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LENS: A Model for Engineering Faculty Development

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ABSTRACT

CONTEXT

Engineering educators could benefit from a faculty development model that meets them where they are, in both their discipline and their journey as educators. It is often difficult to get academics to talk about their teaching as it relates to educational research, and research shows that those in engineering programs, even with a pandemic-imposed accommodation to delivery, participate in fewer educational development opportunities than their colleagues in other disciplines. This reluctance to develop as educators may help explain why student and faculty surveys of student engagement rank engineering educators lowest in the categories of effective teaching practices and providing a supportive learning environment.

PURPOSE OR GOAL

This work presents the LENS (Learning Environments Nurture Success) model of engineering faculty development. The six "lenses" represented in the LENS model align with the evidence-based characteristics of an effective learning environment for engineering students: (1) academic rigour, (2) focus on learning, (3) instructional support, (4) quality of teaching, (5) student-faculty relationships, and (6) student engagement.

APPROACH OR METHODOLOGY/METHODS

The LENS model is based on a conceptual framework that draws on five key areas: (1) student success in engineering programs, (2) change and innovation in Science, Technology, Engineering and Mathematics (STEM) teaching, (3) threshold concepts associated with post-secondary teaching, (4) an educator's journey from novice to expert teacher, and (5) the findings of myriad studies in research-based instructional strategies (RBIS), discipline-based education research (DBER) in STEM programs, and engineering education research (EER). Each of these research areas shares a social constructivist viewpoint with a vision of students who are engaged, successful, and value their learning.

ACTUAL OR ANTICIPATED OUTCOMES

Following a literature review, each lens is defined, identifies commonly used instructional strategies, and suggests evidence-based strategies that can be implemented to enhance one's teaching practice. The breakdown provides level-appropriate recommendations for faculty at three stages of development: first-order change for those wanting to do things better, second-order change for those choosing to do better things, and third-order or epistemic change for those primed to make a transformational shift in their teaching.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

The LENS model contributes to the body of scholarly work associated with engineering faculty development by (1) offering a practical framework that supports educational development and planning for all forms of delivery (face-to-face, remote, blended, or hybrid) that can be used independently, in consultation with an Educational Developer, or in collaboration with colleagues, (2) threading educator-related threshold concepts associated with learning, pedagogy, and assessment through each of the six lenses, and (3) linking interdisciplinary research focused on facilitating the success of engineering students.

KEYWORDS

Faculty development, instructional development, engineering education

Introduction

A recent study describes the culture of engineering to be solution-focused, but with a “strong attachment to tradition” (The Royal Academy of Engineering, 2017, p. 3). This traditional approach is enacted every day in myriad undergraduate engineering classrooms around the world. Engineering educators are reluctant to change their methods, despite mounting evidence that innovative teaching practices improve student learning and engagement. Studies show, however, that there are ways to increase the appeal and relevance of educational development to engineers. This qualitative inductive work provides a research-informed and evidence-based model of faculty development for engineering educators that meets them where they are in both their discipline and their journey as educators.

Development of the Model

This work-in-progress draws upon and integrates the findings of research into five key areas: (1) student success in engineering programs, (2) change and innovation in Science, Technology, Engineering and Mathematics (STEM) teaching, (3) threshold concepts associated with post-secondary teaching, (4) the journey from novice to expert educator, and (5) the findings of myriad studies in research-based instructional strategies (RBIS), discipline-based education research (DBER) in STEM programs, and engineering education research (EER). Each of these research areas shares a social constructivism viewpoint with a vision of students who are engaged, successful, and value their learning. Starting with the instructional triangle as its core, this section outlines the interdependence of these research areas in the shaping of a faculty development model for engineering educators.

Instructional Triangle

For the past five decades, the instructional triangle has provided a way for science educators to focus on the interactions between the three core aspects of education: the student, the teacher, and the content (Hawkins, 1974). The beliefs, attitudes, identity, and actions of the teacher shape the relationships and level of respect established with the students, and the way in which content is prepared and shared with them. Likewise, the beliefs, attitudes, identity, and actions of the student shape the way they interact with the content. A broader learning community extends this triangle to include teaching colleagues who may influence teaching practices, a curriculum that encompasses the content, and a student community that may affect student success.

