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Operationalizing Team Effectiveness with Evidence-based Practice

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The design team is at the core of the capstone ecosystem, so understanding team dynamics is essential to capstone design research and practice. Much has been learned in this domain, but operational (i.e., practical) approaches to enhancing team effectiveness lag behind theoretical findings. At Wake Forest Engineering, the instructional team has adopted an integrative evidence-based practice approach that capitalizes on tools drawn from diverse academic and professional sources to augment team effectiveness. Developmental processes associated with this approach are briefly discussed, and a working toolset is demonstrated to provide a basis for other capstone instructional teams to explore the potential of evidence-based practice.

Keywords: capstone design, team effectiveness, evidence-based practice, integration, agile

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Introduction & Background

The student team exists at the core of the capstone design ecosystem – a dense nucleus around which other elements of the capstone experience revolve (Howe, 2018). The dynamic elements of this nucleus are among the most important predictors of project outcomes (e.g. Dutson et al., 1997, Ohland et al., 2015, Paretti et al., 2011). As such, it's no surprise that team effectiveness is an enduring interest among engineering capstone design researchers. While a capstone-specific review of the team effectiveness literature has not yet emerged, recent reviews of the engineering education teamwork literature provide some essential insight (Borrego et al., 2013; Chowdhury & Murzi; 2019). Despite the wealth of promising strategies identified in these reviews, the path to effective teamwork remains only partially charted. In the authors' words, "there is gap in engineering education research on the use of effective teamwork models and also a lack of consensus among engineering instructors on how to effectively teach teamwork skills to engineering students" (Chowdhury & Murzi, 2019, p.7).

As a relatively new department actively building and refining the capstone design experience, Wake Forest Engineering has found this statement to be *mostly* true. Available resources within the capstone ecosystem are primarily theoretical and observational, in some cases methodological, but rarely interventional. So, where shall we look for operational insight? To the broader academic research, certainly, and we have found evidence-based practices from industry to be equally useful. The present paper describes Wake Forest Engineering's experience using a novel, evidence-based practice approach to integrate robust academic and professional team effectiveness tools into our capstone design experience.

Interventional models for cultivating team effectiveness in capstone design have not yet emerged, but there is a compelling modern history of such approaches in professional engineering practice. General Electric's (GE) story is particularly relevant to the approach we have adopted at Wake Forest Engineering. In the early 1990's, a team of leading organizational management consultants was hired by CEO Jack Walsh to study best practices for change management. The result was the Change Acceleration Process (CAP), which GE and many subsequent adopters use to this day. Among the most critical insights is that attending to cultural and interpersonal elements of work teams was as important to project success as technical quality. Numerous exceptional tools have emerged from CAP over the years, including a multipurpose rubric based on the GRPI model of team effectiveness (Beckhard, 1972) that is used for team assessment and improvement across the company – more on how we adopted this rubric in the next section.

When Jeff Immelt became CEO in 2001, he sought to make GE as celebrated for innovation as it was for operational excellence. Immelt's team recognized the limitations of the linear CAP methodology and incorporated flexible, team-led strategies to promote innovation. As Agile project management took shape and gained steam, GE adopted various Agile values and practices including self-organizing teams with greater transparency and iterative design and feedback processes (Prokesch, 2009; Kim 2012). GE continues to adapt, integrate, and iterate best practices that align with their unique culture and structure. Wake Forest Engineering has adopted an analogous approach to develop capstone design courses which we conceptualize as *integrative evidence-based practice*.

The remainder of this brief paper begins with an overview of our approach, which, beyond displaying initial utility within our own capstone sequence, has broader potential as an operational approach to content development for professionally oriented curricula. Next, we present a set of evidence-based team effectiveness tools currently used in Wake Forest Engineering capstone design. We then touch on key limitations and future directions before wrapping up with some concluding thoughts. Please note that both the general approach and the specific tools presented here are readily adaptable and could serve as the roots of evidence-based methods tailored to meet the specific needs of the design teams at your school.

