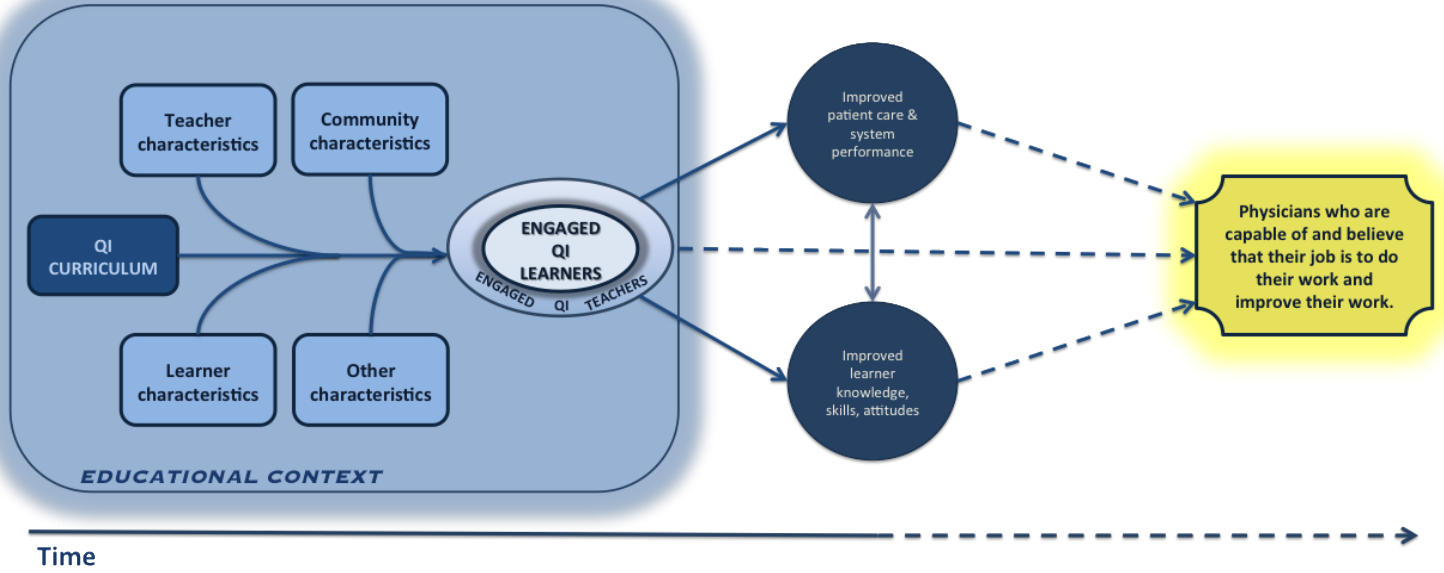


# Supplement 1. Candidate Conceptual Framework



**Supplement 2. Realist Review Data Abstraction Tool.**

<b>Author</b>		<b>Intervention type</b> Clinical OR educational	
<b>Year</b>		<b>Intervention details</b> (chart audit, rotation, continuous project, etc)	
<b>Study Design</b>		<b>Length of Intervention</b>	
<b>Setting</b> (name of school or training hospital)		<b>Comparison</b> (if applicable)	
<b>Population/Participants</b> (medical students, residents, fellows)		<b>CLINICAL OUTCOME</b> Patient care OR system performance	
<b>Specialty</b>		<b>Improvement?</b> (Y/N)	
<b>How participants were selected</b>		<b>Measure Type</b>	
<b>N (Trainees, not patients)</b>		<b>Outcomes</b>	
<b>Length of study</b>		<b>LEARNER/EDUCATIONAL OUTCOME</b>	
<b>Specific clinical setting</b>		<b>Improvement?</b> (Y/N)	
		<b>Outcome</b>	
		<b>Comments &amp; Quotations</b>	

