Factors Motivating Engineering Faculty to Adopt and Teach New Engineering Technologies

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***Abstract*—This work-in-progress paper shares preliminary results from a research project that addresses three primary objectives: (1) to develop a conceptual model of technology adoption among engineering faculty through qualitative interview research; (2) to propose an adaption of existing models for technology adoption with appropriate constructs for engineering faculty; and (3) to propose one or more specific interventions to increase faculty adoption of new engineering technologies. In this paper, we focus primarily on the work in progress to meet the first objective. Specifically, we highlight how our preliminary findings about the factors affecting technology adoption, identified from interviews with engineering faculty, align with or differ from factors in previous models for technology adoption. Subjective norm, voluntariness, utility, technology cost, and facilitating conditions, were all preliminary factors found in our data that align at least somewhat with constructs from previous models [1], [2]. Time, access to the technology, efficiency/ease of work, and self regulation are factors that we have identified which are absent from the most widely applied models of technology adoption. We consider what our findings might imply in engineering education contexts.**

***Index Terms*—technology adoption, engineering faculty, Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), subjective norm, voluntariness, utility, technology cost, facilitating conditions, time, technology access, efficiency/ease of work, self regulation**

I. Introduction

Engineering faculty are essential gate-keepers in the acquisition of new technical skills during the process of formation of new engineers. To maintain the relevance of their course materials, as well as to model lifelong learning and technology adoption to students, it is essential that engineering faculty continually adopt and teach new technologies. The study of technology adoption among faculty has focused on instructional technologies, such as wikis, iClickers, etc., [3]–[6], rather than the technologies that students will use in their careers. Specifically, faculty adoption of new engineering technologies that are used in industry, such as scientific instruments, software, and programming languages, remains relatively unexplored.

Technology acceptance has been widely studied by information systems researchers for decades. Within this body of research, the most prolifically applied model to predict the intention to use a technology is the Technology Acceptance Model (TAM) [1], [7]. The TAM is also the most widely used model to predict teachers' use of instructional technologies [8], perhaps because of its ease of application. The TAM relates intention to use a technology to **Perceived Usefulness** and **Perceived Ease of Use** of the technology [7]. "Intention to use" is viewed as "acceptance" of the technology and the terms are often used interchangeably. **Perceived Usefulness (PU)** is defined as the "degree to which a person believes using a particular system would enhance his or her job performance" [7], (p. 320). **Perceived Ease of Use (PEU)** is defined as "the degree to which a person believes that using a particular system would be free of effort" [7], (p. 320). Davis and Venkatesh later explored other determinants of PEU [9] and PU [10] and subsequently revised the TAM (often called the TAM2) to include external variables that affect PU [1]. Several meta-analyses of the application of TAM in a wide variety of settings have shown that although PU and PEU affect intention to use a technology, they do not account for all variability within such intention [11]–[15]. Even after its revision, the TAM2's variance only increased to 60% [11]. In addition, there has been very little qualitative research on the constructs behind the TAM, with most of the research since its development focused on creating a better understanding of its application rather than further exploring the factors themselves [6]. Thus, there is a need for further exploration to identify the specific factors affecting the adoption of technology, including factors relevant to particular contexts such as the adoption of engineering-specific technologies. This work in progress study uses qualitative interviews of engineering faculty to address this need by answering the question, "What motivations and barriers influence the adoption of new digital technologies by engineering faculty, either for use in their research or teaching?" The study addresses convergence by drawing on work related to technology adoption from information systems researchers. The results have the potential to improve how future engineers are prepared to both enter the field and to continue to learn to use new technologies throughout their careers.