An evidence-based practice approach to capstone course development

Calls for evidence-based practice (EBP) in engineering education are clearer than ever, particularly as a means to closing enduring research-to-practice gaps (e.g. Bruhaver et al., 2018; Finelli, Daly & Richardson, 2014; Finelli & Froyd, 2019; Garousi et al., 2019). Across much of the curriculum, integrating the latest engineering education research into curricular development may be sufficient. Capstone design courses are fundamentally different, however, because they are typically designed to simulate professional environments. Not surprisingly, integration of industry practices into capstone curricula has been regularly promoted. The means of integration is most often via active involvement by industry representatives (e.g. Arnold, 2010; 2014; Aller & Klein, 2002; Jones & Mezo, 2014). Adopting best practices directly from professional sources is a less common strategy, but examples do exist in the literature, including the use of industry-based performance evaluations (Namilae, 2018) and professional standards of conduct (Stanfill, Rigby & Milch, 2014). In addition to scientific evidence and industry practices, an inclusive evidence-based approach to course development should also be strategically informed by organizational knowledge (e.g. working best practices) and core values. Figure 1 below depicts the approach to evidence-based practice used by Wake Forest engineering faculty to guide the development of capstone design curricula. This approach is inspired by an evidence-based model used in medical fields (nursing in particular) that also has a tripartite design that draws from scientific evidence, clinical experience, and patient values. Understanding and attending to patient values is critical to good medical practice, and as a values-based program whose mission is to graduate engineers with strong character, leadership, and interdisciplinary skills, our core values are essential to curricular development. Another feature of our approach to evidence-based practice is functional integration. The various practices we draw from academic research, industry practice, and organizational experience must complement one another in ways that guide and inspire students rather than confusing and frustrating them. An example of such integration is demonstrated in the next section via the toolset that currently supports team effectiveness in Wake Forest Engineering capstone design.

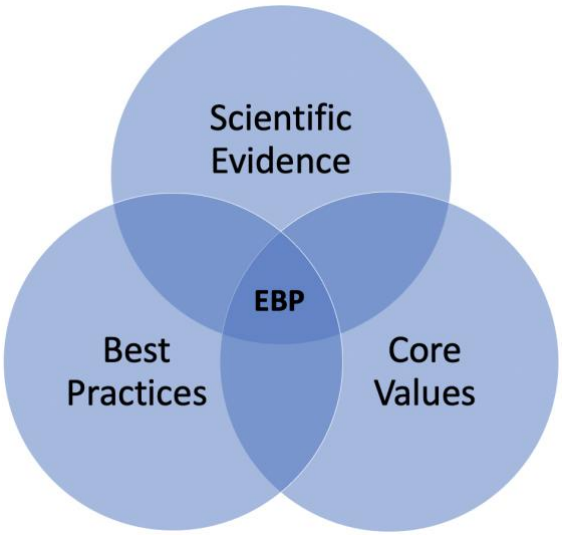

Figure 1. Wake Forest Engineering approach to evidence-based practice (EBP)

An evidence-based set of team effectiveness tools

First, an important reminder that what follows is in overview of *a* set of tools for team effectiveness rather than *the* set. It is unlikely that your school's ideal practices are identical to ours. Best practice approaches often treat contextual factors (i.e. all the differences between your school and ours) as noise that *the* set rises above. Integrative evidence-based practice compels an educational team to design and redesign *your* best set by drawing complementary practices from sources that best align with your priorities and can be adapted to the needs of your student teams. The tools introduced in Table 1 below are currently in practice at Wake Forest. A key advantage of Agile methodologies is the fundamental integration of project issues and team vaules. Other popular approaches like the Project Management Body of Knowledge (PMBOK) (Project Management Institute, 2017) treat team effectiveness as functionally distinct from core values like courage, respect, and openness (Schwaber & Sutherland, 2016). Agile teams are supported by the periodic review of observable products leading to iterative development. From an engineering design perspective, an observable product might be a CAD drawing or a prototype. From an engineering design *team* perspective, as demonstrated by Table 1 below, observable products may be team contracts, retrospectives, rubrics, and peer assessments.

