focuses on the LCME CQI standards. In their "drivers of dashboard development (3D)" process, administrators at the Stony Brook University Renaissance School of Medicine developed a methodology for developing CQI dashboards by identifying and tracking Key Performance Indicators (KPIs) that relate to LCME standards, creating dashboard-based reports based on these indicators and metrics, and creating successive rounds of feedback to improve the utility of these visualizations. While this approach to dashboard development provides a solid starting point for the development of dashboards for medical education, it does not provide further guidance on the development of dashboards that specifically track CQI efforts across multiple kinds of data and support users' decision-making processes.

Emerging Technologies and Strategies

While few institutions have published peer-reviewed articles about how they have approached the development of CQI tracking technologies, this issue has not gone unaddressed in the broader medical education community. While some large institutions use their existing accreditation management software to track their CQI initiatives, many report developing their own custom dashboards and tools using off-the-shelf technologies. For example, at the American Association of Medical College's Western Group on Educational Affairs (AAMC-WGEA) meeting in 2019, several large institutions such as Stanford University, the University of California at Irvine, and the University of Washington presented their approaches to tracking student performance and LCME standard performance using data dashboards that they have designed in-house. These approaches commonly featured a number of key innovations and limitations that provide some insight into how medical schools generally are working to adapt technologies to meet their CQI needs.

On the innovations front, several institutions have begun to move beyond Excel spreadsheets to integrate real-time data analysis tools such as Tableau into their data dashboard strategies. Tableau is a data display and dashboard platform produced by a Seattle-based company that uses a front-end interface to extract data from a data warehouse and present it as a visualization (colloquially called a 'viz'). These visualizations provide a high degree of flexibility for dashboard developers, as the software can reformat the same data into a range of formats such as timelines, bar graphs, or category charts. These visualizations can also be embedded into websites or presented as 'stories' that help users to make sense of the relationships between trends illustrated in multiple visualizations. Tableau also supports role-dependent views of dashboards, a feature that allows developers to restrict user access to data that they are not entitled to see due to HIPPA or FERPA compliance issues. For example, it is possible to create dashboards that present instructors with data related to their teaching performance, but to conceal data

that relates to the performance of other instructors. Tableau also has an active user community that is continually innovating their practice and sharing new lessons at an annual meeting.

However, the innovations presented by these schools also come with limitations of three types. First, the implementation and installation of Tableau visualizations requires some support from information technology experts during setup (especially when importing or storing data in a data warehouse). Second, Tableau and similar technologies are usable by staff who have a moderate level of technological skill, but there is a learning curve associated with adopting the technology and implementing it in a medical education context. While sites such as Lynda.com and YouTube provide video tutorials on Tableau, schools may have to invest funds in sending their dashboard development staff to Tableau workshops or hiring developers to jump-start their dashboard. Third, the successful creation of a Tableau dashboard requires that developers approach the technology from a user-centered perspective. A user-centered dashboard focuses on promoting users' ability to derive meaning from the data in order to make decisions about the direction of their CQI projects and report its progress. However, creating user-centered dashboards requires more than just the right technology; developers must also communicate closely with accreditation and CQI administrators and staff in order to produce tools that serve their needs. The next section of the chapter provides a detailed view of a methodology for achieving a user-centered dashboard for CQI tracking.

An Activity Theory Approach to the Development of CQI Data Dashboards

Every medical school in the LCME jurisdiction exhibits a different profile of available resources and needs. Some schools are attached to Carnegie Research 1 universities, a feature that affords them with greater access to research laboratories or cutting-edge medical facilities and teaching hospitals. Other schools are part of a broader network of medical institutions that are only tangentially connected to local universities. The variance in available human and technological resources requires a flexible strategy for developing CQI dashboards that helps staff and administrators to make the best use of their materials. This part of the chapter provides a detailed worked example of one strategy for deploying resources in an effective and theory-oriented way.

