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ORIGINAL ARTICLE

Identifying and framing potential stakeholders in complex innovation ecosystems

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ABSTRACT

Analysing the types and connections to stakeholders may be daunting for engineering students. Creating stakeholder maps can be scaffolded through prompting for different stakeholder roles, which students may use as a starting point. Drawing from 31 student stakeholder analyses, this case study explores students' ability to identify different types of stakeholders and the range of roles they could play, when provided with a set of stakeholder roles as a point of departure. Students were able to identify a diverse range of stakeholders as well as the multiplicity of stakeholder roles. The role prompting resulted in 36 unique stakeholders and 63 stakeholders identified by multiple students, particularly in customer, supplier, and possible collaborator roles. As such, combining individual, scaffolded mappings can help to capture innovation ecosystems more systematically and illuminate more diverse collaboration opportunities in development projects.

Keywords: Engineering innovation; framing; scaffolding; stakeholder mapping.

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INTRODUCTION

Building socially driven empathetic capacity during mechanical engineering education allows students to better understand the needs, desires, and limitations of the end-users (Walther, Miller & Sochacka 2017), while also potentially improving their instrumental contribution to the stakeholder partnership (Bridoux & Stoelhorst 2016). By understanding different user groups and their diverse backgrounds, engineers can design solutions that are more inclusive, accessible, and accommodate a wide range of user abilities. Understanding diverse user groups is also a precondition for developing stakeholders' engagement and cooperation (Jones et al., 2018). Stakeholder partnerships benefit from a clear understanding of roles and their implications, which can be explored through perspective taking. As such, it is important to not only define characteristics of the stakeholders, such as the interest and power dimensions captured in traditional stakeholder mapping (Boonstra & de Vries 2008), but also the different capacities through which stakeholders connect to a sought-after end goal (Freeman et al., 2018).

Understanding the roles that stakeholders can play in development provides an opportunity to construct a more holistic mapping of the stakeholder ecosystem, including for example non-human stakeholders (Tallberg, García-Rosell & Haanpää 2022). The nature of non-human stakeholders could be artificial, such as technologies, or natural (Veselova, Gaziulusoy & Lohmann 2022). Acknowledging natural non-human stakeholders, such as fauna and flora, or even entire natural ecosystems, supports sustainable development (Beck & Ferasso 2023). Better understanding of the stakeholders and context of engineering innovation, in turn, can support shifting from more traditional solution-based engineering education to a more collaborative, human-centred innovation process (Kojmane & Aboutajeddine 2016; Zoltowski, Oakes & Cardella 2012). The purpose of the study was to explore the scope and multiplicity of stakeholder connections identified through role-based stakeholder analysis in the context of an engineering course. A broader and more connected understanding of relevant stakeholders supports the recognition of collaborative complexities, the multiplicity of stakeholder connections and opportunities within these for design and development,

THEORETICAL BACKGROUND

Balancing task complexity in engineering education is central to maximising the learning outcomes for students through supportive facilitation (Glazewski & Hmelo-Silver 2019). Scaffolding is a multifaceted method that can be used in capacity building for the benefit of students through the provision of a facilitated or methodological support structure that enables a higher level of task competence (Jordan, 2014; Andersson 2015). Scaffolding can refer to a range of interventions and support mechanisms; including technical assignment support, giving students strategies and advice on project completion, demonstrations of tasks or skills, visualisations, and discussion to enhance understanding within a problem-solving process, and finally prompts used by the class facilitator to support thinking and exploration (Pitkänen, Iwata, & Laru 2019). Here, instructors identify boundary conditions that effectively limit the scope of potential complexity for students (Andersson 2015; Kim, Vincentini & Belland 2022). Scaffolding students' cognitive space associated with a task can be particularly beneficial when navigating open-ended assignments, for example involving diverse stakeholders and complex tasks (Andersson 2015; Van den Beemt 2020). The examples and models provided through scaffolding efforts are important early on, in performing tasks due to their role in guiding students' attention (Dasgupta 2019; Schmidt, Rotgans & Yew 2019). These scaffolds can be classified as "soft" or "hard", with soft scaffolds referring to in the moment explicit guidance in a task, classroom dialogue, or conceptual framing, for example (Ertmer & Glazewski 2019). Here, task complexity can be reduced through situation specific guidance regarding content, for example using definitions of a discipline or field (Atkinson, Derry, Renkl & Wortham 2000). Instructors can also model how to approach or complete the problem, allowing for students to compare their personal process to the one modelled for them, which provides a path on which to travel in one's own way (Schmidt, Rotgans & Yew 2019). As such, the use of soft scaffolds in the form of examples and analogies can be used as initiators in the early stages of the learning process where informed decision making through exploration is sought (Anderson, Fincham & Douglass 1997).