Table1. Team Effectiveness Toolset Used at Wake Forest Engineering Capstone Design during AY 21-22

TOOL & PURPOSE	EVIDENCE-BASED SOURCE(S)
Team Contract: Define collaborative expectations & leadership roles	• Rigby & colleagues' (2020) best practices for Agile working agreements • Ohland & colleagues (2015) on team contracts in Capstone Design
Project Backlog: Manage project tasks & deliverables	• Scrum creators Sutherland & Schwaber (2020) on project backlogs in the 2020 Scrum Guide • Sweeney & Cifuentes on agile backlogs in design education (2010)
Team Retrospective: Collaborative reflection on team effectiveness & action planning	• Derby & Larsen's (2006) broadly implemented best practices for team retrospectives
Individual Retrospective: Individual reflection on team effectiveness & action planning	• Developed at Wake Forest Engineering (2020) by adapting Derby & Larsen's five-step model for individual practice
Team Effectiveness Rubric: Clarify standards of practice, self & faculty assessment	• GRPI Model of Team Effectiveness (Beckhard, 1972) • General Electric's GRPI rubric (Change Acceleration Process, 1992)
Self & Peer Evaluation: Formative individual and team assessment	• CATME self & peer assessment (Felder, Ohland, Loughry & colleagues, 2005-2012) • An original tool developed at WFUE to enable constructive peer-to-peer feedback

Agile does not provide a global framework that optimizes team effectiveness, however. To identify a model that suits our goals, we reviewed evidence-based practices in the academic and professional literature and selected the GRPI model of team performance (Beckhard, 1972) for its relative simplicity, ability to represent core concepts more parsimoniously than other models, and a thirty-year record of success at GE (as noted in the introduction). See Figure 2 below for an overview of the model. We then adapted GE's GRPI-based team effectiveness rubric to meet the needs of our student design teams. Eight categories nested within four domains are similar to GE's version, but, based on our core values, we have added elements of leadership and character. Appendix 1 depicts an annotated version this rubric with Agile and CATME tools highlighted to illustrate practical integration.

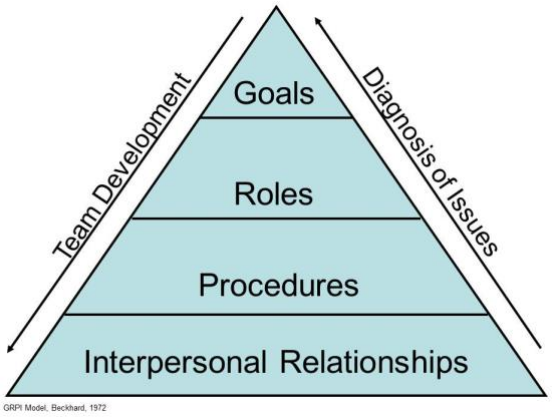

Figure 2. The GRPI Model of Team Effectiveness (Beckhard, 1972)

Finally, to the assessment of team effectiveness. The CATME platform was created by engineering educators and is used in many STEM environments to drive self and peer assessment. CATME's five teamwork dimensions are displayed in Figure 3 below. We found CATME to be ineffective for generating constructive peer-to-peer feedback (94% of comments were positive), so we developed a separate tool for this purpose.

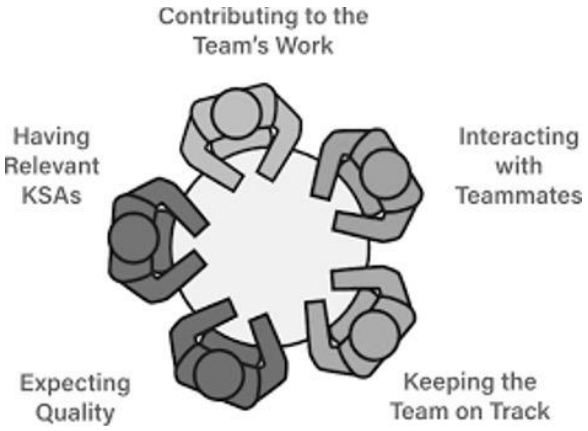

Figure 3. CATME teamwork model (Ohland et al., 2012)