**Supplement 3. Tool for Assessing Methodological Quality of Included Studies**

<b>BIAS</b>	<b>SPECIFIC QUALITY CRITERION</b>
<b>Sampling Bias</b>	<i>Was there clear articulation of the group from which the study population was sampled?</i>
<b>Selection Bias</b>	<i>Was the process for selection of study participants clearly articulated?</i>
	<i>Was the study population itself clearly articulated?</i>
	<i>Was a control/ comparison group used?</i>
	<i>If yes, was the composition of the comparison group clearly articulated?</i>
	<i>If yes, were the groups in fact comparable?</i>
<b>Performance Bias</b>	<i>Was the intervention clear articulated?</i>
	<i>Is it clear WHY the intervention was chosen?</i>
	<i>Is it clear WHAT was done?</i>
	<i>Is it clear BY WHOM?</i>
	<i>Is the timing of the intervention clearly articulated?</i>
	<i>If a secular trend was identified or suspected, did the study attempt to minimize or account for it?</i>
	<i>If applicable, were educational objectives clearly articulated?</i>
<b>Detection Bias</b>	<i>Were the study participants (learners) aware that their performance was being assessed?</i>
	<i>If applicable, were the study participants (learners) aware that their performance was being compared to another group?</i>
	<i>Were patients aware that an improvement intervention was being conducted on them or their process of care?</i>
<b>Attrition Bias</b>	<i>Was it clear when participants (learners) left the study and why?</i>
	<i>Was it clear when patients were being evaluated?</i>
<b>Reporting Bias</b>	<i>Were clinical outcomes reported numerically?</i>
	<i>Was statistical significance of clinical outcomes considered? (either p-value or SPC analysis)</i>
	<i>Were educational outcomes reported numerically?</i>
	<i>Was statistical significance of educational outcomes considered? (p-value)</i>
	<i>Were confounders or effect modifiers accounted for and discussed?</i>
<b>Funding Bias</b>	<i>Was a funding source specified?</i>
	<i>If yes, is it likely that the funding source has no interest in outcomes of the study?</i>
<b>Other Quality Considerations</b>	<i>Sample size?</i>
	<i>Validated outcome measurement?</i>
<b>OVERALL</b>	<b>Excellent – Very good – Good - Fair</b>

## Supplement 4. Methodological Quality Criteria

METHODOLOGICAL QUALITY ASSESSMENT CRITERIA	
Category of Quality	Criteria
<b>Excellent</b>	<p>Systematic bias is accounted for and minimized in the study population.</p> <p>Intervention is clearly described (who, what, when, where, why).</p> <p>If an educational intervention is proposed, learning objectives are clearly articulated.</p> <p>Efforts are taken to minimize exposures that could have accounted for the outcomes of the study other than the intervention itself (i.e. secular trends, other educational interventions, training level of the learner, length exposure to intervention).</p> <p>Results are reported numerically with appropriate comparison group; includes statistical analysis (p-value or SPC analysis).</p> <p>Biases that were present in the study were thoroughly explained and addressed.</p> <p>No apparent funding bias was evident.</p>
<b>Very good</b>	<p>Systematic bias is accounted for and minimized in the study population.</p> <p>At least one of three criteria describing the intervention are met.</p> <p>At least one of three criteria describing the outcome are met.</p>
<b>Good</b>	<p>Intervention is described but not with sufficient detail.</p> <p>If an educational intervention is proposed, learning objectives are articulated but are inadequate or unclear.</p> <p>There are minor systematic biases in the study population.</p> <p>There is an exposure that could account for the outcomes of the study other than the intervention itself but imposes minor biases.</p> <p>Results are reported numerically, but no statistical significance is reported.</p> <p>Major biases that were present in the study were explained and addressed, but minor biases were present and unaddressed.</p> <p>No probable apparent funding bias was evident.</p>
<b>Fair</b>	<p>Intervention is not described.</p> <p>If an educational intervention is proposed, learning objectives are not articulated.</p> <p>There are major systematic biases in the study population.</p> <p>There is an exposure that could account for the outcomes of the study other than the intervention itself and it imposes major biases.</p> <p>Results are reported non-numerically.</p> <p>Major biases that were present in the study werenot explained and addressed.</p> <p>Funding bias was evident.</p>