Expanding on the work of Shroyer, Lu & Chandran, the authors have developed an approach to the data dashboard design process that other schools can adapt to their context. This section of the chapter contains a description of 1) the conceptual framework known as Cultural-Historical Activity Theory and how it relates to CQI dashboards, 2) the process used to design the CQI data dashboard at the Keck School of Medicine, and 3) the dashboard design itself. The worked example that results from this discussion will provide data dashboard designers with a stable process for developing their technology. Theoretical frameworks are crucial tools that enable scholars and practitioners to adapt research done in one context to the needs and demands of another context. Describing the KSOM dashboard in terms of Activity Theory will help scholars at other schools to manage the complex and interrelated decisions that lead to a successful implementation in their own context.

Theoretical Framework: Activity Theory

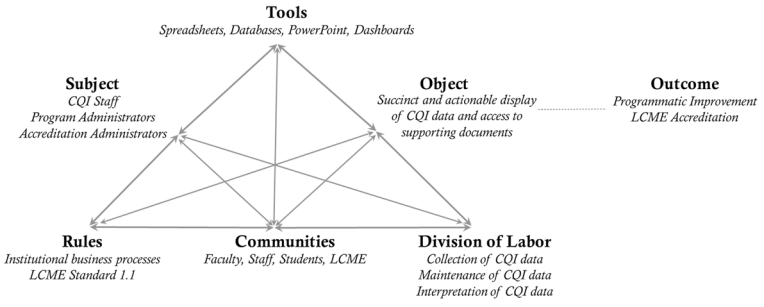
In selecting an appropriate framework for describing the dashboard design process in a generalizable way, this section of the chapter is grounded in Cultural-Historical Activity Theory (Vygotsky, 1978;

Leontiev, 1978; Luria, 1976; Engeström, 2001). Activity Theory focuses on the tensions that arise between key features of work in complex professional environments (Larsen, Nimmon, & Varpio, 2019). Among these crucial tensions are the ways that 'instruments' (such as physical or digital tools) influence the processes, practices, and outcomes of community efforts. These tools play central roles in how individuals communicate and make meaning in and from their work (Kaptelinin & Nardi, 2009; Engeström, 2000; Engeström, 2001; Cole & Hatano, 2007), continually co-evolving with the abilities and needs of their community. Additionally, theorists like Kaptelinin & Nardi (2006) assert that Activity Theory can also inform the design of technologies that scaffold and facilitate work. Recent developments in Human-Centered Design Engineering (HCDE), posit that digital tools and platforms play a similar co-evolutionary role, where users' approach to practical activity can change through interactions with technology (Broberg, Andersen, & Seim, 2011; Kaptelinin & Nardi, 2006). These tools play a crucial role in sensemaking and cognition during the use of data in practice. Recent research in Activity Theory elaborates features of technology design that can support users in accessing and making sense of data in ways that can improve their practice. (Arias-Hernandez, Green, & Fisher, 2012; Broberg, Andersen, & Seim, 2011; Farrell, 2014; Kaptelinin & Nardi, 2006; Kirk, 2012).

Using Activity Theory to plan these new systems can also help to coordinate the design of these CQI platforms with the functions of existing teams within a medical school. To help others understand the activity system and design process that produced our CQI dashboard, the authors diagramed the system using a schematic developed by Engeström (2000) to visualize the components involved in KSOM's longitudinal CQI initiative (Larsen, Nimmon, & Varpio, 2019). For example, the emergence of these platforms as mediating technological tools can connect stakeholders through the development of better business processes. Additionally, new roles, rules, lines of reporting, and tools may need to be developed as a result of the introduction of a CQI tool. Activity Theory provides technology designers with a means of identifying the systemic aspects that shape medical schools' data dashboards needs, and keeps designers focused on the ultimate goal of these data dashboard tools: to make the work of using data easier for accreditation teams and administrators. Figure 1 illustrates the CQI activity system; this diagram can be reused or adapted to other medical school contexts.

