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Engineering Education Research Collaborations: Use of Futures, Values, Systems, and Strategic Thinking

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Abstract

Context

Countries, like the United States, invest millions of taxpayers' dollars to support engineering education research (EER). Many calls for research look to bring novel ways of thinking through interdisciplinary collaborations between engineering researchers and social scientists. However, the use of different ways of thinking is often implicit or taken for granted.

Purpose or Goal

The purpose of this research study is to better understand how ways of thinking are applied in collaborative EER projects. The following research question is explored: *In what ways do collaborating engineering and social sciences researchers use futures, values, systems, and strategic thinking in their EER projects?*

Methods

A survey was distributed to examine the use of four specific ways of thinking in EER – futures, values, systems, and strategic thinking. The participant sample included awardees of one specific National Science Foundation program that required collaboration with a social scientist with the goal of designing revolutionary novel approaches to engineering education. A sample of 84 researchers were contacted with 48 responses received. The open-ended survey responses were analyzed qualitatively for emergent themes to examine use of ways of thinking in EER.

Outcomes

Results uncovered deeper themes behind researchers' enactments of ways of thinking, such as workforce development, pedagogical innovation, inclusion and social justice, weaving a tapestry, and stakeholder engagement. Results highlight how ways of thinking are enacted in EER and influence engineering education practice in order to drive innovation and transformation in the field.

Conclusion

This study contributes to the broader conversation on transforming engineering education through a ways of thinking lens. These thinking approaches, when integrated and applied purposefully, empower stakeholders to anticipate, address, and transcend the complex challenges facing the field, ultimately advancing engineering education in response to the evolving needs of society.

Keywords—ways of thinking, interdisciplinary collaboration, transformation.

I. INTRODUCTION

A well-established body of literature shows the benefits of interdisciplinary collaborations between engineering and social sciences researchers for the improvement of education in engineering colleges (Carr et al., 2017; McKenna et al., 2009; Olds et al., 2005). Such collaborative research typically involves drawing on theories and research methods from learning sciences, instructional design, or educational psychology and applying them to the teaching, learning, and other related activities within engineering education and research. Collaborating researchers share their domain-specific knowledge and skills, engage in meaning-making, evaluate multiple perspectives, and work together to solve the problems (Borrego & Newswander, 2008; Dalal et al., 2017).

The underlying notion behind such collaborations is to foster innovation in the engineering education system. The United States invests millions of taxpayers' funds in engineering education research (EER) via National Science Foundation (NSF), with the goal that resulting research will lead to improved engineering education. Many NSF calls require an interdisciplinary collaboration between engineering faculty and social scientists to bring novel ways of thinking about educational research in the engineering domain (NSF, 2017; Wankat et al., 2002).

Adopting new ways of thinking is seen as one necessary means to bring about change and inform the existing practices within the global engineering ecosystem (ASEE, 2014; NSF, 2017). A necessary first step is to better understand what ways of thinking are currently used in EER. Numerous activities associated with EER collaborations are not well documented. These include problem solving approaches, ways of thinking, vision, values, and strategies toward transformation of the field. The use of different ways of thinking is often implicit or taken for granted. Recent publications have brought this issue to the forefront, including a proposed framework for applying four specific ways of thinking in EER – futures, values, systems, and strategic thinking (Dalal et al., 2021, 2023).

This study aimed to better understand how ways of thinking are applied in collaborative EER projects. The following

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research question is explored: *In what ways do collaborating engineering and social sciences researchers use futures, values, systems, and strategic thinking in their EER projects?* The following sections describe the ways of thinking framework, methods, and results. The results are then discussed in the context of current challenges in EER and potential use in informing future research practices.