**Supplement 5. Methodological Quality of Included Studies**

Author & Year	Unbiased study population?	Intervention described in sufficient detail?	Educational objectives specified?	Other exposures or secular trends accounted for?	Numerical clinical outcomes with statistical analysis?	Biases explained and addressed?	Funding source disclosed?	Overall Assessment
<b>CHART AUDIT</b>								
Gould <i>et al.</i> 2002	No	Yes	No	No	Yes	Yes	Yes	2
Paukert <i>et al.</i> 2003	No	Yes	No	No	Yes	Yes	No	2
Holmboe <i>et al.</i> 2005	Yes	Yes	No	No	Yes	Yes	No	2+
Kaddan <i>et al.</i> 2006	No	Yes	No	No	Yes	Yes	No	2
Krajewski <i>et al.</i> 2007	No	Yes	Yes	No	No	No	No	3
Asao <i>et al.</i> 2009	Yes	Yes	No	Yes	Yes	Yes	No	2+
Carek <i>et al.</i> 2009	No	Yes	No	No	Yes	Yes	Yes	2
Kirschenbaum <i>et al.</i> 2010	No	Yes	No	No	Yes	Yes	Yes	2
Smith <i>et al.</i> 2012	No	Yes	No	No	No	Yes	No	3
<b>PARTICIPANT ON CLINICAL QI TEAM</b>								
Coleman <i>et al.</i> 2003	No	Yes	Yes	No	Yes	No	No	2
Mohr <i>et al.</i> 2003	No	Yes	No	No	Yes	Yes	Yes	2
Landis <i>et al.</i> 2006	No	Yes	No	No	No	Yes	Yes	2
Halverson <i>et al.</i> 2007	No	Yes	No*	No	Yes	Yes	No	2
Stapleton <i>et al.</i> 2009	No	No	No	No	No	No	No	3
Buckley <i>et al.</i> 2010	No	Yes	No	No	Yes	Yes	Yes	2
Fischman <i>et al.</i> 2010	No	Yes	No*	No	Yes	Yes	No	2
Stevens <i>et al.</i> 2010	No	Yes	No	No	No	Yes	Yes	2
Yu <i>et al.</i> 2010	No	Yes	No	No	No	Yes	Yes	2
Vidarthi <i>et al.</i> 2011	No	No	No*	No	No	No	No	3
Steuven <i>et al.</i> 2012	No	Yes	No*	No	Yes	Yes	Yes	2
Carey <i>et al.</i> 2013	No	Yes	Yes	No	No	No	No	2
<b>TEAM PROJECT</b>								
Varkey <i>et al.</i> 2006	No	Yes	Yes	No	No	Yes	No	2
Oyler <i>et al.</i> 2008	No	Yes	No	No	Yes	No	Yes	2
Varkey <i>et al.</i> 2008	No	No	No	No	No	Yes	No	3
Tomolo <i>et al.</i> 2009	No	Yes	Yes	No	No	Yes	Yes	2
Varkey <i>et al.</i> 2009	No	Yes	Yes	No	Yes	Yes	Yes	2
Diaz <i>et al.</i> 2010	No	Yes	Yes	No	Yes	Yes	No	2
Shiner <i>et al.</i> 2010	No	Yes	No	No	Yes	Yes	Yes	2
Clark <i>et al.</i> 2011	No	Yes	No	No	No	No	No	2
Dysinger <i>et al.</i> 2011	Yes	Yes	Yes	No	Yes	Yes	Yes	2+
Laiteerapong <i>et al.</i> 2011	No	Yes	No	No	Yes	Yes	Yes	2
Ogrinc <i>et al.</i> 2011	No	Yes	Yes	No	No	Yes	Yes	2
Oyler 2011	No	Yes	No	No	Yes	No	Yes	2
Arbuckle <i>et al.</i> 2013	No	Yes	Yes	No	No	No	Yes	2
<b>INDIVIDUAL PROJECT</b>								
Weingart <i>et al.</i> 2004	No	Yes	Yes	No	No	Yes	Yes	3
Canal <i>et al.</i> 2007	No	Yes	Yes	No	Yes	Yes	Yes	2
Sockalingam <i>et al.</i> 2010	No	Yes	Yes	No	No	Yes	Yes	2
Oujiri <i>et al.</i> 2011	No	Yes	No*	No	Yes	Yes	Yes	2
Reardon <i>et al.</i> 2011	No	Yes	Yes	No	No	Yes	Yes	2