Activity Theory provides a powerful means of understanding how parties who are responsible for monitoring and enacting CQI initiatives use communications platforms to achieve their goals. However, in developing an Activity Theory approach to the design of CQI tracking systems, the authors recognize that this framework may pose challenges to designers due to a lack of expertise in Activity Theory within North American medical education. To help simplify this framework and make it easier to implement,

Figure 1. CQI activity system



the CQI data dashboard process has been divided into five steps that correspond with important features of Activity Theory networks. These include:

Step 1: Define Success for Your Dashboard (*Outcomes*)

In Activity Theory, the ultimate outcome of the activity system is the achievement of an outcome goal; however, these outcomes refer to the goals of the entire activity system (e.g. LCME accreditation or improved student performance), not the instrumental goals of a particular project (e.g. creating a data dashboard). Beginning with these outcome goals in mind will help designers to set reasonable definitions for success for the dashboard that actively support the broader strategic goals of the medical school. In the case of most medical schools and their CQI efforts, this goal is to achieve programmatic improvements that benefit students as well as to ensure LCME accreditation and compliance with LCME Standard 1.1.

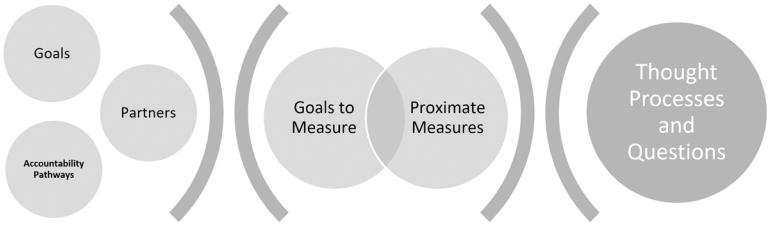
Step 2: Organize Your Data Heuristically (*Subjects*)

In Activity Theory and Human-Centered Design Engineering (Broberg, Andersen, & Seim, 2011; Kaptelinin & Nardi, 2006), the subjects in the system play central roles in conceptualizing and enacting their work, and in using their available tools to achieve the system's desired outcomes. For that reason, it is essential to develop technologies that map to the work of the subjects through their theories of action (Argyris & Schon, 1978). In their work on Action Science, Argyris, Putnam, & Smith (1985) define theories of action as complex, related propositions about the relationships between situations, actions, and consequences. Data dashboard designers who carefully map the theories of action of subjects in the activity system can create a through-line that links stakeholders, goals, data, and data-driven decision-making to produce effective tools for scaffolding decision making about CQI initiatives (illustrated in Figure 2). When this is accomplished, data dashboard designers can tailor the technologies to the work demands of the subjects. Technological developments that fail to balance the goals of the of the subjects, the needs of partners outside the activity system, and the available information and accountability pathways can reduce the utility of the technology and hamstring work within the activity system. In short, in order to help stake-holders use the dashboard to support their thinking, the dashboard must be structured with their thinking in mind. Figure 2 illustrates in generic terms how theory of action development can be applied in readers' home context.

Step 3: Select Your Dashboard Platform (*Tools*)

Scholars in Human-Centered Design Engineering often describe the ability of technologies to improve work outcomes in terms of affordances and constraints (Norman, 2013). An affordance is any property of a technology that improves its utility for the end user in achieving their goals. However, a constraint is any physical, cultural, semantic, or logical component of a technology that frustrates the user's ability to accomplish their objective. Constraints can also arise in technological systems as a result of disconnects between how designers anticipate users' behavior and the actual behaviors of the user.

Figure 2. Illustration of the heuristic development process



Activity Theory extends these concepts into deeper socio-cultural dimensions of work, as the process of building technological tools can benefit work processes by revealing gaps in the larger work flow and supporting the planning of rigorous, data driven improvement efforts and coordinating the attention of various stakeholders (Engeström & Cole, 1997, Engeström, 2000, 2001, 2007; Kaptelinin & Nardi, 2006). In this part of the dashboard design process, developers must consider both the constraints and affordances of technologically-mediated tools, as well as the impact that these tools have on work itself.

Step 4: Develop Dashboard and Element Views (*Rules, Communities, and Division of Labor*)

A crucial component of Activity Theory is its focus on the cultural and historical dimensions of the social reality of work (Nardi, 1995). In the work of Engeström and others (e.g. Engeström, 2000), culture and history are understood to be real forces that shape how subjects within an activity system understand their place in the work environment, how communities within the system form and interact, and how the organization divides rights and responsibilities amongst its members. Extending this concept to dashboard design, dashboard developers must consider how their technologies reinforce the expectations of the organization (rules), standardize communications between institutions and accreditors (communities), and support the work of a range of stakeholders (divisions of labor).

