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Factors influencing faculty's adoption of engineering technology: A qualitative study

Michelle Jarvie-Eggart [a,*], Shari L. Stockero [a], Alfred Owusu-Ansah [b]

[a] Michigan Technological University, United States of America
[b] University of Denver, United States of America

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ABSTRACT

With technologies changing faster than ever before, engineering faculty must continuously update the technologies they use and teach to students to meet accreditation requirements and keep up with industry standards. Many do not, however. Additionally, existing models of technology adoption do not account for all variability within intention to use a technology, nor its actual use. Informed by the Unified Theory of Acceptance and Use of Technology (UTAUT), this study examined which constructs from prior models apply to engineering faculty's adoption of industry-specific technologies, as well as other factors influencing faculty adoption of these technologies for their teaching or research. We interviewed 21 engineering faculty at a Midwestern United States STEM-focused institution about their adoption of engineering technologies. Deductive and inductive coding were used to identify themes within the qualitative data. Constructs from existing models were confirmed to influence faculty engineering technology adoption. We also identified specific Facilitating Conditions (Other People, Digital Resources, Non-Digital Resources, Time, and Formal Training) that faculty leverage to adopt new engineering technologies, and uncovered two additional themes—Access and Personal Traits, including several component traits (Persistence, Humility, Self Efficacy, Growth Mindset, Ambiguity Acceptance, and Curiosity) that influence faculty engineering technology adoption. We propose a new Theory of Faculty Adoption of Engineering Technologies specific to faculty adoption of new engineering technologies. These findings have the potential to help universities determine how to effectively support faculty in providing their students with relevant technological skills for entry into the engineering workforce.

1. Introduction

To meet the technology needs of future employers and the requirements for program accreditation, engineering programs must teach students to use relevant and modern technologies. The Accreditation Board for Engineering and Technology (ABET) General Criteria for Baccalaureate Level Programs requires that engineering programs teach design "utilizing modern engineering tools" (Criterion 5.b; [1]). This task is akin to hitting an ever moving target, however, as technologies are developing at a faster pace than at any point in history [2]. The software, programming languages, and instrumentation taught to engineering students can quickly become out of date, making it critical that faculty continually adopt, learn, and integrate new engineering technologies into their teaching to maintain the relevancy of the technological engineering tools taught to students. By doing so, faculty also model lifelong learning for their students–another essential skill for engineers. Engineering students' "ability to acquire and apply new knowledge as needed, using appropriate learning strategies" is also among the student outcomes required by ABET (Criterion 3.7; [1]). By modeling this behavior for students, faculty create a professional expectation among their students that they will also continue to learn about and use new engineering technologies throughout their careers.

Although engineering faculty often learn specialized engineering technologies to support their research, these technologies are often not germane for practicing engineers within industry. To maintain the relevance of engineering programs, faculty must also integrate into their courses current engineering technologies used within the industries where their students will later be employed. To best prepare students for professional practice, it is recommended that engineering educators "align expert uses of domain-specific computational tools with their affordances for connecting to engineering practice and to foundational disciplinary background knowledge" ([3], p. 11). Yet, they often fail to

* Corresponding author at: 1400 Townsend Dr Engineering Fundamentals, Houghton, MI, 49931, UK.
E-mail addresses: mejarvie@mtu.edu (M. Jarvie-Eggart), stockero@mtu.edu (S.L. Stockero), alfred.owusu-ansah@du.edu (A. Owusu-Ansah).

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do so. This may be due to the limited time engineering faculty have available to learn new engineering technologies [4]. Additionally, engineering design is often valued more than technology education [5], which results in faculty focusing on teaching the design process and often neglecting to teach the use of engineering tools that will be the most relevant for their graduates.

To determine how to ensure that engineering faculty use appropriate technologies to both meet the needs of future employers and the requirements for program accreditation, it is important to first understand what hinders or helps engineering faculty's adoption of new engineering technologies; this is the focus of this study. This work seeks to understand which constructs from existing models of technology adoption are relevant for engineering faculty, and identify any factors missing from the existing models. This new understanding will inform additional work addressing the development of programs and interventions to help faculty continuously update the engineering technologies used in their courses.

2. Background and theoretical framing

Existing models to predict technology adoption among university faculty were originally developed for consumer and information technology settings. The primary models utilized in technology adoption research within academics are the Technology Adoption Model (TAM) [6] and its revision, the TAM2 [7], along with the Unified Theory of Acceptance and Use of Technology (UTAUT) [8], and its revision, the UTAUT2 [9]. In the following sections, we discuss these two models, as well as potential gaps in the models in the context of engineering education. We highlight that this paper addresses the adoption of the computational tools used within the practice of engineering, which we refer to as *engineering technologies*; these are distinctly different from the technologies used to support classroom communication and instruction, which we refer to as *instructional technologies.* We focus specifically on engineering technologies for two reasons. First, the majority of the research on technology adoption within education has focused on instructional technologies, creating a gap in the literature related to the adoption of content-specific technologies. Second, because instructional technologies are often adopted university-wide, there are more support structures in place to aid with adoption; this is in contrast to more specialized engineering technologies that are often adopted by individuals or small groups of users at a university.

