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Teaching Systems Improvement to Early Medical Students: Strategies and Lessons Learned

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Abstract

Purpose

Despite increasing emphasis in medical school education on quality and systems improvement, many medical schools lack sufficient faculty with expertise to teach systems improvement. Using the pedagogical content knowledge framework, this study explores how faculty engage students in systems improvement work and faculty perceptions of the outcomes for the health system and students.

Method

In May–June 2017, the authors interviewed 12 of 13 invited faculty with experience in teaching and engaging first-year medical students in systems improvement work, the course of students' systems improvement work over time, the impact of students' projects on health systems, and students' learning and attitudes about systems improvement. The authors conducted qualitative analysis iteratively with data collection to sufficiency.

Results

Six emergent themes characterized faculty's approach to guiding students in systems improvement work: faculty–student relationship, faculty role, student role, faculty–student shared responsibility for projects, faculty and student content knowledge, and project outcomes. The faculty–student relationship was foundational for successful systems improvement work. Faculty roles included project selection, project management, and health systems interactions. Students engaged in systems improvement as their faculty leveraged their knowledge and skills and created meaningful student roles. Faculty and students shared responsibility and colearned systems improvement content knowledge. Faculty defined successful outcomes as students' learning about the systems improvement process and interprofessional collaboration.

Conclusions

Findings highlight the critical importance of pedagogical content knowledge to engage early learners in systems improvement work, understand their learning interests and needs, and manage their projects longitudinally.

Clinical practice in the evolving health care system requires competence in new systems knowledge and skills. Physicians must not only care expertly for individual patients but also improve patient safety, promote the health of populations, and control health care costs.[1,2] To meet these challenges, there have been several calls for medical training programs to transform their curricula.[3–5] The Accreditation Council for Graduate Medical Education endorses the systems-based practice competency,[6,7] and the CanMEDS Leader Role, developed by the Royal College of Physicians and Surgeons of Canada, guides physicians to improve the systems in which they work.[8] The American Medical Association granted funding for U.S. medical schools for innovative health systems science curriculum development,[9] incorporating "health care financing, population health, quality improvement, socio-ecological health, informatics, teamwork, leadership, and . . . the science of health care delivery."[10] A new entrustable professional activity for graduating medical students addresses quality improvement (QI) and patient safety.[11]

Although faculty expertise to teach systems improvement skills to students seems essential, many medical schools lack sufficient faculty with requisite expertise and seek strategies to increase this teaching capacity.[12–16] From a theoretical perspective, Shulman's framework of pedagogical content knowledge (PCK) may inform how faculty develop strategies to teach systems improvement. PCK incorporates subject matter knowledge, appreciation of how learners conceptualize content and expand and apply their growing knowledge in a learning context, and strategies for effectively guiding learning.[17] For example, experienced teachers anticipate confusing topics and skillfully employ relatable examples to illustrate concepts.[18]

For faculty teaching health systems skills to early medical students, PCK develops through integration of content knowledge with appropriate pedagogical strategies and teaching experience. This learning through experience has been applied successfully for faculty colearning QI skills with residents to increase the number of faculty mentors for resident QI projects.[19] Strategies to prepare faculty who themselves may not have been trained in systems improvement skills to guide their learners to understand and apply these skills are lacking. Using the PCK framework, this study explores methods by which faculty engage students in systems improvement work in the health care system and their perceptions of the outcomes of

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this work for the health system and students. Results can inform educators about strategies to augment their faculty capacity to teach systems improvement skills to early learners.

Method

Study design

This qualitative study is based on an interpretivist paradigm, which assumes that knowledge arises through experience and aims to characterize the perspectives of participants.[20] We used a grounded theory approach with sensitizing concepts, which are ideas that inform or guide how researchers interpret data.[21,22] We chose this approach to explore faculty experiences in their own words and develop an understanding of their approaches to teaching and guiding their students. Our sensitizing concepts were related to the components of PCK[17] and included knowledge of subject matter, knowledge of learners, knowledge of teaching, knowledge of learning context, and how they combine to form PCK (Table 1). These sensitizing concepts guided data collection around faculty teaching methods and insights into their students' systems improvement work.