II. WAYS OF THINKING FRAMEWORK AND LITERATURE

The term *ways of thinking* is often associated with a systematic thought process (Sousa, 2016). Different ways of thinking facilitate different strategies and subsequent actions to innovate. The definition of ways of thinking used by different fields varies depending on the context. For example, the field of learning sciences considers ways of thinking as an approach to solving complex problems through coherent patterns in reasoning (Harel & Sowder, 2005). Business and finance view ways of thinking as combination of intuition and rules that inform decisions (Douglas, 2000). Sustainability education equates ways of thinking to a lens that addresses complex challenges regarding sustainability literacy (Warren et al., 2014). This study operationalizes ways of thinking as a systematic thought process that informs decision-making to address complex engineering education challenges. It is not a heuristic, but rather an approach used by researchers to think, act, and engage with their research. More specifically, the study is guided by the Framework for Applying Ways of Thinking in Engineering Education Research (FAWTEER), that proposed four ways of thinking including futures, values, systems, and strategic thinking to address complex engineering education challenges (Dalal et al., 2021).

Futures thinking focuses on working to address tomorrow's problems today with anticipatory approaches to understand and prepare for future changes, problems, and solutions (Dalal et al., 2023). Values thinking is about recognizing the concepts of ethics, equity, and social justice (Warren et al., 2014). It involves understanding these concepts in the context of varying cultures and accordingly making decisions. Systems thinking involves considering holistic approaches to problem-solving that understand and analyze the complexity of various elements and their interrelationships in the overall ecosystem (McKenna et al., 2014). Strategic thinking is the ability to create a plan of action to achieve the desired vision and act upon the other ways of thinking (Wiek et al., 2011).

Futures, values, systems, and strategic thinking can be implemented in conjunction with one another or used individually depending on the problem under consideration. When used in a networked fashion, they link topics that may seem disconnected and build capacity problem solving capacity with respect to complex engineering education challenges. This study was designed to better understand how these four ways of thinking are used by engineering education researchers in collaborative EER.

III. METHODS

A. Instrument Development

The survey instrument was developed through iterative construction and validation over a three-month period. The survey included Likert scale items to measure importance of various activities associated with different ways of thinking as well as open-ended items focused on examples of ways of thinking enactments. Discussion of the Likert-scale items and scale results are outside the scope of this study. This study is focused on the analysis and results of the open-ended items for understanding how different ways of thinking are applied in collaborative EER projects.

The open-ended items asked participants the following questions: i) In your [NSF Award Name] project, do you believe you have used futures thinking? [yes, maybe, no] ii) If yes, please describe an example from your [NSF Award Name] project that you believe involved futures thinking. iii) If maybe, please describe an example from your [NSF Award Name] project that you think may have involved futures thinking. iv) If no, why do you think you have not? These questions repeated for values, systems, and strategic thinking. A definition of the specific way of thinking was provided before the questions for clarity. The instrument was validated through expert reviews and think aloud pilot sessions (Dalal & Carberry, 2019).

B. Sample and Participants

The potential survey participants were selected from among awardees listed in the public database on the NSF website (https://www.nsf.gov/awardsearch). The database search was limited to one specific programs within the Division of Engineering Education and Centers that stated a required collaboration with a social scientist and the goal of designing revolutionary novel approaches to engineering education. Listserv created within the program was also used to reach other researchers who may not be listed on the NSF site.

A total population of 84 researchers resulted from these processes who were asked to participate in the survey. We received 48 responses (57% response rate) which included 25% researchers from engineering disciplines, 18% from social sciences, 42% from both including engineering education, and 15% did not disclose their discipline.

C. Data Collection & Analysis

The survey was deployed over a five-week period in October and November 2018 using the Tailored Design Method (Dillman et al., 2014) of web-based surveys for attaining higher response rates. A pre-notification was sent three days ahead of the survey link. Three reminders were sent once a week while the survey was open to increase the response rate.

The scope of this study is limited to the open-ended survey responses which were analyzed qualitatively for thematic analysis. coded inductively by the study team following procedures recommended by Saldaña (2009). First-order

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coding followed the inductive, open coding method (Corbin & Strauss, 2015). Second-order, axial coding was then used to understand the relationship among the previously identified open codes, informed by FAWTEER and focusing on a specific way of thinking. Finally, open codes, and second-order codes were configured into themes to answer the research question.