In addition to selecting technologies that accurately report information throughout the activity system, designers in other contexts should consider a visual layout that uses principles drawn from cognitive science (i.e. Clark & Mayer, 2016). Previous research on effective dashboards by the designers has identified several principles of data usage that should be integrated into dashboard designs. In interviews conducted by one of the authors at a large educational institution in Washington state, expert designers articulated five key attributes of well-designed dashboards:

- **Data consolidation:** Great dashboards bring together relevant data from different parts of the organization into one warehouse and dashboard and provides flexible disaggregation of data.
- **Data integration:** Great dashboards integrate relevant data sources into a parsimonious representation in one place.
- **Data interpretation:** Great data dashboards facilitate users' interpretation of data by grouping visualizations logically, managing users' cognitive load, and include text captions that explain the relevance of the data to decision making.
- **Data triangulation:** Great data dashboards facilitate users' ability to support their decisions using several sources of data.
- **Signaling:** Great dashboards use visual markers to help users quickly make sense of important data and information on a dashboard.

Dashboard developers should review their designs against these attributes before proceeding to user testing phases of the development process.

Step 5: Test the Dashboard with Users (*Object*)

The development of a data dashboard is an iterative process that requires periodic reviews of the products of design processes. At the end of each cycle of design, dashboard designers should work with their stakeholders to determine whether the dashboard fits their needs and how it can be refactored around their work. Developers can use a variety of techniques to track how well their dashboards are performing with their end users. These can include quantitative evaluation methods such as page analytics that track the frequency and patterns of use by CQI administrators, as well as qualitative methods such as interviews and focus groups.

Following these five steps, and engaging in periodic cycles of redesign, will provide dashboard designers in medical education with a theoretically and practically achievable approach to the development of their tools that touches on the major Activity Theory framework constructs and ensures adherence to good design processes.

The Keck School of Medicine Data Dashboard Design Process

In applying the logic of the design process from the perspective of the designers and administrators, readers will be better prepared to create their own dashboards in their local context. This section of the chapter will proceed through each of these steps by providing details about the process that resulted in a successful dashboard implementation in the KSOM context.

Step 1: Define Success for Your Dashboard (*Outcomes*)

In order to understand the desired outcomes of the CQI tracking process, KSOM's dashboard designers interviewed a few central CQI team members, and worked with the key administrative stakeholders to identify three parameters that would define success in the final project and reflect the priorities of the stakeholders at the strategic level. Following these discussions, the designers summarized that the resulting data dashboard design would:

- Address all relevant LCME standards and elements that might conceivably require a CQI initiative, and expand to encompass future elements that may be introduced later;
- Look aesthetically pleasing, maintain visual consistency across elements of the standards, accommodate a range of data sources, and communicate important information quickly using visual cues; and
- Be easy to access, use, and maintain by the staff of the school, as they are the ones who must ultimately do the work of tracking CQI initiatives.

Defining these priorities in ways that support the overall outcomes of the activity system and the demands of the key stakeholders provided the dashboard designers with a clear sense of the purposes that the dashboard would serve in the work of the CQI administrators, as well as a means of assessing the project at its conclusion.

Step 2: Organize Your Data Heuristically (*Subjects*)

After mapping the initial round of school goals, administrators and partners, and accountability pathways, the dashboard design team worked with CQI project leaders to create Key Performance Indicators (KPIs), or measures of key constructs of the most proximate measures of success for a specific CQI initiative. The selection and organization of KPIs is particularly crucial, as it simplifies the process of selecting visualizations and graphic views later in the design process. In the context of this project, designers were able to adapt many KPIs from the existing Excel sheets used by CQI administrators, as they had already been through successive rounds of review by the other stakeholders in the CQI process. They also took careful note of the individuals responsible for these KPIs, and any partners (e.g. offices, individuals) associated with completing the CQI projects.