Setting. The University of California, San Francisco (UCSF), School of Medicine Bridges Curriculum, launched in August 2016, includes 3 phases integrating foundational sciences, clinical and systems applications, and inquiry (discovery, evidence-based medicine) over 4 years. In the first phase, medical students experience 18 months of longitudinal immersion 1 half-day per week in clinical microsystems (e.g., primary care clinic, hospital medicine unit, emergency department) focused on health systems improvement (QI, patient safety, and continuous process improvement). Five to 6 first-year medical students are assigned to a clinical microsystem with a faculty coach at 1 of the school's 3 core teaching hospitals (university health system, Veterans Affairs medical center, and county-based public health system). Besides teaching systems improvement and guiding students' systems improvement work, faculty coach responsibilities include teaching foundational clinical skills, career advising, and longitudinal mentoring. Coaches generally are not responsible for foundational sciences teaching, nor do they participate in summative assessment of their own students. Coaches are supported at 20% effort.

Coaches identify and develop systems improvement projects before students' arrival using a workbook (Supplemental Digital Appendix 1 at http://links.lww.com/ACADMED/A710) with guidance from site directors. Coaches and students have lectures and small-group sessions on systems improvement and access to online modules from the Institute for Healthcare Improvement.[23] Throughout the year, coaches can consult course and site directors. Coaches guide students to produce a structured report for presentation at a school symposium. Students use a Lean framework to document their project's background, initial and target conditions, experiments (countermeasures), action plan, and next steps for future systems improvement.[24]

The UCSF Institutional Review Board approved the study as exempt.

Subjects and sampling. Subjects were faculty coaches of students in the first Bridges class. Based on quantitative survey results detailed below, we invited coaches with a range of experience teaching early medical students and conducting systems improvement.

Data collection

To determine coaches' prior experience, we surveyed all coaches in the first Bridges class in April–May 2017. The 10-item electronic survey addressed coach age, gender, academic rank, and primary department. Because both knowledge of subject matter and teaching are components of PCK,[17] the survey queried the extent of experience and role in teaching medical students and prior engagement and leadership in systems improvement. Of the 28 coaches, we excluded 2 coaches, who are study investigators (M.W.H., D.L.); 24 coaches responded to the survey.

Four investigators (D.L., M.W.H., C.B., K.E.H.) inductively developed an interview guide informed by sensitizing concepts based on the components of PCK.[17] After feedback from the course director, course site director, and an educational scholar and 2 pilot interviews with coaches, we further refined the interview guide for clarity. Because no major changes were made, we included the pilot interviews in the analysis.

We invited via email 13 of the 24 coaches with variable student teaching and systems improvement experience who responded to the survey to participate in individual 45- to 60-minute semistructured interviews in May–June 2017. Twelve agreed to participate. Interviewees in the highest tertile had ≥ 9 years' experience teaching early medical students; those in the lowest tertile had ≤ 2 years' experience. The highest tertile with systems improvement had ≥ 12 years' experience; the lowest tertile had none. Nine interviewees were women, and 3 were men. Two were assistant professors, 4 were associate professors, and 6 were full professors. Participants' departments were emergency medicine, medicine, neurology, otolaryngology, and pediatrics. Each systems improvement project had 1 to 6 students. Example projects including the following: Decrease emergency department rate of patients leaving without being seen, increase naloxone training for patients taking opioids for chronic pain, and create a standardized approach for handoffs between the operating room and the postanesthesia care unit.

Interview questions explored coaches' experience with early medical students and systems improvement, their approach to teaching and engaging students in systems improvement, the course of students' systems improvement work over time, the impact of students' projects on the microsystem, and students' learning and attitudes about systems improvement (Supplemental Digital Appendix 2 at http://links.lww.com/ACADMED/A710). Two trained interviewers (M.W.H., D.L.) conducted in-person interviews, which were audiorecorded, professionally transcribed, deidentified, and assigned a random study number (1–60) before analysis. Interview participants received a $25 electronic gift card.

Data analysis

Four investigators (M.W.H., D.L., C.B., K.E.H.) conducted qualitative analysis iteratively with data collection. Initially, 3 investigators (M.W.H., D.L., K.E.H.) read 1 transcript and met to discuss emerging themes. They then read 2 additional transcripts and revised the themes into a codebook. Two investigators

Table 1

Pedagogical Content Knowledge (PCK) and Related Themes, From Interviews of 12 Faculty Teachers of First-Year Medical Students Conducting Systems Improvement Work Within the Bridges Curriculum, University of California, San Francisco, School of Medicine, May–June 2017[a]