IV. RESULTS

Table 1 captures the responses to the survey questions: *I*n your *[NSF Award Name]* project, do you believe you have used futures/vales/systems/strategic thinking? *[no, maybe, yes]*

TABLE I
SUMMARY OF USE OF A SPECIFIC WAY OF THINKING

Use	Futures Thinking	Values Thinking	Systems Thinking	Strategic Thinking
Yes	22	30	31	30
Maybe	13	8	6	5
No	6	4	3	4
N/A	7	6	8	9

Qualitative results are presented for each ways of thinking with relevant themes and illustrative text in a narrative synthesis and Table 2. Participant quotations are embedded in the narrative as evidence and to enhance contextual understanding.

A. Futures Thinking

Futures thinking in EER emerged as a multi-dimensional approach, encompassing themes that drive innovation and transformation in the field. Two major themes included workforce development and pedagogical innovation. Participants seemed acutely aware of the need to equip students with skills and knowledge that will not only serve them well in their current academic pursuits but also make them agile and adaptable professionals for the ever-evolving job market. As one participant aptly put it,

> "All of our innovations are oriented toward producing engineers that are appropriate for the changing social and economic system."

This sentiment underscores the driving force behind the efforts to prepare students as future-ready engineers not only possessing technical expertise but also as individuals who understand the broader societal implications of their work.

The second pivotal theme in the application of futures thinking in EER centered around pedagogical innovation. Participants wrote about reimagining engineering education by incorporating novel approaches to teaching and learning. These approaches extended beyond traditional disciplinary boundaries, encouraging students to think holistically and consider the broader contexts in which their engineering work would take place. Innovative teaching methods such as technical writing in a cross-disciplinary way, active learning, sustainability topics, and the incorporation of future-focused content like fairness in algorithms were mentioned in the survey responses. A few participant responses (*n*=6) also highlighted the need for engineering faculty professional development for pedagogical innovation. Those who stated not using futures thinking (*n*=6) indicated that "it was not relevant to the grant" or "Never heard of it before."

TABLE 2
RESULTING THEMES FOR WAYS OF THINKING

	Theme	Illustrative Quote
Futures thinking	Workforce development	"…doing lots of research into trends in the field and what future employment looks like."
	Pedagogical innovation	"We are encouraging faculty participants to think about a future state of pedagogical innovation for their teaching in the classroom."
Values thinking	Diversity, equity, and inclusion	"We are trying to change the department culture to value students who might come into the program with different professional goals than our current "typical" student (or at least, what the faculty consider to be the typical student)."
	Social justice in engineering education	"…revamping the curriculum […] addressing social justice and empathy as a key factor of design."
Systems thinking	Holistic approach	"Holism is core to our research perspective. Our research questions, data, and publications reflect the engineering school's past-present-future worldview and activities, as well as the context of the engineering school within the broader university setting and academia generally."
	Weaving a tapestry	"We are developing vertical integration of topics…across the curriculum in close collaboration with industry partners. The goal is to change the culture in the field."
Strategic thinking	Project management	"We are always thinking strategically to get the best outcome and optimize our effort. We also think carefully about personnel and how to get the right people to fulfill the right roles."
	Collaboration and stakeholder engagement	"A needs assessment is being conducted that includes the voices from faculty, students, [PROJECT NAME] team, and external stakeholders to identify program strengths and areas for improvement."
	Adaptation and continuous improvement	"We are continuously revisiting and refining our project plan with all team members to ensure that we reach our goals and consider alternative solutions when we meet road blocks."

B. Values Thinking

Two themes of diversity, equity, and inclusion (DEI) and social justice in engineering education emerged from the survey

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data on values thinking examples. The majority of the statements covered examples wherein values thinking was enacted in relation to the concepts of DEI. Enactment examples included faculty and project teams actively engaged in creating environments where participants can authentically express themselves and feel valued for their uniqueness. This statement below coneys the emphasis on DEI:

> "Our aim is to create more inclusive learning and work environments where participants feel both connected and are valued for being their authentic self."

This commitment also extended to students, with a strong emphasis on ensuring that the learning experience was inclusive and considered diversity and equity as evident from the following statement,

> "We have extensively discussed what the values of our department are, how to best serve all of our students, with equity in mind, not just equality. We are mindful of the different cultures present on our campus and are working to create a feeling of inclusiveness in all of our students."