Student Success and Effective Learning Environments

A student-centred approach is “an organizational process and mindset around success for the students served, informed by a deep understanding of the learners, along with their active involvement in selecting solutions that work for them” (Higher Learning Commission, 2018, p. 7). A literature review identifies two significant requirements for student success in engineering: a need for students to be actively engaged in their learning, and quality interactions between educators and students both in and beyond the classroom (Boles & Whelan, 2017). A survey of engineering students reiterates these findings. It reports that while classroom practices remain lecture-based, students recognize that active involvement is beneficial to their learning, and that their instructor can have a significant impact on the learning experience (Nelson & Brennan, 2019b).

Effective learning environments are those that ensure success through value-added learning. The benchmarks used in myriad studies can be categorized into six broad themes: (1) an appropriate level of academic rigour, (2) a focus on learning, (3) supported instruction, (4) quality of teaching, (5) development of strong relationships, and (6) student engagement (Nelson & Brennan, 2019a). Each of these themes represents one or more interactions on the instructional triangle.

Change and Innovation in STEM

Educational researchers have been advocating for STEM reform for decades. Despite their efforts, engineering continues to rank at or near the bottom of all disciplines (Quality Indicators for Learning and Teaching, 2017) (National Survey of Student Engagement, 2018) (UNISTATS, 2018), particularly in areas associated with learning strategies, effective teaching practices, and a supportive environment (Nelson & Brennan, 2019a). Myriad researchers confirm that teaching practices in STEM remain didactic, and lecture-based (Laursen, 2019) with fewer than 20% using evidence-based teaching practices in their classroom (Stains et al., 2018). Suggested reasons include a lack of formal training on how to teach (Nelson & Brennan, 2018), lack of incentive and a perceived lack of value in educational development (R. Felder, Brent, & Prince, 2011), and not seeing the benefit of moving to a more student-centred approach (Allen, 2018). STEM educators rank barriers to teaching innovation higher than all other disciplines, noting in particular that "Active learning takes too much class time causing the coverage of content to suffer" (Allen, 2018).

Felder and his team reviewed the content and structure of instructional development programs and recommend a framework for designing faculty development for engineering educators (R. Felder et al., 2011). They propose that five factors are needed to increase the appeal and relevance of educational development to engineers: (1) the expertise of the instructor in subject matter and ways of teaching, (2) relevance of the content, (3) choice in whether, when, and how to apply the instructional practices, (4) the opportunity to observe, try, and reflect on what's being taught, and (5) sharing experiences with peers. Literature reviews note that effective change strategies must align with, or work to adjust, individual beliefs, require long term interventions, and be compatible with institutional goals (Henderson, Beach, & Finkelstein, 2011). They also report that educational innovation is best served by engaging early and often with educators (Froyd et al., 2017). Finally, most studies on STEM teaching practices do not "address the key issue of what makes the STEM disciplines difficult to learn and challenging to teach" (Winberg et al., 2019, p. 940).

In spite of instructional development efforts, a recent study of novice engineering educators ranks their teaching skills and delivery lower than colleagues in all other disciplines (Nelson & Brennan, 2020). Significant differences exist in the organization, pace, and planning of classes, and the way material is presented to students (Nelson & Brennan, 2021b). Even during the pandemic-induced period of forced change, engineering educators took significantly less advantage of myriad opportunities to learn new teaching-related concepts and skills than their colleagues in other disciplines (Nelson & Brennan, 2021a). This reluctance to develop as educators may explain why student and faculty surveys of student engagement rank engineering educators lowest in the categories of effective teaching practices and providing a supportive learning environment (Nelson & Brennan, 2019a).

Teaching-Related Threshold Concepts and an Educator's Journey

There are many teaching-related concepts and skills that distinguish a competent educator from a great educator. Many of these are threshold concepts which are defined as "portals" to a new way of thinking about, mastering, and practicing one's discipline. These concepts are characterized as troublesome to learn, integrative in the way they pull together key concepts, transformative, irreversible, and context-bounded (Meyer & Land, 2003). A qualitative literature review identifies four clusters of threshold concepts that, when surmounted, could facilitate a change in the day-to-day practice of engineering educators: pedagogy, learning, assessment, and teaching with technology (Nelson & Brennan, 2021c). Threshold concepts in teaching range from reflective practice, care, recognition of student-related threshold concepts, a focus on learning, and constructive alignment of assessments, to experimentation with educational technology.