On the other hand, hard scaffolds can also be leveraged in education, whether paper or technology based using fixed definitions, conceptual descriptions, or behavioural limits (Ertmer & Glazewski 2019). Hard scaffolds can take many forms in the instructional setting, such as a computer-based platform for collaboration and negotiation like that created by Choi, Land and Turgeon (2015) with predetermined question categories to facilitate meaningful questions among students. Or, scaffolds can be paper-based as in the case of design diaries (Puntambekar & Kolodner 2005). In engineering education, physical models have been also used to help students practise engineering design productively (Dasgupta 2019). Overall, the diversity of scaffolds, particularly in the case of science education, have been shown to be valuable in their support of information literacy, argumentation proficiency and productive task engagement (Kim, Vintentiini & Belland 2022; Andersson 2015; Schmidt, Rotgans & Yew 2019).

METHODS AND DATA

To explore the diversity of stakeholders connected to engineering innovation as well as the diversity of roles that a single stakeholder can be seen as playing, first year master's level mechanical engineering students were tasked with a role-based stakeholder analysis of a healthcare technology under development facilitated by a definition based conceptual scaffolding.

The healthcare technology case and scenario

Students engaged with a diagnostic technology case that aims to bring the detection and study of pathogen infections and diseases closer to point-of-care to make healthcare more efficient. The context of the case was a future of healthcare which is connected to, and leveraging appropriate technologies (Dang, Arora & Rane 2020; Khan & Mir 2021; Qadri et al. 2020). The socio-technical nature of the healthcare case, which brings together the human experience and the potential of technology, enhances the complexity of the use scenarios. These scenarios allowed for the review of a plethora of potential stakeholders and thus presented a suitable case for students to explore. Central to the guiding principle of the case task, innovation requires framing the use and implication of emerging technologies in different contexts and recognition of the perspectives of multiple stakeholders and their motivations. The scope of emerging stakeholder ecosystems within this context is broad and dynamic, presenting a challenging learning experience for engineering students and appropriate case context for exploring scaffolded stakeholder identification.

Data collection and analysis

Students were introduced to the concept of stakeholder mapping as a conceptual hard scaffold to support their understanding of the process and the terminology associated with stakeholder analysis. Students were supplied a 2-page case introduction, generated by the technology developers, after which they were tasked to explore the types and role of stakeholders in relation to the point-of-care diagnostic technology. An in-depth case introduction was avoided to lessen potential bias towards stakeholders mentioned during a formal case introduction. Completed stakeholder analyses were submitted by n=31 students (P1-P31).

Stakeholder roles were used to conceptually scaffold the activity and support student exploration through guiding attention and managing complexity with the goal of encouraging engagement with the task. The potential roles (Table 1) communicated to students were stakeholders as beneficiaries, collaborators, competitors, customers, hostiles, suppliers, and supporters. The customer, supplier, collaborator, and supporter roles were drawn from a stakeholder mapping tool, originally developed to support identifying co-creation opportunities in the context of a Business Finland funded applied research project to support small-business experimentation during the pandemic. Students were able to assign multiple roles to a single stakeholder and could include additional stakeholders.

Table 1. Conceptual scaffolding: Stakeholder role characteristics

Role	Defining characteristic
Beneficiary	A person or organisation direct and personally benefiting from the existence of the technology and product
Collaborator	A person or organisation playing an active role in developing and/or commercialising the technology and product.
Competitor	A person or organisation with a technology or product which offers (or is planned to offer) the same, or very similar benefits and value thus directly competing for resources and end-users.
Customer	A person or organisation positioned to purchase the product or service once available.
Hostile	A person or organisation perceiving the existence of the technology and product as negative or problematic and would prefer it did not exist.
Supplier	A person or organisation playing an active role in supporting a range of resources to the development and commercialization of the technology and product.
Supporter	A person or organisation perceiving the existence of the technology and product as positive and is willing to offer limited knowledge and input to ensure the technology and product succeeds.