Components of PCK framework[17] and related themes	Definitions[17]	Major findings	Implications for faculty guiding medical students in health systems improvement learning
Knowledge of subject matter • (B) coach role in project • (E) coach and student content knowledge of systems improvement	Faculty knowledge of systems improvement terminology and principles, project selection, and project development	• Relevant subject matter knowledge includes identification of appropriate project selection, management of the project, and beliefs and values around the outcomes of systems improvement projects. • Faculty with limited systems improvement knowledge colearn with students. • Faculty with systems improvement experience are more attentive to project selection. • Successful project outcomes include student learning.	• Ability to facilitate students' learning supersedes the importance of subject matter knowledge. • Colearning is an effective strategy for faculty with limited systems improvement knowledge. • Engaging a separate systems improvement expert as project manager may be helpful. • Faculty often serve as project managers and must be available and aware of project progress (or lack thereof). • Attention to feasibility and resources should be prioritized during project selection. • Faculty need curricular map of this new content domain.
Knowledge of learners • (A) coach–student relationship • (B) coach role in project • (C) student role in project	Faculty understanding of student's prior and developing knowledge of systems improvement as well as the larger curriculum and particular student stressors	• Effective systems improvement teaching strategies focus on understanding the developmental trajectory and experiences of early medical students in these new roles. • Students can learn systems improvement quickly by actively engaging in systems improvement projects.	• Interpersonal relationships with individual students and the small group of students are critical to optimizing learning. • Knowledge of learners comes directly from working regularly with students.
Knowledge of teaching • (B) coach role in project • (C) student role in project	Faculty knowledge of teaching strategies and importance of finding meaningful and authentic roles for early learners	For students to be engaged and learn systems improvement, they need to assume meaningful roles.	• Faculty need small-group management skills. • Systems improvement projects can be useful opportunities to apply interprofessional communication skills. • Explicit teaching of project management skills may be useful for faculty.
Knowledge of learning context • (A) coach–student relationship	Faculty knowledge of larger medical curriculum, health system, and microsystem	• Knowledge of health system allows faculty to troubleshoot problems students face in the progress of their systems improvement projects. • Knowledge of students' larger curriculum and potential stressors (e.g., upcoming exam on another subject) enables faculty to emotionally support students and reprioritize project goals. • Faculty awareness of organizational system improvement priorities aids in project selection.	• Faculty need awareness of health system goals and resources to aid in project implementation (e.g., who the major stakeholders are, how to secure buy-in). • Knowledge of students' larger curriculum and stressors must be a priority for faculty. • Some students may need help "relating" systems improvement with clinical care or tempering high expectations for their projects.
Application of PCK • (A) coach–student relationship • (D) coach–student shared responsibility for project • (F) project outcomes	Faculty knowledge about what they know about teaching and how it applies to what they know about the subject itself (in this case, systems improvement work)	• Transforming faculty's expertise or limited content knowledge into successful experience requires establishing strong relationships with students. • Faculty role is complex, with multiple relationships (see Figure 1).	• Longitudinal relationships foster trust, which is critical for developing and applying PCK. • Faculty and students share responsibility for project selection and implementation. • Need for further research on what systems improvement concepts students struggle with, best teaching strategies to address them, and how best to assess learning outcomes.

[a]Themes, identified by letters in parentheses, correspond to lettered themes in the text and Figure 1.

(M.W.H., D.L.) coded all 12 transcripts separately and reconciled discrepancies through discussion until consensus. Data collection continued until no new themes emerged, suggesting sufficiency.[22] Four investigators (M.W.H., D.L., C.B., K.E.H.) then reviewed coded data and considered the sensitizing concepts from PCK. Through multiple meetings, investigators iteratively generated larger themes and a model characterizing coaches' approach to guiding students' systems improvement work. For coding and organizing the data, we used Dedoose web application, version 8.0.31