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II. Theoretical Framework

The identification of factors that affect engineering faculty's technology adoption in this study is informed by prior research that has identified a range of internal and external factors that generally affect technology adoption. The TAM defined PU and PEU as internal factors that affect such adoption, while the TAM2 added seven external constructs that affect PU [1]: **subjective norm** (the influence of other people on an individual's decision about using the technology, which is moderated by **voluntariness** and **experience**), **image** (the desire of an individual to maintain a positive standing with others, moderated by subjective norm), **job relevance** (applicability of the technology to a job/position), **output quality** (performance of the technology for specific tasks), and **result demonstrability** (production of tangible results). Because the TAM/TAM2 does not account for all variance in technology adoption [11], additional factors must be considered. Venkatesh combined constructs from the TAM, along with other theories and models of individual acceptance [17], [18], into one grand Unified Theory of Acceptance and Use of Technology (UTAUT) [16], which he later revised as the UTAUT2 [2]. Although the UTAUT is less often used in educational settings than the TAM, some of its constructs may shed light onto additional factors to consider in engineering faculty technology adoption. These factors include: **performance expectancy** ("the degree to which using a technology will provide benefits to consumers in performing certain activities" [2], (p.159)), **effort expectancy** (comparable to the TAM2's PEU), **social influence** (similar to the TAM2's subjective norm), **facilitating conditions** (perceptions of resources and support available), **hedonic motivation** (fun or pleasure from technology use), **price value** (the tradeoff between the perceived benefits using a technology and its cost), and **habit** (which is operationalized as prior behavior/experience and personal belief about the behavior as automatic). Although these factors from the literature provide an initial lens for our work, there may be additional factors that are unique to engineering education that have not been identified in prior research. Based on a literature review, we theorize that these factors may include **self-efficacy** [4]–[6], [19], **time** [5], [20], **student engagement and meeting learning objectives** [5], and **usefulness to students** [19]. To identify factors that affect engineering faculty members' technology adoption, we will use analytic induction [21] with the initial codes drawn from the literature, while allowing for new factors specific to the engineering education context to emerge from the data.

III. Methodology

Twenty one engineering faculty from across the College of Engineering at a Midwestern US University were interviewed via Zoom; all interviews were recorded. Participants were solicited through campus and college wide emails, and offered a small incentive to participate. Selection of the candidate pool was deliberate to ensure representation from across the college of engineering resulting in a mix of tenure track (TT) and non-tenure track (NTT) faculty, a mix of career stage, and gender. Overall, the interviewees included 7 female identified and 14 male identified faculty. Eight interviewees were NTT, while 13 were TT. With regard to time spent in academics, 5 had less than 7 years, 11 had 7-14 years, and 5 had greater than 14 years. Four had no industry experience, 6 had less than 5 years, 7 had 5-10 years, and 4 had greater than 10 years. Two participants had served as department chairs or administrators.

Initial interview questions were reviewed by a panel of four experts and piloted with two interviewees before further revision. The final interview protocol included questions about why and how faculty use specific technologies, their process of learning the technologies, how they overcome specific difficulties when they get stuck learning new technologies, barriers to technology adoption, and how universities could better support them in technology adoption.

Each interview was transcribed for analysis. The Grounded Theory method of analytic induction was utilized during coding as it allows for codes to be informed by prior research, as well as for new codes to emerge from the data [21]. The complete analysis process will include multi-pass convergent coding of each interview between two researchers for factors that either support or inhibit the adoption of new technologies, as well as how faculty determine what technologies to adopt for their research or teaching. Results of the qualitative analysis will be reviewed with participants (member checking) as a means of validation. Initial model constructs and proposed interventions that are developed will be reviewed with a panel of experts, as well as with research participants, and revised accordingly. The results reported here come from our *preliminary* analysis of the data.

IV. Preliminary Results

Qualitative analysis of the interview data is still in its early stages. Initial codes have been developed but data analysis has not reached saturation. Definitions in the final code book may change somewhat during analysis. However, initial analysis of the data has identified the following factors affecting faculty adoption of engineering technologies: time, subjective norm, technology cost, access to the technology, utility, efficiency/ease of work, available tech support and other resources, voluntariness, and self regulation.