The submitted stakeholder analyses were initially open coded by the first author to identify the types of stakeholders noted and the multiplicity of their roles, using a qualitative data analysis software (Altas.ti) for data management. The most prominent stakeholder groups identified by students and the extent to which students recognized the multiplicity of stakeholder roles within a single case was established through Qualitative Data Analysis (QDA), and the author team discussed and reviewed the coding to reach consensus.

RESULTS

Using the stakeholder roles as a point of departure, students were able to identify a wide array of types of stakeholders (detailed in Appendix A, Supplementary Material). Stakeholders connected to specific roles were associated with an array of types of people and organisations as customers, suppliers, collaborators, competitors, supporters, beneficiaries, and hostiles. The final list of stakeholders (n=99) included both groups of people (such as laboratory technicians, environmentalists, and technophobes) as well as public and private organisations of varying specificity. Stakeholders could be noted in multiple roles, by different students, resulting in n=600 mentions of stakeholders across the maps (Table 2). The nature of the case impacted the identified stakeholders, which were predominantly health and wellbeing related or engineering and technology related. The distribution of stakeholders' roles identified, and relative novelty varied (Table 2) as did the number of students who identified a stakeholder (detailed in Appendix B, Supplementary Material)

The most instances of a stakeholder being identified were commercial entities, industry, and private companies (n=278), followed by types of people (n=131), governmental and public concerns (n=110), non-profit organisations (n=31), academia (n=30), private institutes (n=9), the natural world (n=5) and religious institutions (n=2). The emerging themes within the analysis link closely to the context of the case presented. Health and Wellbeing, Engineering and Technology and a series of smaller clusters linked to military activity, research, environmentalism, among others (detailed in Appendix C, Supplementary Material).

Stakeholder roles and types: Health and wellbeing cluster

The Health and Wellbeing cluster represented stakeholders from all roles and from a variety of types. The 3 most common roles are competitors, beneficiaries, and hostiles. The least recognised role for stakeholders within his cluster were as suppliers. In general, identified beneficiaries, competitors and hostiles were clearly mainly health related. When viewed through the lens of multiplicity, the diverse roles of individual stakeholders were apparent across student submissions. Three stakeholders were identified as active within six of the noted seven roles:

- Private medical care and centres were identified as beneficiaries (n=3), collaborators (n=1), competitors (n=5), customers (n=3), hostiles, (n=7) and supporters (n=2).
- National and local government healthcare systems were identified as beneficiaries (n=6), collaborators (n=2), customers (n=3), hostiles (n=1), suppliers (n=1), and supporters (n=4).
- Groups of medical and healthcare professionals were identified as beneficiaries (n=7), collaborators (n=6), competitors (n=2), customers (n=9), hostiles (n=4), and supporters (n=4).

A student (P24) noted the complex relationship patients might have with healthcare innovation. Noting that immunodeficient or chronic patients may be beneficiaries of the technology but may also resist or be hostile towards it:

> If people in such a situation could be tested immediately for even minor symptoms, and get reliable results right away, it would help, because then the disease could be treated immediately, and their chances of survival would be better.
>
> Such individuals resist and have rejected the biomedical way of thinking and do not believe in the importance of medical treatment. The development of new technology and medical innovation would thus be exactly what they abhor...

When analysing students' stakeholder analyses reflective comments were noted, such as a student (P31) who noted the stressors on medical professionals:

> The medical industry has taken a big hit during the past few years and it is a great time to help reform it and to decrease the stress from medical professionals so they can do their best job […] It will not change the system upside down but instead, it will be a small step in the right direction.

Only eight stakeholders in the health and wellbeing cluster were identified in relation to only one of the seven roles, with an average of 2.9 roles per identified stakeholder in the cluster. The cluster contained n=5 unique stakeholder types that were named by only one student. Three of these were companies, one a national healthcare provider and an individual, each of which represented different roles (collaborator, competitor, beneficiary, and a potential hostile).