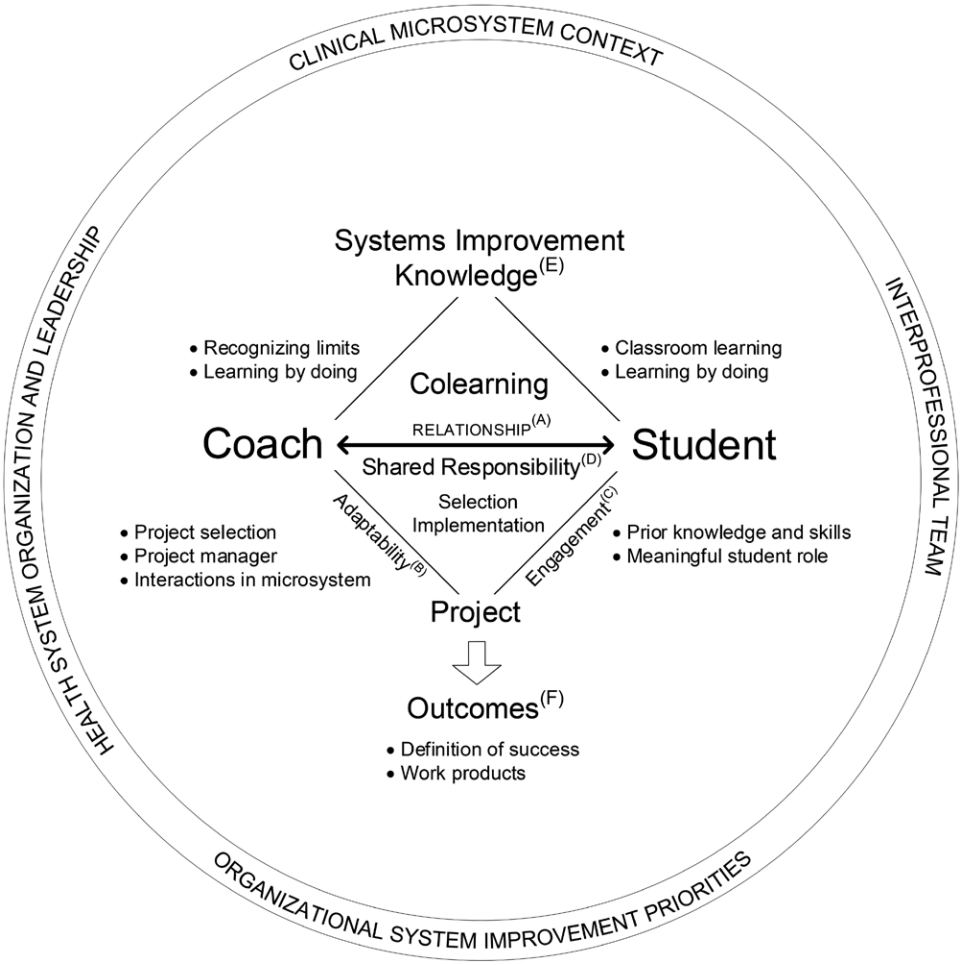

Figure 1 Theoretical model of coaches' experience guiding early medical students' systems improvement work. Based on interviews with 12 physician coaches at the University of California, San Francisco, in May–June 2017, this model shows themes characterizing how coaches engaged medical students in systems improvement work by colearning and sharing responsibility for projects to produce successful outcomes. Major themes and interrelationships in the model: (A) coach–student relationship, (B) coach role in project, (C) student role in project, (D) coach–student shared responsibility for project, (E) coach and student content knowledge of systems improvement, and (F) project outcomes.

(SocioCultural Research Consultants, LLC, Los Angeles, California; www.dedoose.com).

Attention to reflexivity occurred throughout data collection and analysis.[25] The author team included 2 coaches (M.W.H., D.L.), an educational scholar (C.B.), and 2 leaders within the coaching and systems improvement curriculum (E.P., K.E.H.). They shared their perspectives, potential biases, and experiences related to the data at research team meetings and aimed to check against one another's desires to see the curriculum succeed. The investigators who developed the codebook (M.W.H., D.L., K.E.H.) kept reflexivity journals throughout the study.

Three interviewees participated in member checking with one investigator (K.E.H.). Member checking entails sharing results with participants to confirm accuracy of interpretations.[26] They reviewed the results in Figure 1 and offered feedback, which reinforced the findings and led to clarifications of some results.

Results

We identified the following themes characterizing how coaches engaged students in systems improvement work and their perceptions of project outcomes: (A) coach–student relationship, (B) coach role in project, (C) student role in project, (D) coach–student shared responsibility for project, (E) coach and student content knowledge of systems improvement, and (F) project outcomes. Relationships among themes are described below with participant quotations and coach study number in parentheses. Figure 1 illustrates the relationships among the themes. Table 1 organizes our findings within the PCK framework. The first column of the table outlines the components of PCK and the themes from our study (A–F). The second column supplies the corresponding definitions of each component of PCK. The third and fourth columns of the table connect major findings and implications for guiding medical students in health systems improvement learning with the components of the PCK framework.

(A) Coach–student relationship

Coaches developed knowledge of students and their experience in the context of the coach–student relationship. As shown in Figure 1 and Table 1 (knowledge of learners, knowledge of learning context, and application of PCK rows), this relationship was central to coaches' description of their students' systems improvement learning.