Limitations and Lessons Learned

After two years of development and implementation, our integrative evidence-based practice approach to supporting capstone design teams is showing promise. There are limitations, of course, the most obvious of which may be resource cost. Identifying, integrating, implementing, evaluating, and improving a diversified toolset takes significant time and effort. At Wake Forest, one member of the capstone instructional team focuses

entirely on coaching team effectiveness and project management. From an instructional perspective, team effectiveness tools must well-integrated with one another and with core design experiences. Functional integration is more difficult with more tools. An important lesson we are learning is that most teams strongly prefer to focus on core design project tasks as much as possible, so successful integration of team effectiveness tools is critical. Students also have difficulty providing honest, constructive feedback to their teammates. Fortunately, our evidence-based practice approach supports the integration of new practices, and the peer feedback tool we added in Spring 2022 has been effective.

Future Directions and Concluding Remarks

Across the next iterations of capstone design, we will strategically generate student feedback and learning data to assess the impact of our integrative evidence-based practices. Until then, the approach is simply a collection of potentially useful ideas that have demonstrated utility in other disciplines and show promise at Wake Forest. We will continue to refine our working set of team effectiveness tools based on emerging student needs, practical lessons learned, and data-driven outcomes. Some may say that the present approach is unwieldy or too complex for practical implementation. Consider, though, that thirty years ago GE discovered team dynamics to be as important as technical solutions. Contemporary project management approaches like Agile and Six Sigma put team dynamics front and center. As noted in the introduction, the capstone design community has also come to understand the vital importance design team dynamics. With all this in mind, perhaps attending to team effectiveness with the same vigor we teach technical effectiveness is appropriate after all.

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APPENDIX 1.

GRIP Strength: 2022 WFUE Capstone Team Effectiveness Rubric (Annotated w/ Agile & CATME tools)

Goals, **R**oles, **I**nteractions, & **P**lanning		Excellent	Very Good	Good	Fair	Poor
G	**Purpose & Outcomes** Team understands stakeholder needs & is aligned on project mission			🐝		
	Primary Agile tool: Team Retrospective — **Primary CATME assessment domain: EXPECTING QUALITY**					
	Goals & Deliverables Team has clear project goals & understands how to achieve them		🐝			
	Primary Agile tool: Individual Retrospective — **Primary CATME assessment domain: CONTRIBUTING TO THE TEAM'S WORK**					
R	**Leadership & Character** Team members occupy discrete leadership roles & lead with character		🐝			
	Primary Agile tool: Team Contract — **Primary CATME assessment domain: HAVING RELEVANT KSAs**					
	Functional Equity Team's approach to sharing responsibility is transparent & equitable	🐝				
	Primary Agile tool: Team Contract — **Primary CATME assessment domain: CONTRIBUTING TO THE TEAM'S WORK**					
I	**Interpersonal Expectations** Team defines & upholds clear expectations for collaborative conduct			🐝		
	Primary Agile tool: Team Contract — **Primary CATME assessment domain: INTERACTING WITH TEAMMATES**					
	Interpersonal Dynamics Team communicates well & maintains productive working relationships			🐝		
	Primary Agile tool: Team Retrospective — **Primary CATME assessment domain: EXPECTING QUALITY**					
P	**Short-Term Planning** Team maintains an effective backlog of ongoing tasks & deliverables				🐝	
	Primary Agile tool: Team Backlog — **Primary CATME assessment domain: KEEPING THE TEAM ON TRACK**					
	Long-Term Planning Team maintains effective long-term plans that include key milestones			🐝		
	Primary Agile tool: Team Backlog — **Primary CATME assessment domain: KEEPING THE TEAM ON TRACK**					