NSF-RED: Outcomes-Based Education is Necessary but Insufficient

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There have always been challenges facing engineering education. Today's challenges include preparing students to address complex socio-technical issues, managing the cost of a degree, navigating the increase of engineering knowledge, and how technologies are impinging on student learning. The National Science Foundation RED project at Bucknell University hypothesizes that addressing these issues can best be achieved by expanding individual pathways for students, enabling an engineering education that is broader and more intersectional with other disciplines.

To better align the difficult work needed to expand student pathways through a curriculum in the highly constrained structure of most engineering degree programs, the Bucknell RED project adapted the capabilities approach which asserts that development—individual, economic, and societal—occurs when individuals have the access to personally meaningful capabilities—which are real and accessible opportunities—that they can convert into societally recognized achievements that have real value to the person. In this framework student opportunities are identified at multiple levels, from those required for all human thriving to those specific to engineering students. This opportunity set informs outcomes, which in turn have the potential to foster student achievements that are societally recognized. Adopting the capabilities approach shifted our internal perspectives beyond educational outcomes to the role that opportunities (capabilities) and achievements (functionings) play in education. As our RED project wraps up, we have concluded that ABET's outcomes-based approach limits the ability of engineering education to adapt to changing circumstances and times.

This poster compares the framework that underlies ABET to the capabilities approach, highlighting strengths and weaknesses of both. The ways that ABET-derived and capability-based frameworks intersect with the rest of the curriculum are highlighted, as is how the capabilities approach can be used to highlight barriers to pursuing a wider array of curricular pathways.

When the Electrical & Computer Engineering (ECE) Department at Bucknell University began preparing a Revolutionizing Engineering Departments (RED) proposal, we were five years into a major curriculum reform that reduced required non-major engineering coursework, trimmed the required ECE core, expanded technical electives and design experiences, and added open electives; the changes reduced the overall curricular complexity from 242 to 181 [1], [2]. These structural changes created space to reconsider how we educate students in a shifting higher-education landscape and in light of engineering's role in climate, environmental, and equity challenges. If engineering contributes to systemic harms, incremental improvement may be insufficient; RED's framing of "revolution" resonated because revolutions require compelling ideas that justify disrupting the status quo.

Our working assumption was that durable change depends less on adopting new pedagogies than on rethinking the governance frameworks that shape decisions about what counts, what evidence matters, and what trade-offs are acceptable [3], [4]. Here we use 'framework' to mean the enculturated mindsets and belief systems that make certain governance practices seem normal.

This paper first identifies and critiques the prevailing outcomes-based education (OBE) and continual quality improvement (CQI) governance framework in engineering education and then describes how the RED project at Bucknell University drew on the capability approach to surface limitations and test alternative practices.

Governance in engineering education emerges from a loosely coupled, multi-scale system that is often invisible to faculty [4]. Micro-scale decisions occur in courses and departments; meso-scale governance sits in institutions and state systems; and macro-scale entities include NSF, NAE, major employers, professional societies, and—most consequentially for programs—ABET through accreditation. This distributed system enables multiple decision frameworks (often historical precedent), but ABET's expectations make the frameworks on which ABET practices are based—outcomes-based education and continual quality improvement—the de facto national framework for accountability and improvement.

The framework of outcomes-based education (OBE) centers governance on the outputs of education—what graduates can demonstrably do—paired with procedures that hold programs accountable. In ABET practice, OBE operationalizes as: define a common set of student outcomes, assess evidence of attainment, and use results to justify program changes. In this logic, being educated is equivalent to achieving mandated outcomes. The framework of continual quality improvement (CQI) in higher education borrows from industrial quality movements and aligns with OBE on the importance of having defined and measureable outcomes. CQI presumes that "quality" is sufficiently definable and measurable to support management decisions; that reducing undesirable process variation improves performance; and that adherence to standards, stakeholder needs, and externally validated reviews (e.g., accreditation) are essential for improvement. In people-centered organizations like universities [5], [6], however, high human variance, legitimate diversity of pathways (electives, multiple trajectories), and the difficulty of attributing learning gains to specific process changes can make CQI cycles costly and ambiguous, which are familiar challenges in ABET reviews.