To help students understand how systems improvement fits into the larger curriculum, coaches themselves needed to understand typical early medical students, their development, their emotional needs, and their curriculum outside of systems improvement work. The coaches described gathering much of that information directly from students:

> I had to learn a lot more about and understand what their structures were, what they actually went through, kind of the emotional development of an early medical student. (38)

Coaches fostered relationships with individual students and group cohesion as strategies to advance students' systems improvement work. They established relationships up front through the schools' orientation and found getting to know students as individuals, including their backgrounds, preferences, experiences, and skills, to be productive both overall and for systems improvement work. Coaches also facilitated relationships and trust within the student group by providing space and time for students to talk together each week:

> The function as a coach was creating trust and support and a safe space for them within the group, and that I needed to create that, so that was more important than really anything else. (7)

Coaches were able to leverage the group's relationship as they monitored students' engagement and effort. One coach described negotiating the situation of 1 student being a "slacker":

> We actually intentionally revisited the [group] charter and added language about being a team player and not letting your colleagues carry the bulk of the work. (53)

(B) Coach role in project

Coaches interfaced with projects through project selection, their role as a project manager, and interactions in the microsystem (Figure 1). The coach role in the project(s) required continuous coach adaptability and, from the PCK perspective, knowledge of subject matter and learners (Table 1, knowledge of subject matter, knowledge of learners, knowledge of teaching rows).

Project selection. Coaches chose microsystems that they were familiar with, and before students' arrival, they engaged microsystem stakeholders when brainstorming project ideas. Coaches emphasized choosing projects with which students could engage authentically and that had potential for interprofessional and patient interaction. However, little emphasis was placed on matching students to projects on the basis of students' backgrounds or previous experience. Compared with coaches with less systems improvement experience, coaches with more experience demonstrated greater attention to feasibility and resources during project selection (Table 1). They prioritized projects that seemed achievable in the time frame; had resources such as financial support, dedicated staff, or a preexisting task force; and could employ a project lead separate from the coach. Only 1 coach with greater prior experience cited alignment with the medical center's quality goals as a major driver of project selection.

Project manager. All coaches described their primary role as project managers who needed to know "where the project was anytime" (36) and be continuously aware of students' work (Table 1). They achieved this knowledge by situating themselves in the microsystem and monitoring actively by being "very available" (28) and "always around" (50). Coaches observed that students needed their help in identifying next steps, coordinating work with multiple stakeholders, and finding specific people to contact.

Coaches' commitment to being available enabled them to address problems in the progress of students' projects:

> That was a key ingredient to having the projects work. . . . If there were things that came up that could have potentially led to them stopping progress for a week, I could immediately, most of the time, redirect or fix. (28)

Coaches described addressing other problems with project progress, including the need for data to measure the baseline state or impact of an intervention or the need to promote more student interaction with interprofessional team members. Coaches discussed becoming adept at addressing difficult problems by recognizing, adapting, and coaching students to adapt. A common challenge was student frustration or impatience with project progress. Multiple coaches shared how they confronted students' expectations or attitudes about the goals of a project:

> A lot of my job I think as a coach is reframing, to continue buy-in. (7)

Some coaches recognized that a project's timeline did not align with students' availability, with the project moving too fast or, in one case, too slow. They addressed this challenge by finding a new activity, such as reassigning a gap analysis or identifying a different part of the project for students to work on. For example, with a project on delirium, students were ready to launch an intervention, but a clinical task force was not. The coach thus refocused students on incorporating volunteers and caregivers into the project, an initiative not originally part of the task force's program but later incorporated based on students' work (Table 1, knowledge of learning context row).

Others created offshoot projects or engaged more or different stakeholders when the original project failed to progress. With projects that were not progressing in a way that advanced students' learning, the decision to change projects weighed heavily on coaches' minds. One coach reflected:

> The discharge [project] was stalled and wasn't going to move the way I had originally intended. I've worked with them to try to find a new angle with that project, but in retrospect, I wish I had found a new project. (44)

Interactions in microsystem. Many coaches identified their role as interfacing with the project lead or other key faculty and promoting microsystem buy-in. These interactions were often without students' knowledge, a behind-the-scenes strategy that enabled students to feel ownership and be productive during their curricular time. Students seemed adept at operationalizing plans that coaches had helped set in place in advance. Coaches used their knowledge of and relationships with people in the microsystem to promote and sustain microsystem buy-in to the project and the students' contributions (Table 1, knowledge of learning context row).

(C) Student role in project

Coaches described engaging students in systems improvement by leveraging students' prior knowledge and skills and working to create meaningful student roles. Coaches felt that students need meaningful roles to engage and learn systems improvement (Figure 1 and Table 1, knowledge of learners, knowledge of teaching rows).