Note: No\*=Clinical interventions which would not be expected to report educational objectives.

## Supplement 6. Themes and Illustrative Quotes from Realist Review

Theme	Illustrative Quotes
<i>What Works</i>	
<i>Accurately account for the time it takes to deliver QI education in the clinical setting due to competing demands, existing workload of trainees, and work-hour rules.</i>	<p>"This multifaceted curriculum does not require a substantial time commitment by either the resident or the faculty member. For the resident, it is just four half-days over the course of four weeks with a modest amount of time needed for outside reading. The time commitment for a faculty member is just three hours spread over four weeks once the curriculum is in place." Holmboe 2005</p> <p>"Psychiatry residents identified workload as a major barrier to the QIPs...Residents emphasized the need for clearly allocated educational time to complete QIPs and offset the workload demands." Sockalingam 2010</p> <p>"Because residency is a period of training and career development, residents have many competing responsibilities including inpatient rotations, academic research, outpatient clinic, and education. These responsibilities make it challenging for residents to dedicate time to additional projects outside of requirements." Laiteerapong 2011</p> <p>"The Accreditation Council for Graduate Medical Education requires that residents be involved in patient safety and quality improvement, but this is a challenge given work hour restrictions and service-educational obligations...Residents also have difficulty allocating precious time for institutional goals that do not correspond to areas that they perceive as needing attention and improvement." Steuven 2012</p>
<i>Identifying educational and clinically relevant project topics is challenging.</i>	<p>"Substantial work needs to be done to give students good options for project themes. Ideally, there should be a mix of project themes that can stand alone, as well as those that can be repeated or followed up by the next group of students." Dysinger 2011</p> <p>"The greatest challenge was to identify meaningful projects that could be completed within 3 weeks. Several projects were not completed because the objective was too ambitious." Weingart 2004</p>
<i>Consider having trainees choose their own project.</i>	<p>"Informally, residents said that they liked working on problems that vexed them during their clinical rotations. Many found the elective to be an eye-opening window on hospital QI activities." Weingart 2004</p> <p>"Perhaps the optimal combination of curriculum in quality improvement would involve our curriculum in the first or second year of residency followed the next year by the opportunity to create a quality improvement project." Holmboe 2005</p>
<i>Choose topics of clinical importance.</i>	<p>"The factors that are considered in choosing a project include its relevance to preventive medicine, significance to patients and the learners, scope for improvement, and feasibility for completion within the duration of the rotation." Varkey 2009</p>
<i>Use near-misses as a way to identify system errors.</i>	<p>"Only with continuous academic teaching with feedback on near-misses and medical errors can residents and young physicians, however, learn to maintain protocols and a high work standard...by encouraging participants to report cases of error and weaknesses in the system, the findings had an effect on other services provided by the ED as well." Kaddan 2006</p> <p>"Our approach involved the house staff at many different levels and in different ways. Fellows learned to evaluate delivery of care on an institutional level and critique not only the care of junior house staff and nurses, but also themselves and their peers...As part of the process, they also gained exposure into root cause analysis of individual cases." Kirschenbaum 2010</p>