With regard to time, faculty discussed the time constraints of their busy schedules. The time to learn new technologies, as well as to stay up to date with changes in technologies, was often cited as a barrier to engineering technology adoption. In the words of one participant:

"Definitely it's about the time. When you have things that need to be graded and other responsibilities, finding the time to learn that [new technology] is tough."

Faculty expressed more willingness to use quick-to-learn technologies for themselves and their students. Additionally, when deciding whether to use a technology in a course, the time taken away from other topics was also a consideration. For example, a participant remarked, *"[I consider] how I'm going to carve out lecture time to introduce the software. So [I consider] lecture time as well as my time, you know. It has to go into the equation too."*

Subjective norm was found to affect faculty decisions to use engineering technologies in two ways. The opinions of other researchers (as expressed in journal articles, at conferences, and in interactions with colleagues), affected which engineering technologies faculty utilized for their own research and teaching. A participant remarked,

"A colleague told me about PhET (Physics Education Technology) because they've used them in physics. So I've used PhET in some way or another in all of my courses."

Their decisions were also influenced by the opinions of engineers working within industry (through departmental advisory boards, trade publications, colleagues in industry), who were described as having a great influence on faculty perceptions of which engineering technologies are more relevant for their students to know upon entry into industry.

As faculty often fund their own equipment purchases through grants, cost was another factor that was found to affect faculty decisions to adopt new engineering technologies, both for their research and their teaching. This is especially true for software, for which free or university provided versions may be available. For example, a participant had the following to say about cost:

"One of the benefits of all of the things that we've managed to find so far has been that we can do the development for either little to no cost for the software tool set. And so, if it was going to cost, you know, thousands of dollars per license for this one class that [students are] going to take, that's not really worth it."

Access to technologies was also found to affect faculty use. As mentioned, each university licenses specific software for faculty and student use. Additionally, laboratory instruments can be easier or harder to access on campus depending on the funding of their purchase and whether they have been formally established as a university-wide resource. Proprietary behavior of faculty towards their labs, or lack of communication about shared resources, can provide barriers to technology use by other faculty. One faculty member commented,

"[E]ven though the nano enabler is sitting in the micro-fab [facility], I doubt it's getting used that much because there aren't that many people who know about it...So it's a challenge. There's not a perfect system, but there are always ongoing barriers to people getting access to equipment."

Faculty indicated that sometimes they adopted a new engineering technology for its utility in performing a specific task in their research or in teaching/modeling technical concepts. For example, a participant who does a lot of collaborative work with colleagues in biology pointed out how learning R was important for their research, saying that they learned R because

"R is used a lot more in biology fields. And so I do a lot of collaboration for research with people in biology fields. And I actually needed it to do some of those types of analyses...It's also great for doing correlations and other things. And generally, it can do some really nice plots and so I do use R quite a bit if I need to make histograms, box plots."

Faculty also mentioned learning engineering technologies to make their work more efficient or easier. This especially came up in relation to teaching, when complex calculations could be performed very quickly by software, freeing class time to explore applications and more complex investigations to support advanced understanding. Additionally, some faculty used specific technologies within their classrooms because the students already knew how to use them. For example, one faculty member noted,

"When we started the course, we picked the software. So I guess we picked hyperworks, because there's kind of a thread through all these Mechanical Engineering Practice classes, or all three of them anyway [use hyperworks]." By maintaining consistency in the engineering technologies used across classes, less class time would be needed to build foundational knowledge of the technology.

Facilitating conditions, such as available tech support and other learning resources, also affected faculty technology adoption. Faculty specifically mentioned that free government software often does not come with tech support, but purchased software does. The availability of learning materials that are freely available online was also mentioned as a positive influence on their ability to learn technologies, and lack of organized learning resources was a barrier. In the words of a participant, they are more willing to learn and teach technologies that

"have the most resources or support...not only obvious resources and support on campus in terms of licensing but support... in terms of help available."