Students' prior knowledge and skills. Some coaches were surprised or impressed by students' ability to apply skills gained from prior experiences and to learn QI principles quickly:

> They did far better than I imagined they would. I was really impressed. (50)

In some cases, students lacked key knowledge or understanding and needed more help for the clinical aspects of QI to be relatable. Other students needed coaches' help moderating their high expectations for accomplishing systems improvement. Students with a research orientation sometimes needed guidance to adjust to the QI framework. One coach reflected:

> They got a much better appreciation that when you're talking about QI, you're talking about information in the moment, not like a randomized control trial. (36)

However, coaches also observed how rapidly students can learn:

> What surprised me was how quickly they picked up on the concepts . . . when I was learning about it, it just took me longer to really wrap my mind around some of the concepts of why do you start small with PDSA (plan, do, study, act) and why do you actually have to do the whole PDSA cycle. (38)

Meaningful student roles. Coaches strived to create and maintain meaningful student roles and identified the importance of fostering students' perceptions of autonomy. One coach explained:

> If you define autonomy by whether the coach was there, they had no autonomy, but I gave them free reign to work on elements as we advanced through the project. (30)

Coaches described harnessing students' high enthusiasm and fresh perspective. Multiple coaches, even those with extensive prior experience with students, described learning what generated student excitement and capitalizing on that:

> It was really enlightening to me to see what makes an impression on them . . . just the interaction with a nurse is like, "Wow. That was amazing." (23)

Students' appreciation of the relevance of this work seemed heightened by opportunities to talk with patients and interprofessional colleagues in clinical settings. Coaches described adjusting students' roles to promote these interactions; examples included encouraging a student who was focused on data analysis to emerge from this activity into the microsystem and working with a project lead to engage introverted students with people in the microsystem.

(D) Coach–student shared responsibility for project

Coaches and students shared responsibility for project selection and implementation (Figure 1 and Table 1, application of PCK row).

Project selection. As instructed by course leadership, coaches spent significant time before students' involvement identifying potential projects that would engage students authentically in systems improvement work with opportunities for interprofessional and patient interaction while also meeting a microsystem need. Additionally, coaches felt that students desired some choice and described various strategies to provide choice within a defined options list. Some coaches presented students with options after vetting a larger list with microsystem stakeholders; others presented a fixed number of options and asked students to assign themselves. One coach with greater QI experience had students walk through the microsystem to make observations that would inform their project selection. Another asked students to list pros and cons for each project and then discussed the lists as a group before students' project selection. Only 1 coach gave no choice. This coach had limited QI experience and felt that assignments were necessary to proceed to project work; this coach did not identify subsequent problems with this approach.

Project implementation. Project implementation overlaps with the subtheme of project manager but with greater emphasis on the coach's role in organizing students' activities rather than the health system or the project as a whole. Coaches described discovering the importance of planning with students each week and employed different planning strategies to create shared responsibility. Coaches commonly accomplished planning through "a group meeting about what they were to do that day or that week" (11), which 1 coach described as both setting a clear agenda and ensuring that "every student heard everyone else's role" (11). Another coach managed the agenda to clarify expectations:

> I would write down the things that I was expecting for each of the projects; how that happened, I would leave to them. (28)

Coaches conducted ongoing decision making about how much direction to provide students and when, deliberating between letting students learn by trial and error versus stepping in and providing hands-on direction. Many used the strategy of always being available to students while simultaneously assessing how much guidance students wanted. Over the year, communication patterns with students evolved to satisfy both parties' needs:

> It took a number of months for us to really develop a good flow about the best way to communicate and when to meet and what things we should cover. (23)

Coaches appreciated students' ability to function progressively more independently and adjusted their supervision accordingly. One explained, "Over time, the hand-holding became less" (38) as students who were previously "scared" to enter the microsystem alone later questioned why the coach accompanied them for tasks they could do independently.

(E) Coach and student content knowledge of systems improvement

As shown in Figure 1, coaches and students colearned systems improvement knowledge. Multiple coaches described their own limited content knowledge. Many with less systems improvement experience related that they needed to know just enough to stay 1 step ahead of students (Table 1, knowledge of subject matter row). Although 1 coach described following course instructions exactly,

most used course resources more as a guide, which enabled them to activate their teaching knowledge despite some content questions. Admitting their knowledge gaps to students was also identified as helpful. They emphasized their own continuous learning and felt that their learning by doing was effective:

> If I see my role as providing the practical opportunities for the concepts that they're learning from other people, then as long as I'm familiar with what they're learning, then I feel like I'm okay. (44)

One coach with less systems improvement and student experience reflected on the challenge of trying to conduct the work in isolation from other QI experts:

> I had no exposure, no prior experience, and then having to teach it was totally overwhelming. . . . What I've been encouraging some colleagues who are now going to be coaches for the next group is to absolutely partner up with people who have experience in this to engage students in projects. (53)