Much is written about the journey professionals take from novice, through competence and proficiency, to expertise within their discipline (Dreyfus & Dreyfus, 1980) (Benner, 1982)

(Lyon, 2015). While engineering educators are considered experts within their discipline, many do not move beyond competence as educators because there is a “transformation, a qualitative leap, from the competent to proficient levels of performance” (Benner, 1982, p. 406). These transformative leaps most likely correspond to teaching-related threshold concepts.

Engineering Education Research (EER)

The application of education, learning, and social-behavioural sciences research is one of five key shifts in engineering education over the last 100 years (Froyd, Wankat, & Smith, 2012). Although formalized EER is still considered to be in its infancy (Borrego, Foster, & Froyd, 2014) it is well supported by societies across the globe such as REEN (international), ASEE (USA), CEEA-ACEG (Canada), SEFI (Europe), and AAEE (Australia).

Rigorous research in engineering education can be categorized into one of four levels of inquiry: (1) excellent teaching, (2) scholarly teaching, (3) scholarship of teaching, and (4) rigorous research (Streveler, Borrego, & Smith, 2007). These levels recognize the benefit of both theory- and practice-oriented research. Whether it is called DBER, common in STEM-related publications, RBIS, a more generic term, or Scholarship of Teaching and Learning (SoTL), common to practice-based work, there is still, as previously noted, a gap between EER and its use in the engineering classroom.

Bridging this gap requires renewed educational development efforts that: (1) align with current motivation theories for adults, (2) inform and help shape faculty practices and conceptions about teaching and learning, (3) recognize the cultural and organizational norms as part of a strategic shift to evidence-informed teaching, and (4) address the barriers that impede changes in teaching practice (Singer, Nielsen, & Schweingruber, 2012).

This work-in-progress presents the LENS (Learning Environments Nurture Success) model of engineering faculty development that shifts the focus away from ‘learning to teach’ toward providing a more effective learning environment. It recognizes, integrates, and builds on the research into student success, change and innovation in STEM, threshold concepts and the educator’s journey to expertise, and EER. It can be used independently, in consultation with an Educational Developer, or in collaboration with colleagues, and supports all forms of delivery (face-to-face, remote, blended, or hybrid).

The LENS Model

The LENS model encourages engineering educator to use an agile approach, making small, level-appropriate, and evidence-based change in their teaching practices. This requires a willingness to learn, experiment, and reflect on one’s teaching. LENS consists of six “lenses” that align with the characteristics of an effective learning environment: (1) student engagement, (2) student-faculty relationships, (3) instructional support, (4) focus on learning, (5) academic rigour, and (6) quality of teaching. These six lenses can help shape a longer-term educational development program for individuals or programs, or be used for just-in-time, interest- or needs-driven development.

The description of each lens identifies the associated aspects of teaching and learning, and commonly used instructional strategies. It then suggests evidence-based strategies for enhancing one's teaching practice with level-appropriate recommendations for faculty at three stages of development: first-order change for those wanting to do things better, second-order change for those choosing to do better things, and third-order or epistemic change for those primed to make a transformative shift in their teaching (Sterling, 2003).

Student Engagement Lens

Figure 1a shows the instructional triangle, the core of the LENS model. It frames the relationships between the student, the teacher, and the content. Student engagement is the primary means of connecting students to the content (see Figure 1b). It is characterized by the time and effort students put into their studies and learning activities, student motivation, and the success initiatives provided by the institution. There is a strong relationship between student engagement and all four clusters of threshold concepts, so increasing the quality and level of student engagement will improve both teaching and the learning environment. Common practices for novice to competent engineering educators include using grades as motivators, and assuming students have well-developed learning strategies and are responsible for their own success.