Voluntariness, or lack thereof, also played a part in engineering technology adoption, with many faculty having little choice in learning a technology; in many cases, they learned it as a student during their own coursework, they entered a research group or work place using the technology, or the technology was already being taught when they took over a course from another faculty member. As described by one participant,

"Well, it wasn't really my choice, I guess. It was more the department saying: We're going to use Matlab to kind of teach these."

Finally, individual personality traits which determine self regulation behaviors were found to affect engineering technology adoption among faculty. Faculty specifically mentioned letting go of their ego, being comfortable with not knowing, dealing with frustration, being confident in their abilities to learn new technologies, and being patient, as part of the process of learning and adopting new technologies. In the words of one participant,

"You have to set aside your ego. You can watch stuff playing out, but when you go to do it, you have this innate expectation that you're going to be able to do stuff just as quickly. And I discovered that my patience over the years is not what it should be, and I just have to kind of take a deep breath."

V. Discussions and Implications

Two factors that affect faculty engineering technology adoption identified in this study, **subjective norm** and **voluntariness**, are also included in the TAM2 [1]. Additionally, utility, the specific use of a technology for a work task, might align with the TAM2 constructs of **job relevance** (applicability of the technology to a job/position), or **output quality** (performance of the technology for specific tasks), depending on whether interviewees focused on usefulness or performance of the technology. During our preliminary code development, utility has included both the usefulness of a technology to the faculty member in their own research, as well as its use to students in learning. The latter was anticipated to be a factor based on the literature [19]. Student engagement and meeting learning objectives were also anticipated to be factors which affect technology adoption based on the literature [5]. Thus, subsequent data analysis will examine the utility code to determine whether it should be further divided.

Within the UTAUT2 [2], the construct of **price value** (consumers' tradeoff between the benefits and costs of using a technology) is similar to the technology cost factor identified in this work. However, technology cost does not examine the tradeoff, so much as the actual cost. There may be great benefits for using an expensive technology, but that does not mean faculty have the money to purchase it. The UTAUT2 also includes the construct of **facilitating conditions** (perceptions of resources and support), which aligns with the factor of available tech support and other resources.

The study also identified several factors that have not been included in prior models. Time is a new factor absent from either the TAM2 or UTAUT2; however, it was anticipated to be a factor based on the literature [5], [20]. Discussions of time included both faculty time restrictions, as well as time involved in students learning a technology. The perceived time in learning a technology may moderate the existing TAM construct of PEU. Another new factor identified by this preliminary work is that of efficiency/ease of work, which pertains to the personal gains within faculties' own work, not the ease of using the technology itself (PEU). However, PEU may be moderated by perception of the difficulty of the manual completion of a task (or previous method) for which the technology is applied, so the relationship between PEU and efficiency/ease requires additional investigation. Another factor absent from both the TAM2 and UTAUT2 is access to the technology, as these models focus on consumer behavior and assume access. Likewise, neither model includes user self regulation behavior or personality traits that might account for the users' willingness or ability to persevere through the difficulties of learning a new technology. The preliminary code for self regulation includes some element of efficacy, which we anticipated to emerge as a factor based on literature [4]–[6], [19], as it included faculty confidence in their ability to learn new technologies. Ongoing work includes additional exploration of personality traits that govern self regulation behavior to better understand how they align with other constructs in the literature, and determine which should be included in revised codes.

Our initial results indicate some potential implications for promoting new engineering technology adoption among faculty. For example, efforts to relieve the limitations on available faculty time, such as a temporary reduction in teaching load, could free more time to learn and adopt technologies to integrate into their research and teaching. Faculty technology learning groups, similar to writing groups, could be used to support the adoption of new technologies by sharing learning resources, providing accountability, and normalizing the struggle among faculty. Further stages of this study will propose and develop a conceptual model for engineering faculty technology acceptance as well as institutional interventions to promote engineering technology adoption among faculty. Future work that is beyond the scope of this project will develop and validate measurement scales, validate a proposed structural model, and test proposed interventions.

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