The ability to facilitate students' learning superseded the importance of content knowledge for coaches with both limited and more extensive systems improvement knowledge. One coach with more experience observed that teaching content was not essential:

> I didn't see my role as trying to specifically add more knowledge to their systems improvement practice. I felt like my role was to give them practical opportunities for the things that they were learning in the curriculum. (44)

Coaches envisioned resources that could be helpful for their own knowledge. Course resources, such as the course systems improvement template, enabled coaches to feel familiar with concepts that they needed to ensure that their students learned. Only 1 suggested that coaches need a coach for individual feedback and guidance or support within their clinical unit. More commonly, coaches described finding strategies to compensate lack of systems improvement content knowledge by collaborating with a more knowledgeable person or focusing on reinforcing rather than introducing curricular knowledge. Adjusting to learning contemporaneously with students empowered multiple coaches:

> I was learning as we went along also about the projects, so I think we just took it 1 week at a time and asked, "What do we need to do this week to accomplish our current goal?" (23)

(F) Project outcomes

Coaches primarily defined successful project outcomes as students learning the systems improvement process rather than what work products were created (Figure 1 and Table 1, application of PCK row). Because project outcomes often depended on health system factors (support from health system, type of project, etc.), coaches accepted that some projects might yield less benefit for the microsystem but still achieve students' learning aims. Coaches overwhelmingly valued "real-life experience in systems improvement work" (38).

Coaches sought evidence that students had engaged in the systems improvement process, which encompassed understanding of the aims, people, and context:

> Were they able to be involved in the different steps of the project? Were they able to know what was going on? . . . Were they able to interact with different people and patients over that time and were they able to see the dynamics of it? . . . That for me was more important than what the actual outcomes were. (36)

As important secondary aims, coaches identified students' work products as valuable. Multiple coaches proudly described students creating materials or developing understanding that benefited clinical microsystems. Examples included physician or patient education materials used in patient rooms or in the electronic health record or a clinical setting's enhanced recognition of a clinical problem. Other measures of success were scholarly abstracts showcasing students' work at academic meetings.

Discussion

This study illustrates faculty approaches to facilitate students' learning through participating in systems improvement work in clinical environments. Coaches' project selection and longitudinal guidance of students prioritized opportunities for meaningful student roles in systems improvement with a range of stakeholders. Coaches' attention to students' relationships with peers, coaches, and microsystem clinicians seemed to strengthen students' engagement and commitment to systems improvement. Through this role, coaches reached a common view of desired outcomes focused on students learning, appreciating the QI process, and collaborating with peers and the interprofessional health care team.

Results of this study, as shown in Table 1 (implications column), suggest that faculty teachers believe they can successfully facilitate students' learning about systems improvement by focusing on learning about students and strategies to engage them in the work rather than by prioritizing their own subject matter knowledge. This finding reinforces the tenets of PCK.[17] For example, coaches transformed their thinking toward the goal of students needing to understand QI as a process of repeatedly planning their work, trying interventions, and reviewing outcomes rather than achieving a particular outcome. Similarly, PCK of elementary students' learning emphasizes recognizing students' conceptual understanding and common misunderstandings or frustrations.[18]

These findings should not imply that teachers do not need any subject matter knowledge but rather that they evolve toward increasing reliance on PCK gained through experience.[27] Because many medical centers lack sufficient faculty with QI expertise,[19] the implications of this reframing of faculty qualifications around understanding students and managing projects can expand the pool of faculty who provide relevant learning experiences beyond those with extensive prior QI experience (see Table 1, implications column). Faculty development focused on how students learn through experience and on how guidance from near-peer faculty with relevant teaching experience could help faculty develop this skill set.[28,29]

Our results highlight the importance of effective mentoring relationships between faculty and students as the foundation for successful systems improvement work, as elaborated in Table 1 (implications column). Identifying and monitoring appropriate projects required that faculty not only understand students' skills and knowledge but also appreciate students' motivations and individual learning needs. Previous studies have also suggested that ideal teacher–student relationships are fostered by qualities that reflect teachers'

flexibility, emotional support, and trust relationships with their students.[28,30,31] Our findings suggest the presence of reciprocal influence,[31] which is characterized by learning interactions that lead to growth for *both* learner and teacher. In our curriculum context, coaches described coconstruction and comanagement of systems improvement work that provided personal development opportunities for both students and coaches. One structural support that may have fostered positive student–teacher relationships is the longitudinal curriculum that enabled frequent interactions over time. Previous studies advocating for longitudinal integrated clerkship experiences also emphasized the importance of longitudinal relationships as key to curricular success.[32]

This study has limitations. We interviewed coaches at several teaching hospitals within a single institution; experiences could differ in other institutional contexts. We did not corroborate coaches' reports by interviewing students or other microsystem stakeholders. Because the program is new, these findings represent coaches' initial experiences rather than a mature group's perspective, although some participants had previous experience with systems improvement and medical students. For this study, we did not collect evidence of students' systems improvement work products.