Theme	Illustrative Quotes
<p data-bbox="52 99 205 131"><b><i>For Whom</i></b></p> <p data-bbox="52 240 541 331"><b><i>Medical students can, and should be expected, to contribute to quality of care in the clinical setting.</i></b></p>	<p data-bbox="562 136 2028 224">"Our data show that medical students can successfully initiate CQI activities at practices in which they participate with positive effects on the quality of care delivered. The use of medical students to initiate these efforts may represent an underutilized resource in efforts to improve the quality of care afforded the public." Gould 2002</p> <p data-bbox="562 250 2028 315">"It [the 1-month QI required medical student rotation] is, however, an experience that is consistently valued and can lead to improvements in processes of care." Dysinger 2011</p> <p data-bbox="562 363 2028 451">"Some may question whether students—particularly those in the early years of their medical education—are capable of systematically analyzing and changing systems as early as second-year medical school. Our work clearly demonstrates that students can develop and use these skills early in their careers....The curriculum thus becomes a vehicle for learning and improving patient care." Ogrinc 2011</p>
<p data-bbox="52 704 541 824"><b><i>Residents are front-line providers and have deep insights into the clinical processes and the knowledge for improvement within the system.</i></b></p>	<p data-bbox="562 493 2028 581">"...in their role as frontline physicians, they [residents] often are the first to recognize and identify systemic problems in the delivery of care that lead to inefficiencies and diminish quality. As future leaders in academic and community settings, they represent a group that should be educated and empowered with new skills and knowledge." Weingart 2004</p> <p data-bbox="562 607 2028 760">"Resident practices, by their nature, facilitated practice redesign to implement the CCM. For example, residents, as frontline caregivers, were effective and active participants in redesign and CCM implementation. In addition, evidence-based practice was highly valued and readily adopted in these training settings. Similarly, residents are by nature competitive in their commitment to providing good patient care; hence, teams both competed and readily learned from each other as change strategies were adopted across the diverse Collaborative settings" Stevens 2010</p> <p data-bbox="562 802 2028 922">"Lastly, and most importantly, our residents took on a much larger role than passive recipients of the chronic illness training. Not only did they participate in all stages of planning and implementation of the diabetes clinic, but they also designed QI activities, performed population-based management, and became the physician champions for spreading change to other members of the residency program." Yu 2010</p> <p data-bbox="562 964 2028 1029">"Residents are willing and effective participants in a QI program. As front line providers, their experiences are valuable and their willingness to share insights can be an impetus for change." Smith 2012</p>