Another aspect of values thinking focused on social justice in engineering education. This emergent theme illuminated that for the participants the curricular focus was not solely on technical knowledge but also on fostering graduates who are socially conscious, responsible global citizens. One participant highlighted this by writing,

> "Our project explicitly includes finding ways to include discussions of social justice in engineering classes. That meant that we talked about the scope of the topics that we thought could be included and the kinds of issues we might like to see addressed through values thinking."

Overall, the values thinking examples underscore the importance of not only technical knowledge but also the broader societal and ethical dimensions of engineering education. Those who stated not using values thinking (n=4) indicated that it was not part of the scope of what they were trying to accomplish.

C. Systems Thinking

Two themes of holistic approach and weaving a tapestry emerged from the survey data on systems thinking examples. Participants emphasized the importance of taking a holistic approach to engineering education reform. This involves considering the entire ecosystem of engineering education, including curriculum, faculty, students, and the broader institutional context as evident from this statement:

> "Our approach to achieving the goals of the project is holistic and multipronged - for example, we provide direct support to students, integrate new content in classes, provide faculty development for inclusive pedagogy, partner with other colleges to leverage expertise, establish seed funding grants to bring in more faculty, and are developing a certificate program that counts toward T&P."

Several participants (n=9) specifically mentioned the application of systems thinking in the redesign of engineering curricula. They emphasized the importance of considering how changes in curriculum affect students, faculty, departments, colleges, and the university as a whole. One participant noted:

> "During new curriculum development, we considered the impact on the students, department, college, university, and we involved faculty, students, staff, and faculty from other departments in the development."

Participants also emphasized the value of working with different departments, faculty members, and external industry partners to weave a tapestry and bring synergy and alignment in the engineering education initiatives using systems thinking. One participant mentioned,

> "We are developing a new degree (BA in CS with a minor in education) that has resulted from a systems thinking approach and involvement of folks: teachers, HE educators, researchers, non-profits, industry..."

Multiple participants (n=7) mentioned considering institutional context and goals and aligning their research goals accordingly to bring synergy and potentially greater impact. Overall, the examples of systems thinking highlighted the interconnectedness of different elements within the system and the need to address multiple aspects of engineering education simultaneously to bring about comprehensive change. Those who stated not using systems thinking (n=3) indicated that the work was just starting, and they would know better about systems thinking later.

D. Strategic Thinking

Three themes of project management, collaboration and stakeholder engagement, and adaptation and continuous improvement emerged from the survey data on strategic thinking examples. Project management was a prevalent theme in the responses highlighting the importance of careful planning and strategic resource allocation to achieve project goals. Participants described the need to set clear objectives, develop timelines, and allocate resources effectively to overcome project implementation challenges. A few statements below capture the emphasis on planning with strategic thinking:

> "We have made attempts to set goals and timelines...we need to do more of this to be optimally effective."
>
> "We created a logic model...planned how to intervene in our curriculum...creating a communication plan...to carry out the planned work."
>
> "Curriculum and program changes that affect and depend upon multiple factor such as human resources, funding, space and lab resources …"

One participant mentioned teaching project planning to students by embedding strategic thinking in the curriculum.

Collaboration and engagement with stakeholders, both within and outside the department or institution, were highlighted as key aspects of strategic thinking. Respondents stressed the importance of involving key offices, faculty, staff, and students strategically to garner support and drive change:

> "We have worked hard to ensure that the project is not viewed as a disciplinary endeavour...members were

chosen strategically to ensure participation by key offices."

This also involved a needs assessment involving all stakeholders as evident from the following quotation: "A needs assessment is being conducted...to identify program strengths and areas for improvement."

Collaboration and engagement with stakeholders also covered thinking strategically about scaling up and sustaining the impact in the future. While this theme is similar to the theme of weaving a tapestry under systems thinking, there are nuances. Systems thinking about collaborations with industry and other departments was about bringing in alignment and synergy in the engineering education efforts, whereas strategically thinking about collaborations was more about long term sustainability of initiatives that aim to transform engineering education.