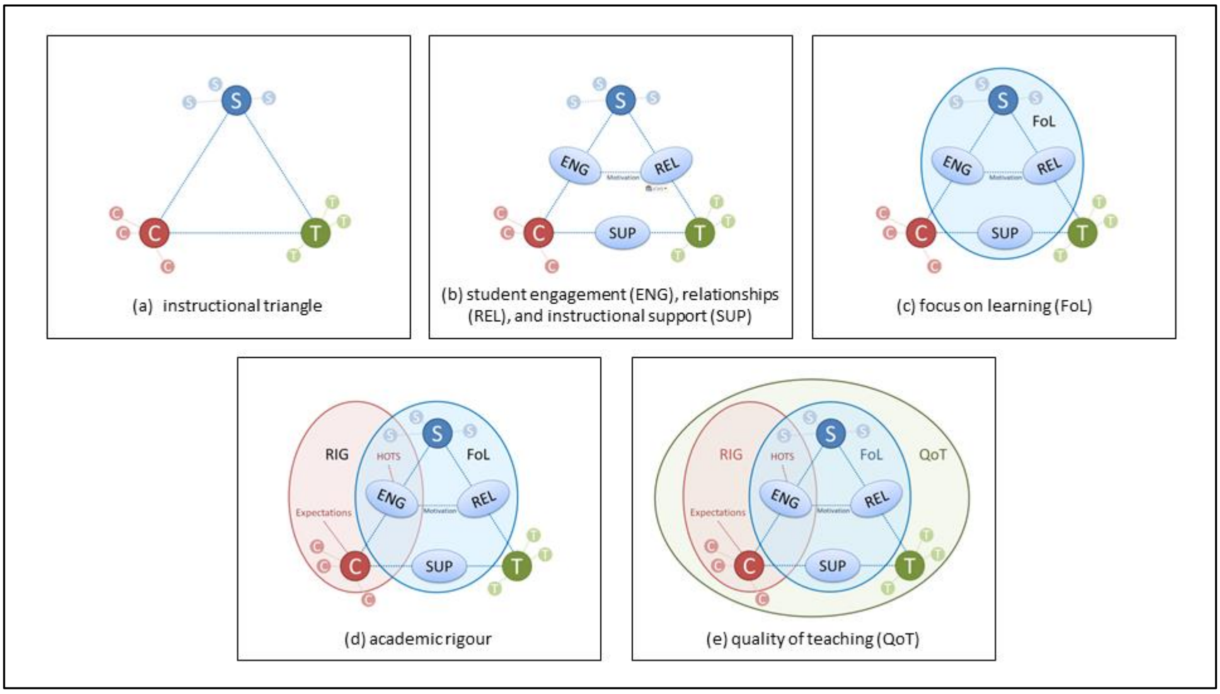

Figure 1: Evolution of the LENS faculty development model – the six lenses

Evidence-based strategies for less experienced educators who want to do things better could include taking a few minutes before introducing a topic to establish its context within the discipline and explain why it is important to know. Choosing discipline-specific examples and problems over more generic ones will help demonstrate its value. Students are more attentive to things that are relevant, important and useful, so will be motivated to engage with the content (R. M. Felder, Woods, Stice, & Rugarcia, 2000). Faculty who have reached a point in their career that they want to do better things could choose assessments that emulate the problems encountered in the workplace (Biggs & Tang, 2011). Finally proficient or expert educators could incorporate high impact pedagogies such as problem- or project-based learning, flipped learning, or service learning (Evans, Mujis, & Tomlinson, 2015).

Strong Relationships Lens

Strong relationships connect students to the teacher (see Figure 1b). This lens considers the interactions between students and their professors, how accessible educators are to their students, openness of educators to hearing the student voice, and their support of learning communities. There is a strong link between this lens and the pedagogy threshold concepts. Common practice for novice to competent engineering educators generally places a teaching assistant (TA) between the student and professor, signalling an implied distance.

Evidence-based strategies for those who want to do things better include providing informal, virtual opportunities for students to ask questions and/or clarify their understanding of the content (Smith, Chen, Berndtson, Burson, & Griffin, 2017). Faculty who are ready to do better things may consider asking for, and responding to, constructive feedback from the students partway through the term. A Stop, Start, Continue survey is an effective method to gather this qualitative feedback (Hoon, Oliver, Szpakowska, & Newton, 2015) Finally proficient or expert educators should ensure their classrooms are culturally responsive and respectful. This includes minimizing biases and the perpetuation of norms, policies, and practices that may cause educational inequality (Wlodkowski & Ginsberg, 2017).