Working with the project leaders, the designers again reviewed the KPIs and developed a heuristic approach to organizing the information. Heuristics are understood to represent metacognitive mental shortcuts to information processing (Mark & Wong, 2001). These shortcuts can reduce the cognitive load associated with decision-making by organizing information into meaningful questions that can be

answered with the data presented. In addition to creating a narrative around the KPIs that linked the proximate measures to their goals, heuristic questions can help to guide the thinking of the user. As an added benefit, organizing the KPIs into heuristic categories enabled the designers to easily transpose the design across multiple technologies during the prototyping phase.

Figure 3 represents the reorganization of KSOM's KPIs into a simple structure that facilitates the kinds of decision-making processes that users expected to use in their tracking of the progress of CQI initiatives. These heuristics are likely to vary by an institution's KPIs, but the organization of KPIs into heuristics should be an iterative and integral part of the dashboard design process. Each row in Figure 3 is designed to represent a question that scaffolds the thinking of the user, with each cell representing a piece of data that is necessary to answer that question. In the final phase of this iteration of KSOM's design definition, the rows answer the following questions:

- **Row 1:** Who is responsible and how much progress have we made?
- **Row 2:** What key data will help me to demonstrate that progress?
- **Row 3:** What are we doing and when do we need to return to this LCME element?
- **Row 4:** What LCME-related steps are necessary for follow-up?

The heuristic organization of these key pieces of information allow users to quickly make sense of the answers to these key questions. Other schools may wish to create similar organizational schema to reduce the cognitive load associated with interpreting and relating KPIs.

Step 3: Select Your Dashboard Platform *(Tools)*

As a first step in development of the platform, designers examined existing practices of the staff and administrators in charge of tracking CQI initiatives across the school, and briefly interviewed some of the participants. Prior to the development of the CQI platform, the administrators in charge of CQI kept track of their progress using Excel spreadsheets, a common practice in LCME CQI tracking efforts. As a CQI administrator noted during our interviews:

I believe a lot of schools, when they're initially embarking on their CQI process for LCME, start with an Excel spreadsheet. I feel like it's a clunky mechanism to use because you're not able to put in a lot of detail, a lot of narrative, any kind of documentation or tables or data. It all has to be very text based….

Figure 3. Responsibilities, information, and KPIs for the LCME CQI dashboard template page, organized heuristically to facilitate user analysis of data

Responsible Administrator	Point of Contact	Status
Metric	Data Sources	Data and Evidence Files
Notes	Review Interval	Review History
Follow-Up		

That's when we recognized the need, that our Excel spreadsheet technology was not optimal to do all that we wanted to do regarding tracking CQI. And so [the Excel document] just became kind of a mass and it was difficult to share with people with, especially with having to supply documentation for backup or if there's multiple people or multiple dates, it all just becomes a little bit difficult to track in Excel. (CQI Administrator, June 2018)

As the administrator described in development discussions (echoing Hedrick et al., 2019), Excel spreadsheets have several significant limitations. First, Excel files can become unwieldy quickly and require significant scrolling and movement both horizontally and vertically, increasing the perceived visual distance between key pieces of information. Second, Excel sheets are difficult to use for tracking as they are text-oriented, row and column constrained, and based on the information organization logic of cells. This reduces the user's ability to flexibly control the layout of the information for visual communications. Third, Excel files do not allow users to easily access and view PDFs, real-time visualizations, or other files during the course of their compliance reviews. These intrinsic limitations in tool functionality produced serious limitations for the decision-making potential of the CQI tracking process. For example, the additional extrinsic cognitive load of interacting with CQI data in a cellular format would be expected to put pressure on the user's finite working memory resources (Clark & Mayer, 2016). These usability limitations were identified as issues that designers must overcome during development.

The designers identified four questions to guide the selection of an appropriate technology to house the CQI tracking tool:

- How might the tool support access, updates, and decision-making by multiple users?
- How might the tool best support multiple kinds of media, including web-based links, videos, PDFs, Microsoft Office documents, and data visualizations?
- How might the selected technologies support the continuous improvement of the CQI dashboard and more cohesive improvement activities?
- How does the technology enable visual signaling of important data, as well as the triangulation of data sources that will be used in heuristic decision-making?