Table 2. Distribution of stakeholders' roles identified, and relative novelty.

	Health and wellbeing stakeholders			Engineering and technology stakeholders			Other stakeholders			Total across groups		
Prompted stakeholder role	No. of mentions overall	No. of stakeholders identified only in this role	No. of stakeholders identified by only	No. of mentions overall	No. of stakeholders identified only in	No. of stakeholders identified by only	No. of mentions overall	No. of stakeholders identified only in	No. of stakeholders identified by only	No. of mentions overall	No. of stakeholders identified only in	No. of stakeholders identified by only
Beneficiary	51	2	1	2	0	0	20	2	2	73	4	3
Collaborator	27	1	1	20	2	2	43	3	3	90	6	6
Competitor	64	1	1	9	2	2	6	0	0	79	3	3
Customer	33	1	1	9	1	0	64	4	3	106	6	4
Hostile	42	2	1	5	2	2	16	4	5	63	8	8
Supplier	5	0	0	84	9	7	20	0	0	109	9	7
Supporter	32	1	0	2	0	0	46	7	5	80	8	5
Total	**254**	**8**	**5**	**131**	**16**	**13**	**215**	**20**	**18**	**600**	**44**	**36**

Stakeholder roles and types: Engineering and technology cluster

The Engineering and Technology cluster represented less diverse stakeholder roles than noted in Health and Wellbeing. Stakeholders represented mainly suppliers (n=87) or collaborators (n=20) and were most often companies. Within the cluster there were clear groupings of activity, including: materials and technology (e.g., recyclable plastic processes and 3D printing), product components manufacturers, sensors production and testing, data and informatics suppliers, and energy and raw material suppliers. In general, identified suppliers were often technology related, which is understandable given the nature of the case explored and the engineering background of students.

Similar to comments noted in other clusters, students offered insight into their understanding of stakeholders' future intentions. One student (P24) referenced the monitoring of health through the wearable technology offered by companies: "It is a growing trend that we want to know more about our body and the state of our health. The public has grown more interested in health in the past years and this change of perception and interest in our health could be seen as inspirational."

Sixteen stakeholders in the engineering and technology cluster were identified in relation to only one role, with an average of 1.6 roles per identified stakeholder in the cluster. Of the sixteen single role stakeholder n=15 were companies, and the remaining stakeholder was academic. Furthermore, 13 stakeholders were identified by only one student, again all but one representing different types of companies. Suppliers made up half of the stakeholders identified by only one student, with the remaining 7 representing customers, competitors, and hostiles.

Additional stakeholder roles and types

Smaller clusters (collected under *Other*) noted in the analysis represent a range of roles and types. Research institutions and organisations (n=49) were typically identified as collaborators, marine companies, and logistics (n=37) were most often customers, but groups of people within this sector were also noted as possible end-user collaborators, as supporters lobbying for the product's use and as beneficiaries. One student (P28) discussed the different roles sailors could play:

> Workers can also drive change in companies so if the workers for large companies are convinced that they need this type of product to have a better working life in the hard conditions then they can do lobbying towards getting these devices into the company.
>
> …a faster response time to the need of diagnosis can help with workplace safety as people with diseases can be put in quarantine faster, impacting the overall health of the sailors aboard the ship when there is a long way to the nearest treatment centres and medical professionals.

Private financiers and funding bodies (n=23) were viewed as supporters. Environmentalists and sustainability references (n=23) and military and crisis organisations (n=17) formed clusters that included customers, collaborators, supporters.

The remaining cluster of stakeholders contained n=18 stakeholders identified by only one student, of which the most prominent types were five different types of people, four companies and corporations, and three government agencies. In total, 20 stakeholders outside of the health and technology clusters were identified in relation to only one role, with an average of 1.9 roles per identified stakeholder in the cluster.