In conclusion, this study characterizes the unique PCK employed by clinician–educators to guide early medical students in authentic systems improvement in clinical microsystems. Findings illustrate how the relevance of QI subject matter knowledge is superseded by the critical importance of pedagogical knowledge about strategies for engaging early learners in clinical microsystems, understanding their learning interests and needs, and managing their projects longitudinally. Further research is needed to examine strategies for training faculty to teach systems improvement skills and assess the outcomes for their learners and health care systems. These findings can inform the design of students' systems improvement learning experiences employing diverse faculty and faculty development for those teachers.

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Teaching and Learning Moments
The Transformative Power of Teaching and Learning

I grew up in a rural Appalachian town in southern middle Tennessee. The high school dropout rate there is 20% (the U.S. average is around 6%), only 12% of residents hold a bachelor's degree or higher, and less than 1% of the population holds a PhD. My parents fit within the lower tier of these statistics. My mom has a high school diploma, and my dad finished eighth grade but never matriculated into high school. I came very close to following this same path.

I failed first grade, was kicked out of my eighth grade algebra class, and because of my disdain for school, decided to pursue a technical training track in high school rather than prepare to attend college. I was nearly expelled from high school after being caught with a Zippo lighter in gym class my freshman year. I didn't have the lighter because I smoked but because I thought it was cool. Had I been expelled, my fate as a student destined to fall into the low education attainment statistics that plague my community would have likely been sealed. However, instead of sending me to the principal's office, the teacher who caught me with the lighter intervened directly. After an expletive-filled rant about how I was on track to fail or be kicked out of high school, the teacher made it clear that I could use education to radically change my life and career trajectory. Through his intervention, this teacher showed me that he cared, and he convinced me that mentors could help change my life. No teacher had connected with me like this before. He sent me home that day with the lighter and a challenge to change my life's trajectory, and he told me that he and others would help me if I chose to be an active participant. A few days later, I found myself in the guidance counselor's office enrolling in new courses that would allow me to attend college. A math teacher then took me under her wing. I spent a significant amount of time with this teacher, as she taught me geometry, precalculus, and trigonometry. She was dead set on getting me ready to go to college, and, well, she did. The rest is, as they say, history. I went on to graduate college with a BS degree in agricultural biotechnology with a 3.97 GPA and earn a PhD in biochemistry with a 4.0 GPA and an MBA with a 4.0 GPA.

As a college professor now, I believe that teaching and learning are done best in a student-centered environment in which students are actively engaged in the process. I also believe that teaching and learning are reciprocal: I teach and guide my students, and they teach and guide me. I vigorously challenge my students in didactic and experiential opportunities; in return, my students compel me to remain vigilant and sharp in my pedagogical practices, and as a result, I learn new concepts from them. I believe that students are inspired to model their teacher's excellence; thus, I model a dedication to teaching, mentoring, lifelong learning, service, and working hard to cultivate a successful career. Through this philosophy, my ultimate goal is to have a career trajectory-building and life-changing transformative impact on my students.

My teaching philosophy and the way I operationalize my philosophy in the classroom and other learning environments are directly connected to my experiences as a young student. Just as my high school teachers did, I work to build a personal rapport with my students. This rapport requires a strong foundation of mutual collegiality and respect. I am convinced that it is important to treat students as teaching and learning colleagues. I believe it is important to earn respect from my students, and to earn their respect, I must give them respect. Much of my personal rapport is developed through the individualized mentorship I provide in which I guide, challenge, motivate, and encourage my students and hold them accountable. To accomplish this, I invest significant one-on-one time with them. Again, for this approach to work well, students must be actively engaged in the process. This approach grows out of the concern I have for my students. I care deeply about how they learn, what they learn, and the application of what they learn. I care deeply about their future careers and personal outcomes. My genuine commitment to students is deeply rooted in the care others had for me.

I believe that truly outstanding teachers are great at teaching within their discipline and at connecting with their students on a personal level such that they have a transformative influence on their students' career and life trajectory. I want to make a positive impact on my students' trajectories and support their educational, career, and life dreams, whatever those happen to be. I want to pay the transformative power of teaching and learning forward to my students for years to come.

My hope is that all teachers and mentors use their own positive learning encounters to shape their own transformational experiences for their students.

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