These questions enabled the designers to evaluate available technological platforms in advance of the prototyping phase. For example, the designers recognized that the CQI tracking tool would need to be web-based in order to provide real-time access to multiple stakeholders. This decision, based on the idea that the CQI data should not become sequestered in a single individual's computer, helped to rule out several offline technological platforms such as Microsoft PowerPoint, Word, Excel, or other database tools like Filemaker Pro or Access (which do not easily sync the work of multiple users across the sources of data).

Ultimately, the ease of access to Microsoft's SharePoint through the Microsoft 365 platform made it a compelling option, as it supports the integration of multiple file types into a widely available online platform. The additional communications features available in SharePoint (such as Outlook integration, which automatically provided up-to-date contact information for responsible administrators in CQI efforts), as well as its ease of use and wide availability to members of the medical school, made it the final choice for the delivery of the dashboard. The SharePoint platform's affordances opened the project to a range of new possibilities for the collection and display of non-quantitative CQI data such as policy documents, committee reports, and videos. Further, the platform's pages could be archived, saved, and

cloned as often as the users deemed necessary, creating a continuous record that can be referenced for other accreditation and reporting activities in the future.

Step 4: Develop Dashboard and Element Views (*Rules, Communities, and Division of Labor*)

To create a tool that supported the work of the CQI groups, designers at KSOM assembled the existing CQI information from our administrators' Excel files into an online platform that provided both a dashboard-level view of the status of the organization's CQI initiatives (Figure 4), as well as views of the heuristically-sorted responsibilities, information, and key performance indicators (Figure 5). In the main dashboard view in Figure 4, the current status of each project element is signaled to the user with a red 'X' icon, a yellow exclamation point icon (not shown), or a green checkmark icon. Standards with active CQI projects also feature a unique 'CQI' symbol that visually flags the element for review. This color coding provides higher-level administrators with an at-a-glance view of CQI project progress and is suitable for presentations at status meetings.

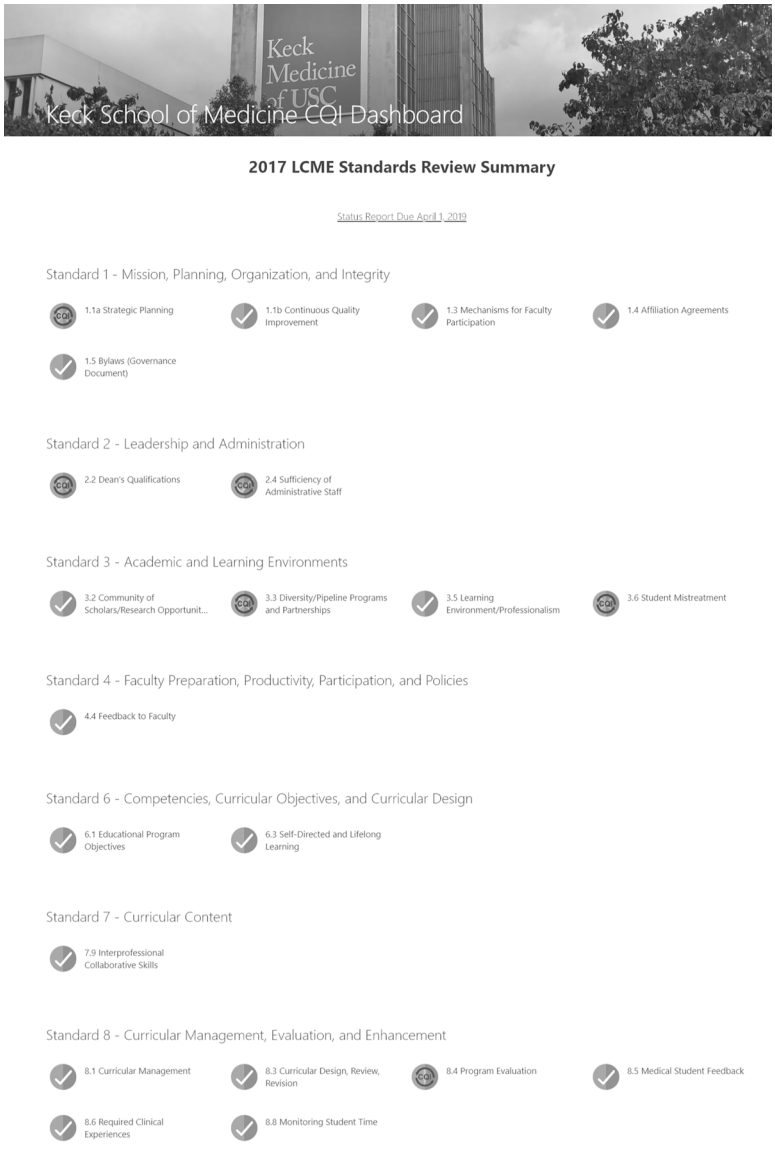
In addition to a dashboard-style interface, we designed the final iteration of the site to include integrated secure data and evidence storage locations, workflow automations, and other communications tools. Figure 5 provides an overview of the individual element page for each LCME standard. Each page follows the same pattern defined in the KPI and heuristic development phase, and includes:

- **Standard Text:** The full text of the LCME element standard, so that users are clear about what the included data describe.
- **Responsible Administrator:** The name of the individual or committee responsible for the project.
- **Point of Contact:** Displays the name of the person responsible for the information. In this system, the field is tied into the university's Outlook database of users, providing current email and telephone contact information for the individual.
- **Metrics:** A reference field for goals and related expectations.
- **Data Sources:** A listing of the available sources of data that address the element.
- **Data and Evidence Files:** Links to key web pages that provide supporting documentation. The site also includes access to a Microsoft OneDrive file management system to store and sort documents within the site.
- **Data Visualizations:** Built-in histograms of key data sources, with support for future integrations from Tableau or Microsoft PowerBI services.
- **Notes:** A text field for reminders, caveats, and other information about this version of the review.
- **Review Interval:** A text field that identifies the frequency of review events in the Review History.
- **Review History:** This field uses built-in Outlook calendaring functionality to add review event reminders to a user's work calendar and track past review deadlines.
- **Follow-Up:** An editable text field that includes notes on next steps and reminders for future activity
- **Comments:** Additional time-stamped comments from users.

Step 5: Test the Dashboard with Users *(Object)*

In the final step of the Activity Theory-derived development process, dashboard designers returned to the CQI administrators and allowed them to test a functional prototype of the final 'object' produced by the process. This type of user testing can play an important role in validating the assumptions of the designers and developers. In review meetings, the CQI Dashboard was evaluated against the initial design parameters produced in Step 1. In our discussion, administrators found that the final design was capable of addressing the LCME standards and elements at varying levels of granularity and could

Figure 4. Dashboard view of LCME CQI projects; CQI projects are signaled with a special symbol, as in element 1.1a, 2.2, 2.4, 3.3, and 3.6.



expand to accommodate future developments in the LCME standards or other CQI initiatives. Second, the administrators were asked if the individual pages of the dashboard maintained visual consistency across the site, were judged aesthetically pleasing, and integrated several data sources and file types, and communicated the information in a parsimonious way. Finally, we asked our administrators if they were able to easily access and manipulate the dashboard overview and element pages. Usage statistics from the SharePoint platform indicate that the site was accessed more than 1800 times by administrators during an 18-month period.

Figure 5. An example of the CQI Dashboard's LCME element pages, based on Key Performance Indicators and heuristic organization.

Another positive sign for the user acceptance of the dashboard came as end-users began to create their own approaches to their ongoing tracking strategies. For example, when the platform's built-in graphing functions were not able to produce trendline and stacked histograms within the dashboard software, the users began to include screenshots of their existing graphs from PowerPoint presentations and other sources. The users' ability to innovate within the platform to fit their own needs indicates that the dashboard platform provided a suitable base for future developments in CQI tracking. Further, the autonomous use and continued improvement of the platform by non-technical staff indicates that the platform is well suited to adaptation to other contexts.