Together, OBE/CQI function as a tacit governance framework: programs are accountable to external standards; learning must be documented, compared to thresholds, and iteratively improved; and leadership structures emphasize compliance and documentation. OBE/CQI is a *predictive* framework, that is it is intended to guide present actions to change a future state. Because this framework is now deeply enculturated, it has become effectively invisible to most faculty. It is just what we do. The authors were blind to its implications and only through our RED work did the depth of our own habituation to "outcomes thinking" become apparent as we tried to reason from a different starting point.

In the Bucknell RED project, we have considered two alternative frameworks. Convergence—common in science policy—argues that disciplinary structures are poorly suited to complex, societally embedded problems [7]; we address it elsewhere [8], [9]. The more disruptive alternative for engineering education was the capability approach, developed in welfare economics and human development to evaluate well-being in terms of opportunities and freedom rather than quality or performance [10]. In contrast to OBE/CQI the capability approach is a *normative* framework, that is it foregrounds questions of value—what people have reason to value—and therefore what educational systems ought to enable.

Two concepts anchor the capability approach:

1) *Capabilities* are the genuine opportunities (and freedoms from constraint) a person has to pursue valued ways of living.
2) *Functionings* are the achieved beings and doings—recognized accomplishments—realized from that opportunity set.

Operationally, people convert capabilities into functionings; the evaluative focus is therefore on what opportunities are available and usable, rather than a focus solely on observed achievements. Differences in disability, talent, resources, and environment shape opportunity sets and thus what achievements are realistically possible.

The achievements people attain are based both on their opportunity set, but also that the person has and is given sufficient agency to utilize these opportunities. Put another way, each individual needs to have aspirations and sufficient freedom to form an evolving vision of how to live and what to pursue for herself, based on her own life goals, valued activities, capacities, and aspirations. Agency is a topic much discussed in engineering education [11], [12], [13] but OBE/CQI frameworks relegate agency to secondary status at best if they consider it at all. Agency, however, is central to the capability approach, particularly navigational agency [14]. Since many people generally have more opportunities than they can realistically convert to achievements, they must navigate choices of where to invest their effort and time. Navigational agency consists of the four complementary abilities shown in Table 1 which depend both on internal abilities and external opportunities and the ability to set goals and freely act to achieve them.

Table 1. Components of navigational agency (from [14]).

	Autonomy in Goal Setting	**Freedom to Act**
Internal Capabilities (developed abilities)	Opportunities to set their own ends and means.	Knowledge and skills to work towards desired ends.
External Capabilities (opportunities)	Non-manipulated awareness of personal options.	Ability to act freely and without interference.

With the capability approach sketched, we now compare it to OBE/CQI as a governance framework. No framework is universally "right" or "better"; each highlights different problems, legitimates different evidence, and privileges different forms of accountability. Because engineering education co-evolves with society (and shapes it, albeit slowly), the question is how well a framework aligns with a program's mission and the futures it seeks to serve. Below we compare the two frameworks on a variety of relevant factors.

Unit of analysis: one aspect in choice of frameworks is what the unit of analysis is, in other words what does the framework choose to focus on to guide day-to-day decisions. OBE/CQI governs primarily at the level of the degree program; the capability approach takes the individual as the focal unit because only persons can determine what they value. CQI treats variation as a defect to be controlled, whereas the capability approach treats heterogeneous goals, histories, and constraints as fundamental, and therefore demands attention to unequal opportunity sets. Individual preference is peripheral to OBE and anathema in CQI since variation is an unwanted perturbation. Prior to political push-back to DEI, ABET was slowly introducing changes to

ensure such differences led to less disadvantage for students, but this effort was abandoned due to the political situation in states hostile to DEI[1].

Theory of change: Frameworks are based on theories of change [15]. The capability approach posits that expanding equitable opportunity sets—and students' navigational agency to use them—enables people to pursue valued life achievements; evidence from human development research supports opportunity expansion as a driver of societal development [16], though education-specific evidence is still emerging. In contrast, OBE/CQI posits an accountability chain: specify valued outcomes, align curriculum and assessment, and use feedback loops so more graduates reliably attain those outcomes, thereby benefiting employers and society. The national EC2000 "Engineering Change" evaluation found only modest employer-perceived gains (teamwork, communication, ability to learn) and little change in technical fundamentals [17], [18], [19]. There is currently limited evidence of broader societal effects.