DISCUSSION AND CONCLUSIONS

The findings reveal that students were able to identify a range of potentially relevant stakeholders to consider in development. However, the role-based analysis also revealed opportunities for additional hard scaffolding to support considering social and sustainable impact. Diverse actor types were recognized as stakeholders, typically in relation to more than one potential role, which can create a basis to reframe the challenge from the role perspective of a single stakeholder. On the other hand, particularly the roles of supporters, suppliers and hostiles resulted in identifying several unique stakeholders, helping to broaden the range of stakeholders considered as potentially relevant in the engineering innovation case. Furthermore, a third of the identified stakeholders were identified by up only one of the 31 students, emphasising the value of combining individual perspectives and multiple prompts for a more holistic understanding.

Exploratory soft scaffolding in tasks involving role identification could be used in the development of improved hard conceptual role scaffolds for broader implementation in the future. As an extension, research comparing the variety of stakeholders in role-prompted and unprompted stakeholder maps is needed to further assess the benefits of scaffolding. Ultimately, the goal is to support students in identifying and considering a broader range of stakeholders to make informed choices, with scaffolds designed to prompt exploration of diverse considerations. However, such scaffolds need to be carefully designed to avoid fixation that would limit rather than expand student considerations (Vasconcelos & Crilly 2016).

Findings in this study are limited to a small group of students working on a single case, and suitability of role prompting in different study contexts should be explored. The approach does however not require specialised materials and allows students the opportunity to identify stakeholder from their own analysis. The implementation of the approach across student groups and disciplines, irrespective of demographics, location, or educational resources, is thus possible. This presents an opportunity for educators across disciplines to leverage a role-based exploration as potential scaffolding for stakeholder related assignments or exercises. In subsequent development cycles a more formalised method, grounded in the initial insights from this study and additional research, is planned as an open-source toolkit.

Finally, the intentions, values and goals linked to different roles offer central bonding points for successful reciprocity in potential development collaborations (Freeman, Phillips & Sisodie 2018; Jones, Harrison & Felps 2018), a next step which initial mapping should facilitate. As such, future studies should examine how readily stakeholder identification translates into collaboration intentions. While the current study suggests that prompting for a variety of roles can offer a starting point for considering different frames into an innovation ecosystem, the ultimate goal of helping to identify a broad range of stakeholders is to be able to broaden the range of needs and perspectives included in engineering innovation decision making. While the current study utilised a practice-based mapping tool as the scaffold, research-based stakeholder role categories could be developed to further support identifying collaboration opportunities in industry. In practice this may present research and development practitioners with the ability to map their stakeholder network and identify possible collaborators or partners more holistically.

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SUPPLEMENTARY MATERIALS

Full stakeholder lists and thematic grouping of stakeholders available as supplementary documentation.

REFERENCES

Anderson, J.R., Fincham, J.M. & Douglass, S., 1997, The role of examples and rules in the acquisition of a cognitive skill, Journal of experimental psychology: learning, memory, and cognition, 23(4): 932. https://doi.org/10.1037/0278-7393.23.4.932

Andersson, P., 2015, Scaffolding of task complexity awareness and its impact on actions and learning. ALAR: Action Learning and Action Research Journal, 21(1): 124-147. https://alarj.alarassociation.org/index.php/alarj/article/view/148

Atkinson, R.K., Derry, S.J., Renkl, A. & Wortham, D., 2000, Learning from examples: Instructional principles from the worked examples research. Review of Educational Research, 70(2): 181-214. https://doi.org/10.3102/00346543070002181

Beck, D., Ferasso, M., 2023, Bridging 'stakeholder value creation' and 'urban sustainability': the need for better integrating the environmental dimension. Sustainable Cities and Society, 89: 104316. https://doi.org/10.1016/j.scs.2022.104316

Boonstra, A. & de Vries, J., 2008, Managing stakeholders around inter-organizational systems: A diagnostic approach. The Journal of Strategic Information Systems, 17(3): 190-201. https://doi.org/10.1016/j.jsis.2008.04.001

Choi, I., Land, S.M. & Turgeon, A.J., 2005, Scaffolding peer-questioning strategies to facilitate metacognition during online small group discussion. Instructional Science, 33: 483-511. https://doi.org/10.1007/s11251-005-1277-4

Dang, A., Arora, D. & Rane, P., 2020, Role of digital therapeutics and the changing future of healthcare. Journal of Family Medicine and Primary Care, 9(5): 2207-2213. https://doi.org/10.4103%2Fjfmpc.jfmpc_105_20