FUTURE DEVELOPMENT

As data visualization tools become more broadly available, administrators and accreditation supervisors will be able to take advantage a range of new functionalities for their CQI data dashboards. These technologies provide high quality data visualization tools right out of the box at an affordable price. However, CQI dashboard developers will need to consider three new sets of challenges and opportunities as these tools become commonplace. Future research in CQI data dashboard development will need to work to better anticipate the consequences of the integration of 1) data warehouse technologies, 2) real time data representations, and 3) AI technologies into CQI tracking efforts in order to provide administrators with the best possible tracking technologies. We will briefly outline each of these challenges.

First, as data dashboard tools such as Tableau and Microsoft's PowerBI become more affordable, administrators are likely to request that developers create and integrate visualizations that track historical and long-term trends in medical school performance and map the current performance of the school against these trends as they relate to LCME standards. This will require the development of data warehouses capable of ingesting, organizing and presenting this information in flexible ways. The arrangement of the historical and current data in these warehouses can require careful deliberation in order to render these data usable in visualizations. Further, the hierarchy and arrangement of these data in warehouses can affect how dashboard software interprets these data

Second, CQI-specific dashboards will make greater use of real-time visualizations to allow administrators to make important decisions based on the most recent available data. However, these real-time dashboards must be designed to also present historical data in ways that make the context of the present situation clear. For example, a particular KPI might appear to have increased by 30% this year, but this statistic is misleading if not compared to overall historical declines evinced by the historical data set. This could lead to additional errors in interpretation by the LCME during its accreditation reviews. Therefore, designers must carefully consider the ways that real time visualizations can confound decision-making processes, and design around those pitfalls.

Third, the emergence of Artificial Intelligence (AI) and Big Data cloud services will create new opportunities in predictive analysis that will help administrators to anticipate changes or needs associated with specific CQI initiatives. AI is a generic term that describes a range of technologies that employ algorithms to make decisions about data based on calculations performed on large quantities of existing data (Zimmerman, 2018). While AI presents new opportunities for quality monitoring and improvement, ultimately humans must make decisions based on the analytic outputs of the algorithms that govern these systems (Williamson, 2016). Dashboard designers and CQI administrators must understand how these AI systems arrive at their conclusions in order to avoid the pitfalls of poor data interpretation.

The successful navigation of these issues has the potential to produce more useful decision-support systems for LCME and CQI accreditation administrators in the future. The ability to access historical data, compare it to real time data, and use AI to support interpretation presents real opportunities for improving the capacity of administrators to improve the work of their staff and student learning.

CONCLUSION

The goal of the CQI process is the improvement of medical education and to meet accreditation standards. A properly designed CQI dashboard has the capacity to facilitate the work of continuous quality

improvement and track that work. In describing an Activity Theory-derived process for developing dashboards, the authors hope that readers will be able to use this technique to support their own CQI and accreditation activities.

The authors look forward to seeing the kinds of tools that other institutions develop based on the initial version of our tool described in this worked example. Further, this chapter will ideally support additional opportunities to help other schools to develop their own versions of the CQI dashboard through future presentations and publications.

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KEY TERMS AND DEFINITIONS

Artificial Intelligence (AI): In the context of this chapter, a term for analytic tools that use advanced algorithms to analyze large data sets and augment human analysis of data.

Big Data: A term used to describe large-scale data sets that include multiple kinds of demographic, behavioral, or performance data. Sometimes used to describe the unique kinds of data analysis that can be performed on these data sets.

Continuous Quality Improvement (CQI): A business process philosophy that promotes goalsetting, data collection, and program evaluation towards the end of providing students with better experiences and outcomes.

Data Dashboard: A grouping of related data visualizations that provides users with information about the state of a system.

Data Visualization: A visual representation of data that uses a range of graphic forms to help the user make sense of a particular set of data.

Data Warehouse: A data system that ingests, stores, and retrieves data for use in other systems.

Key Performance Indicator (KPI): Proximate measures of performance that are used to identify how well a given program or system is operating based on predefined goals.

Liaison Committee on Medical Education (LCME): A joint body of the American Association of Medical Colleges (AAMC) and the American Medical Association (AMA) and other groups that evaluates and accredits physician training facilities in the United States and Canada.