Instructional Support Lens

Instructional support connects students to the content (see Figure 1b). This lens encompasses things that are 'for' the student. This includes the selected instructional method(s) and the materials used to support that delivery. It establishes the learning opportunities the students will have, and the effectiveness of the classroom experience. There is a strong relationship between instructional support and all four clusters of threshold concepts. Common practices for novice to competent engineering educators include a lecture, slides, prescriptive labs, an assigned text book, and additional resources linked through a learning management system.

Educators trying to do things better may want to calculate the student workload in their courses; it is often much higher than assumed (Barre, 2016). Faculty ready to do better things may consider breaking their classes into 15-20 minutes segments, each of which gives learners the opportunity to actively engage with each level of complexity as it is delivered (Collins, 2006) . Proficient or expert educators may consider experimenting with technology in the classroom. Adding strategic elements of simulation, gamification, and formative feedback may increase students' depth of learning (McGowan, 2012).

Focus on Learning Lens

The Focus on Learning encompasses the student community, their engagement, motivation, relationships and the way their learning is supported (see Figure 1c). This lens focuses on things that are done 'by' the student. This includes active and collaborative learning, opportunities for skill development, and metacognition. There is a strong relationship between this lens and all four clusters of threshold concepts. Common practice for novice to competent engineering educators is to structure learning time around in-class worked examples, labs, and homework.

Educators looking to do things better might consider spreading in-class exercises throughout each class. Each time a new concept is introduced and modeled, follow it with a similar problem for students to try (Collins, 2006). Faculty who are ready to do better things could incorporate retrieval practice into their course to increase across-semester knowledge retention (Lyle, Bego, Hopkins, Hieb, & Ralston, 2020). Finally proficient or expert educators could move to a learner-centred perspective that appreciates how students construct their knowledge of the discipline (Kinchin & Miller, 2012) (Devitt, Kerin, & O'Sullivan, 2014).

Academic Rigour Lens

Active rigour intersects the Focus on Learning lens and shares the student engagement lens (see Figure 1d). This lens ensures students are appropriately challenged to maintain standards established by the institution and any accrediting bodies. There is a strong relationship between academic rigour and the pedagogy, learning, and assessment threshold concepts. Common practices include content coverage during transmission-based classes, labs, homework, and exams that expect students to integrate what they have learned.

Educators trying to do things better can use a requirements prioritization method like MuSCoW to differentiate key topics within a unit from those that are nice-to-know (Hulshult, 2019). They can use this analysis to focus on topics that require rigorous study. Faculty ready to do better things may consider aligning their assessments with course learning outcomes (Biggs & Tang, 2011). Proficient or expert educators could seek out course-specific threshold concepts and ensure students actively explore those transformative concepts throughout the course (Male et al., 2012).

Quality of Teaching Lens

The Quality of Teaching lens encompasses all other lenses (see Figure 1e). This lens focuses on the teaching practices, attitudes, and beliefs of the educator. There is a strong relationship between the quality of teaching and all four clusters of threshold concepts. Common practices for novice to competent engineering educators include fast-paced, content-heavy classes, the assumption that students understand even if they don't ask questions, and minimal chance for students to provide ongoing feedback.

Evidence-based strategies for those looking to do things better may include slowing down to a pace where students can think about and assimilate what they're learning. They may also want to handwrite in-class notes so students can keep up (Nelson & Brennan, 2019a). Those who are ready to do better things should consider using an evidence-based lesson planning template to ensure that each class is organized, interactive and focused on the key outcomes (Nelson & Brennan, 2021b). Finally, proficient or expert educators may want to practice reflective teaching to explore ways in which they can further improve their teaching (Biggs & Tang, 2011).

Concluding Thoughts

The LENS model offers a practical framework that encourages an agile approach to the educational development of engineering educators. With a focus on learning, it informs and helps shape faculty practices and conceptions about teaching and learning. It aligns with current motivation theories for adults, recognizing that individuals are each at a different stage in their professional growth as educators. It inspires movement from competent to great teaching by threading elements of educator-related threshold concepts through each lens. The LENS approach narrows and directs the engineering educator's instructional development efforts to the most impactful practices in today's engineering classroom.

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