Dasgupta, C., 2019, Improvable models as scaffolds for promoting productive disciplinary engagement in an engineering design activity. Journal of Engineering Education, 108(3): 394-417. https://doi.org/10.1002/jee.20282

Ertmer, P.A. & Glazewski, K.D., 2019, Scaffolding in PBL environments: Structuring and problematizing relevant task features. The Wiley Handbook of Problem-Based Learning, pp.321-342. https://doi.org/10.1002/9781119173243.ch14

Glazewski, K.D. & Hmelo-Silver, C.E., 2019, Scaffolding and supporting use of information for ambitious learning practices. Information and Learning Sciences, 120(1/2): 39-58. https://doi.org/10.1108/ILS-08-2018-0087

Jordan, T., 2016, Deliberative Methods for Complex Issues: A typology of functions that may need scaffolding. Group Facilitation: A Research & Applications Journal, 13, pp.57-78.

Khan, A. & Mir, M.S., 2021, E Health and M Health: Future of healthcare. Journal of Anatomy & Physiology 2(3): 38-41. https://doi.org/10.26717/BJSTR.2021.36.005864

Kim, N.J., Vicentini, C.R. & Belland, B.R., 2022, Influence of scaffolding on information literacy and argumentation skills in virtual field trips and problem-based learning for scientific problem solving. International Journal of Science and Mathematics Education, pp.1-22. https://doi.org/10.1007/s10763-020-10145-y

Kojmane, J. & Aboutajeddine, A., 2016, Strengthening engineering design skills of first-year university students under resources constraints. International Journal of Mechanical Engineering Education, 44(2), pp.148-164. https://doi.org/10.1177/0306419016641006

Pitkänen, K., Iwata, M., & Laru, J., 2019, Supporting Fab Lab facilitators to develop pedagogical practices to improve learning in digital fabrication activities. In: Proceedings of the FabLearn Europe 2019 Conference, pp. 1-9. https://doi.org/10.1145/3335055.3335061

Puntambekar, S. & Kolodner, J.L., 2005, Toward implementing distributed scaffolding: Helping students learn science from design. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 42(2): 185-217. https://doi.org/10.1002/tea.20048

Qadri, Y.A., Nauman, A., Zikria, Y.B., Vasilakos, A.V. & Kim, S.W., 2020, The future of healthcare internet of things: a survey of emerging technologies. IEEE Communications Surveys & Tutorials, 22(2): 1121-1167. https://doi.org/10.1109/COMST.2020.2973314

Schmidt, H.G., Rotgans, J.I. & Yew, E.H., 2019, Cognitive constructivist foundations of problem-based learning. The Wiley Handbook of problem-based learning, pp.25-50. https://doi.org/10.1002/9781119173243.ch2

Tallberg, L., García-Rosell, J.C. & Haanpää, M., 2022, Human–animal relations in business and society: Advancing the feminist interpretation of stakeholder theory. Journal of Business Ethics, 180(1): 1-16. https://doi.org/10.1007/s10551-021-04840-1

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R. & Boon, M., 2020, Interdisciplinary engineering education: A review of vision, teaching, and support. Journal of Engineering Education, 109(3): 508-555. https://doi.org/10.1002/jee.20347

Vasconcelos, L.A. & Crilly, N. 2016, Inspiration and fixation: Questions, methods, findings, and challenges. Design Studies, 42, 1-32. https://doi.org/10.1016/j.destud.2015.11.001

Veselova, E., Gaziulusoy, I., and Lohmann, J., 2022, Mediating the needs of human and natural nonhuman stakeholders: Towards a design methodological framework, in: Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), DRS2022: Bilbao, 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.524

Walther, J., Miller, S. E. & Sochacka, N. W., 2017, A model of empathy in engineering as a core skill, practice orientation, and professional way of being. Journal of Engineering Education, 106(1): 123-148. https://doi.org/10.1002/jee.20159

Zoltowski, C.B., Oakes, W.C. & Cardella, M.E., 2012, Students' ways of experiencing human-centered design. Journal of Engineering Education, 101(1): 28-59. https://doi.org/10.1016/j.jii.2021.100311