Participants also emphasized the need for adaptability and continuous improvement in strategic thinking. They mentioned the importance of revisiting and refining project plans, monitoring progress, and adjusting strategies based on changing circumstances and stakeholder feedback:

"We are always thinking strategically...carefully about personnel (and personalities) and how to get the right people to fulfill the right roles."

"Looking back at goals in proposal and checking to see where we are...checking in with stakeholders' views vs. our own."

A few participants (n=4) mentioned that strategic thinking encapsulated everything as "This is central to our five-year project that we hope will lead to permanent change." Overall, the survey responses highlighted the application of strategic thinking in EER through planning and resource allocation, collaboration and stakeholder engagement, and a focus on adaptability and continuous improvement. Some of those who stated not using strategic thinking (n=4) stated: "While [we] see the importance of strategic thinking, we have not applied this approach well."

V. DISCUSSION

In the realm of (EER), the adoption of multifaceted thinking approaches plays a crucial role in addressing complex challenges and fostering innovation (JEE 2006; Dalal et al., 2023). Four distinctive ways of thinking—futures, values, systems, and strategic thinking—have been identified as integral components of EER, each offering unique perspectives and methodologies (Dalal et al., 2021). This discussion explores the emergent themes within each of these thinking approaches and underscores their interplay in the pursuit of advancing engineering education.

Futures thinking in EER encourages scholars to explore uncharted territories, anticipate evolving trends, and embrace uncertainty (Warren et al., 2014). The emergent themes underscore the importance of preparing the future workforce and innovation. Participants in our survey emphasized the significance of staying attuned to technological and social advancements and emerging pedagogical paradigms to prepare future-ready engineers. Futures thinking in EER embodies the spirit of proactivity, acknowledging that the engineering landscape is constantly evolving (Dalal & Carberry, 2018). By incorporating this perspective, educators and researchers can proactively anticipate shifts in the engineering field, align curricula with emerging needs, and prepare students to thrive in a rapidly changing environment.

Findings for Values thinking illuminate the moral compass that guides EER endeavors. Participants in our survey emphasized the importance of embedding shared values, such as inclusivity, social justice, and diversity, into the fabric of engineering education. These values often serve as guiding principles for curriculum design, faculty development, and decision-making processes. The emergent themes within values thinking underscore the commitment of educational stakeholders to create inclusive and equitable learning environments. By prioritizing values such as social justice and DEI, engineering education can become a more holistic and empathetic endeavor, instilling these principles in the next generation of engineers (Leydens & Lucena, 2017; Swan et al., 2014).

Systems thinking in EER fosters a holistic understanding of educational ecosystems (McKenna et al., 2014). Participants stressed the importance of recognizing the interdependencies between various components of the engineering education system. Participants also recognized the interconnectedness of educational institutions and stakeholders. Systems thinking encourages a shift from isolated problem-solving to systemic change, facilitating a more comprehensive approach to addressing persistent challenges. By considering the broader context in which engineering education operates, researchers and educators can develop interventions that create cascading effects and leverage sub-systems to drive change.

Strategic thinking in EER emphasizes deliberate planning, resource allocation, and stakeholder engagement (Wiek et al., 2011). Survey participants stressed the importance of setting clear objectives, developing timelines, and collaborating strategically with key offices, faculty, staff, and students. The emergent themes within strategic thinking underscore the need for structured planning and the flexibility to adjust strategies in response to changing circumstances. By adopting a strategic approach, researchers and educators can enhance the efficiency and efficacy of interventions aimed at improving engineering education. Strategic thinking also extends to sustainability planning, ensuring that the impact of initiatives endures beyond the project's duration.

While each of these thinking approaches—futures, values, systems, and strategic thinking—bring its unique strengths to the field of engineering education research, they are not mutually exclusive. Instead, they complement and enrich one another. For instance, values thinking informs the ethical underpinnings of strategic planning, ensuring that educational strategies align with overarching principles of inclusivity and social justice. Systems thinking, on the other hand, aids in the

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identification of strategic partners and key stakeholders whose collaboration is essential for implementing meaningful change.