Theme	Illustrative Quotes
<p><b><i>Under What Circumstances</i></b></p> <p><b><i>Successful QI teaching in the clinical setting requires support from both educational and care delivery leaders and the work of the trainees.</i></b></p>	<p>"The support of the department chair, the vice chair of clinical affairs, the residents program director, and the training site clinical directors was essential to making possible the changes in the clinical schedules that permitted team meetings." Coleman 2003</p> <p>"Patience, persistent education, and commitment from the administrative, academic, and clinic leadership is critical to fully engage faculty and to reach the tipping point of a cultural change in which mistakes, waste, and planning silos are eliminated." Stapleton 2009</p> <p>"Part of the process of discoveries was the recognition of other stakeholders/professions (medical and non-medical)." Tomolo 2009</p> <p>"Nursing and departmental support were important, particularly in those areas requiring changes in policies." Kirschenbaum 2010</p> <p>"In addition to these interventions, we found three factors to be critical to our success overall: leadership committed to change, increased involvement of clinic staff, and residents as change agents." Yu 2010</p> <p>"At our institution, this was not successful until both the administration and the resident staff met and discussed the important components of such a system and, in fact, made it a priority, which illustrates the strength of a combined "top- down" and "bottom-up" approach." Clark 2011</p> <p>" From the medical center perspective, there is now a cohort of trainees who have skills and are engaged in the quality and safety mission of the hospital. They can be called on to lead their peers and superiors into engagement." Vidyarthi 2011</p>
<p><b><i>Data are critical. The availability of data, especially through health information technologies, has a direct positive impact on learner satisfaction and engagement.</i></b></p>	<p>"Getting learners to embrace the process of quality measurement and improvement, however, will be challenging as long as data collection re- mains tedious. Creative approaches to data collection and measurement (use of available managed care organization claims data) and active involvement of students in the planning process will be necessary to improve student experiences. We recommend further efforts in this area." Gould 2002</p> <p>"The need for data collection without dedicated personnel or an electronic medical record necessitated limiting the frequency and volume of data collection." Coleman 2003</p> <p>"Advanced information systems were central to this effort. The diabetes registry and subsequent reports were dependent on the data stored in our electronic medical record. Modifications of our medical record were necessary to capture items of particular interest, such as diabetic foot exams. The reports measuring practice progress toward our goals were critical for committee guidance." Halverson 2007</p>
<p><b><i>Opportunities for interprofessional engagement and education can be found in teaching about QI within the clinical setting.</i></b></p>	<p>"Our core clinical team included appointment secretaries, accounting representatives, clinic administrators, nursing personnel, laboratory technicians, physicians, nurse practitioners, and resident physicians." Halverson 2007</p> <p>"Chief residents were involved in interdisciplinary interactions with nursing and evaluation of house staff care." Kirschenbaum 2010</p> <p>"If programs are teaching systems-based practice via QI curricula, then it makes sense to teach across specialties and professions with nursing, social work, and administration." Reardon 2011</p>
<p><b><i>Programs can be successful by either engaging all faculty around QI or by having dedicated QI faculty for teaching QI within the clinical setting.</i></b></p>	<p>"We believe several features of our program contributed to its success... all faculty had quality improvement knowledge and experience (which may be lacking in many settings)." Mohr 2003</p> <p>"To learn how to refine and continually improve the QI-based curriculum, the program directors attend medical education– and QI-themed sessions at several national meetings each year... All members of the division faculty attend education-themed conferences offered by our institution's school of graduate medical education. By doing so, they stay up-to-date with current teaching and assessment methodologies as presented in the context of the ACGME competencies. Their attendance record is reviewed annually by the program directors who make recommendations for future conference attendance when areas for improvement are identified. Although the time commitment for these activities at times may pose a challenge to our faculty, each member of our staff considers that the clinical outcomes and their own professional development (including performance in practice credit) are well worth the effort." Carey 2013</p>



Theme	Illustrative Quotes
<p><b><i>To Achieve What Outcomes</i></b></p> <p><b><i>There is lack of clarity around whether educational and clinical outcomes are of equal or relative hierarchical importance.</i></b></p>	<p>"What may be more pragmatic and effective is to focus on clinical outcomes and allow educational outcomes to follow. The education of trainees (and others) may come more from doing QI than from studying it." Buckley 2010</p> <p>"We hope that the educational benefits extend beyond simply identifying unstable patients and escalating care. The decrease in house staff errors of judgment suggest that this might be the case." Kirschenbaum 2010</p>
<p><b><i>Sustainability is important for the clinical setting and the trainee. Sustainable projects can impact the culture of the clinical setting, but unsustainable projects may leave the trainee and other participants disheartened about improvement work.</i></b></p>	<p>"An apparent limitation of several previously reported house officer QI initiatives is a failure to create a durable infrastructure for sustaining the initiative." Weingart 2004</p> <p>"Beyond sustainability, our curriculum creates an ongoing residency-level project with the potential to improve the care of patients over the long term." Holmboe 2005</p> <p>"The following were the common themes that residents noticed while evaluating their projects...QI initiatives which decreased burden in clinic were more likely to be sustained...Structural changes to the clinic, while positive for clinic workflow, often had unintended consequences that affected the sustainability of QI projects." Oyler 2011</p>