Power, legitimacy, and decision making: All frameworks are political to some extent and rely on leadership and power structures so they can be implemented and maintained. OBE/CQI implements through hierarchical authority: accreditors and institutions define required outcomes and processes, programs document compliance, and students are largely objects of assessment. The capability approach is more bottom-up: students' valued goals guide which opportunities matter, and programs are judged by what they enable. This shift requires curricula that intentionally develop navigational agency.

Implementation: Another consideration is how a given framework will be practically implemented and how that impact should be measured. In our RED framing, capability-based implementation emphasizes (1) ensuring equitable access to key opportunities at three levels (human, higher-education, and engineering-specific), (2) building navigational agency, and (3) providing structured ways to convert opportunities into meaningful achievements. OBE/CQI begins with outcomes and asks whether students meet them; improvement is triggered when evidence falls "out of specification," privileging procedural control over opportunity expansion.

Theoretical foundation: Another factor is how well a framework is aligned with relevant, valid theories and the extent to which those theories can inform effective practices. The capability approach is grounded in ethical and social welfare theory (Aristotelian eudaimonism, social justice, feminist ethics). The two foundational ideas that arise from these theories are pluralism—the existence of multiple, incommensurable dimensions of well-being—and contextualism, or that capabilities differ across societies and individuals so there is no single measure of "the good life". OBE draws on mastery/competency traditions that privilege measurability and alignment of curriculum, instruction, and assessment. CQI draws from Deming-inspired quality management and systems thinking, emphasizing feedback, measurement, and continuous process improvement.

Alignment with cultural norms: The legitimacy, compliance, and long-term impact of any framework depends on how well it resonates with local cultural expectations, societal values, and institutional norms. OBE/CQI resonates strongly with engineering culture's technical-rational norms-standardization, evidence, feedback loops, and performance metrics. The capability

[1] One of the authors is a former ABET PEV who resigned over this policy decision.

approach is compatible with, but less culturally "native" to, engineering because it centers agency, freedom, and values-based professional formation; it asks engineering education to treat human thriving and justice as primary considerations, not just ethical add-ons.

Ontology: A final consideration is the framework's implicit assumptions about what kinds of entities exist, what counts as a legitimate object of governance, and how those entities relate to one another. Before a framework can inform governance, it must determine what the system it seeks to govern is made of. The effectiveness of a framework is not just about design of rules, but also the ontological match—is it designed to govern the same kind of world as the one it actually faces? Ontological assumptions determine what problems are visible, what counts as evidence, who or what can be held accountable, and what kinds of change is imaginable. OBE/CQI assumes that outcomes are real, stable, and assessable; that programs can be treated as causal systems that produce those outcomes; and that documented artifacts and metrics are valid proxies for learning. Accountability is therefore program-level and documentation-heavy, which supports enforceable standards and legal robustness in high-stakes accreditation. The downside is a tendency to treat complex human development as if it were a controllable production process. The capability approach assumes individual agents with heterogeneous circumstances, constraints, and freedoms. Governance evaluates systems by what they enable—whether opportunity sets and agency are equitably supported—rather than by uniform outcome attainment alone. This orientation fits long-horizon aims (social mobility, justice, democratic participation) but is harder to enforce through fixed metrics and may require more deliberative, locally legitimate definitions of valued opportunities.

In conclusion, the RED project at Bucknell University proposes that large-scale changes to engineering education will require modification or adaptation of the governance frameworks which underlie engineering education. Currently, the dominant framework draws from outcomes-based education and continual quality improvement. We have used the capability approach—which focuses on opportunities as well as outcomes—to interrogate assumptions built in to the OBE/CQI model. Currently the frameworks we use standardize learning outcomes across programs. The issue with standardization, however, it that what may be valued life achievements for me may not be for you. College is a critical period in learning to shape one's life and it is realistic to assume, despite P. Floyd's argument to the contrary [20], that the vast majority of educators wish students to succeed. However our current frameworks focus on programs, and thus are blind to whether differences between students are unjust and what barriers or, on the contrary, special opportunities a person faces in their own unique context. The frameworks best suited to the future of engineering education should be a topic for public debate; the comparative analysis in this paper is intended to help inform that debate. To adapt to the future the larger engineering community education should be constantly exploring viable alternatives to current governance structures. Our RED project has some ideas to contribute.

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