Our purpose in sharing these results, particularly from one specific program, was to show how cross-disciplinary partnerships and ways of thinking could cross-fertilize ideas that work broadly to bring a cultural change in engineering education. Prior studies have concluded that when professionals from different disciplines come together for a common goal, they often deconstruct traditional disciplinary ways of thinking, change their beliefs, values, and attitudes, and "assimilate new ways of thinking into new approaches to practice" (Borrego & Newswander, 2008; Frodeman et al., 2010; McCallin, 2004, p. 38). The need for re-conceptualizing how we think about engineering education necessitates research that identifies novel ways of thinking and how they are applied. It was also surprising to see statements that indicated not using strategic or values thinking or not knowing about futures thinking. Such statements further highlight the need to create awareness about ways of thinking and their explicit use in EER endeavors.

It should be noted that the study's sample size was limited to one particular NSF award and hence small. The scope of the qualitative study was intentionally limited to get a preliminary sense and deepen our understanding of the futures, values, systems, and strategic ways of thinking used in EER projects. This effort to qualitatively assess ways of thinking was not intended for generalizability. With the initial findings on hand, future research could explore each way of thinking in further detail through broader surveys. We intentionally refrained from collecting gender data from participants for this study believing that this demographic would not likely have an impact on responses. Future research could investigate differences in ways of thinking among various groups (e.g., experience, gender, or discipline). Replication of this empirical investigation with other samples would help strengthen the evaluation of futures, values, systems, and strategic thinking for EER in different contexts.

We believe this study contributes to the broader conversation on transforming engineering education through a ways of thinking lens. Results highlight how futures, values, systems, and strategic thinking are enacted in EER and influence engineering education practice. Integration of thinking approaches equips researchers and educators with a comprehensive toolkit to effect positive change in engineering education.

VI. CONCLUSION

In conclusion, the four ways of thinking—futures, values, systems, and strategic thinking—play pivotal roles in shaping the trajectory of engineering education research. These thinking approaches, when integrated and applied purposefully, empower stakeholders to anticipate, address, and transcend the complex challenges facing the field, ultimately advancing engineering education in response to the evolving needs of society. As the field continues to evolve, the fusion of these thinking approaches will remain instrumental in fostering innovation and promoting inclusivity in engineering education.

REFERENCES

Creswell, J. W. (2012). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (4th ed). Pearson.

Crouch, C. H., & Mazur, E. (2001). Peer Instruction: Ten years of experience and results. American Journal of Physics, 69(9), 970–977.

Esakia, A., & McCrickard, D. S. (2016). An adaptable model for teaching mobile app development. 2016 IEEE Frontiers in Education Conference (FIE), 1–9.

Fellah, A., & Bandi, A. (2018). The Essence of Recursion: Reduction, Delegation, and Visualization. Journal of Computing Sciences in Colleges, 33(5), 115–123.

Guzdial, M., & du Boulay, B. (2019). The History of Computing Education Research. In S. A. Fincher & A. V. Robins (Eds.), The Cambridge Handbook of Computing Education Research (1st ed., pp. 11–39). Cambridge University Press.

American Society for Engineering Education (ASEE). (2014). Transforming undergraduate education in engineering (TUEE) phase I: Synthesizing and integrating Industry perspectives. American Society for Engineering Education, Arlington, VA.

Borrego, M., & Newswander, L. K. (2008). Characteristics of successful cross-disciplinary engineering education collaborations. Journal of Engineering Education, 97(2), 123-134.

Carr, G., Blanch, A. R., Blaschke, A. P., Brouwer, R., Bucher, C., Farnleitner, A. H., … Blöschl, G. (2017). Emerging outcomes from a cross-disciplinary doctoral programme on water resource systems. Water Policy, 19(3), 463–478. http://doi.org/10.2166/wp.2017.054

Corbin, J., & Strauss, A. (2015). Basics of qualitative research, (4th ed.). Los Angeles: Sage.

Dalal, M. & Carberry, A. (2018). Work in progress: 'ways of thinking' of interdisciplinary collaborators. Proceedings of the 2018 American Society for Engineering Education (ASEE) Annual Conference & Exposition, Salt Lake City, UT. doi: 10.18260/1-2—31317

Dalal, M. & Carberry, A. (2019). Work in progress: Exploring 'ways of thinking' of interdisciplinary collaborators. Proceedings of the 2019 American Society for Engineering Education (ASEE) Annual Conference & Exposition. Tampa, FL. https://doi.org/10.18260/1-2--33614

Dalal, M., Carberry, A. & Archambault, L. (2021). Developing a ways of thinking framework for engineering education research. Studies in Engineering Education, 1(2), 108-125. https://doi.org/10.21061/see.38

Dalal, M., Carberry, A., & Archambault, L. (2023). Exploring the use of futures, values, systems, and strategic thinking among engineering education research collaborators. Journal of Engineering Education, 112(2) 382-402. https://doi.org/10.1002/jee.20511

Dalal, M., Larson, J., Zapata, C., Savenye, W., Hamdan, N. & Kavazanjian, E. (2017). An interdisciplinary approach to developing an undergraduate module on biogeotechnical

engineering. In Proceedings of Society for Information Technology & Teacher Education International Conference 2017 (pp. 2074-2079), Chesapeake, VA: Association for the Advancement of Computing in Education (AACE).

Dillman, D. A., Smyth, J. D., & Christian, L. M. (2014). Internet, phone, mail, and mixed-mode surveys: the tailored design method. 4th Ed. Hoboken, NJ: Wiley & Sons

Douglas, M. J. (2000). Trading in the zone: master the market with confidence, discipline and a winning attitude. Paramus, NJ: New York Institute of Finance.

Frodeman, R., Klein, J. T., & Mitcham, C. (Eds.). (2010). The Oxford handbook of interdisciplinarity. Oxford University Press.

Harel, G., & Sowder, L. (2005). Advanced mathematical-thinking at any age: Its nature and its development. Mathematical Thinking and Learning, 7(1), 27-50.

Journal of Engineering Education. (2006). Special report: The research agenda for the new discipline of engineering education. Journal of Engineering Education, 95(4), 259-261.

Leydens, J. A., & Lucena, J. C. (2017). Engineering justice: Transforming engineering education and practice. Hoboken, NJ: John Wiley & Sons.

McCallin, A. (2004). Pluralistic dialoguing: A theory of interdisciplinary teamworking. The Grounded Theory Review, 4(1), 25-42.

McKenna, A. F., Froyd, J., & Litzinger, T. (2014). The complexities of transforming engineering higher education: Preparing for next steps. Journal of Engineering Education, 103(2), 188–192. http://doi.org/10.1002/jee.20039

McKenna, A. F., Yalvac, B. & Light, G. J. (2009). The role of collaborative reflection on shaping engineering faculty teaching approaches. Journal of Engineering Education, 98(1), 17-26.

National Science Foundation. (2017). PFE: Research initiation in engineering formation (PFE: RIEF) Retrieved from https://www.nsf.gov/pubs/2017/nsf17514/nsf17514.pdf

Olds, B.M., B.M. Moskal, & R.L. Miller. (2005). Assessment in engineering education: Evolution, approaches and future collaborations. Journal of Engineering Education 94(1), 13-25.

Saldaňa, J. (2009). The coding manual for qualitative researchers. London, UK: SAGE Publications Ltd.

Sousa, D. A. (2016). How the brain learns (5th ed). Singapore: Sage Publications Asia-Pacific Pte. Ltd.

Swan, C., Paterson, K., & Bielefeldt, A. R. (2014). Community engagement in engineering education as a way to increase inclusiveness. In Johri, A., & Olds, B. M. (Eds.). Cambridge handbook of engineering education research (pp 357-372). New York, NY: Cambridge University Press.

Wankat, P. C., Felder, R. M., Smith, K. A., & Oreovicz, F. S. (2002). The scholarship of teaching and learning in engineering. In Huber and Morrealle (Eds), Disciplinary styles in the scholarship of teaching and learning: Exploring common ground (pp 217-238), Washington, D.C.: AAHE publications.

Warren, A., Archambault, L., & Foley, R. W. (2014). Sustainability education framework for teachers: Developing sustainability literacy through futures, values, systems, and strategic thinking. The Journal of Sustainability Education, 6(1), 1-14.

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. Sustainability Science, 6(2), 203-218.

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