2.1. Technology adoption model (TAM)

Both the TAM [6] and its revision, the TAM2 [7] link the Behavioral Intention to Use a technology to Perceived Ease of Use and Perceived Usefulness of the technology. Perceived Ease of Use refers to "the degree to which a person believes that using a particular system would be free of effort" ([6], p. 320) and Perceived Usefulness refers to the "degree to which a person believes using a particular system would enhance his or her job performance" (p. 320). The TAM2 added social influences to Perceived Usefulness, including the increase in Image associated with using the technology and Subjective Norm (the opinions of peers about the technology) [7]. Experience was also added as a moderating variable for Subjective Norm. In addition, the TAM2 incorporated cognitive instrumental processes that influence Perceived Usefulness, including the Job Relevance of the technology, the Output Quality (how well the technology performs a given task), and Result Demonstrability (the production of tangible results from using the technology). In this model, Perceived Usefulness and Perceived Ease of Use predict Behavioral Intention to Use a technology, which is also directly influenced by Subjective Norm and moderated by Voluntariness of use. In turn, Intention to Use may lead to actual use (Use Behavior). Although Behavioral Intention to Use does not perfectly predict Use Behavior, it is often used as a proxy for Use Behavior within studies [10].

2.2. Unified theory of acceptance and use of technology (UTAUT)

Venkatesh combined constructs of the TAM with other popular behavioral models to create the Unified Theory of Acceptance and Use of Technology (UTAUT) [8]. The UTAUT revised the predictors of Behavioral Intention to Use a technology to include Performance Expectancy (similar to the TAM/TAM2 Perceived Usefulness), Effort Expectancy (similar to Perceived Ease of Use of the technology in the TAM/TAM2), Social Influence (similar to the TAM2's Subjective Norm), and Facilitating Conditions (the user's perceived supports for using the technology). Age, Gender, Experience and Voluntariness were all moderating variables. In the original UTAUT, Behavioral Intention to Use a technology, again with Facilitating Conditions combined to predict Use Behavior.

The UTAUT was later revised to the UTAUT2 [9] to take into account a consumer context, as opposed to the workplace context of the earlier model. As a result, the UTAUT2 dropped Voluntariness from the variables influencing these constructs. An important contribution of the UTAUT2 was its inclusion of several new constructs related to Behavioral Intention to Use a technology. These constructs included Hedonic Motivation, Price Value, and Habit; Habit also directly influenced Use Behavior [9]. Even with these additions, the prediction of Use Behavior is still not 100 %, indicating the existence of other yet unaccounted for constructs influencing Use Behavior.

2.3. Additional constructs related to technology adoption

We reviewed the literature to identify constructs not included in current models that might be relevant to engineering technology adoption by faculty. For example, these models do not consider barriers (e.g., time, money, expertise) that might prevent a person who wishes to adopt a technology from actually doing so [11]. In fact, the literature indicates that time might be an important factor in faculty adoption of new instructional technologies [12–15]. The commitment of time by faculty to learn new instructional technologies is dependent upon extrinsic motivating factors such as organizational incentive structures, as well as intrinsic motivating factors that vary by individual. Moser [12] suggested that adequate incentive structures and support need to be provided to motivate the faculty adoption of new instructional technologies.

Fatherman et al.'s [16] examination of faculty's acceptance of learning management systems in higher education found self-efficacy to be an important factor affecting the acceptance of such technologies. Self-efficacy was also identified as important for faculty teaching online [15] and for faculty's adoption of mobile technologies for educational use [17]. Self efficacy was proposed for inclusion in the original UTAUT, but it was removed because Venkatesh et al. [8] found self efficacy to have no significant effect on Behavioral Intention to Use a technology, and the effect was believed to be captured by Effort Expectancy. However, the technological self efficacy of teachers has been shown to be a significant predictor of their use of instructional technologies [18]. Hence, it is anticipated that self-efficacy may influence faculty engineering technology adoption as well.

A unique aspect of a faculty position is that faculty need to adopt technologies to both support their own research and the learning of their students. Thus, a faculty member's perceptions of a technology's usefulness to support student learning may be another important factor affecting their adoption of new engineering technologies. In fact, faculty were found to consistently identify student engagement and meeting learning objectives in online platforms as essential considerations in assessing the relevance of instructional technologies [15]. These findings are supported by Buchanan et al.'s [19] finding that faculty members' perceived usefulness of a technology to their students or to their area of teaching was among the strongest barriers affecting faculty adoption of instructional technologies. We thus theorized that the usefulness of a technology to students may be an additional variable related to Performance Expectancy; that is, engineering faculty may not only consider technologies that improve their own work, but that also improve their students' experience or learning in their courses.

Although personal traits have not been widely studied in relation to technology adoption, there is some research that has found connections between the two. On a broad scale, Barnett et al. [20] applied both the UTAUT and the Five Factor Model of Personality [21] to study students' acceptance of instructional technologies, finding some associations between particular personality traits and technology use. Research on specific personal traits also suggests some traits that might play a role in technology adoption. Howard & Crayne [22], for example, found that persistence matters for workplace activities. There is also some indication that mindset influences technology adoption. For example, Dang and Liu [23] found that individuals exhibiting a *growth mindset* [24] were more willing to interact with AI robots, while Rolley [25] found that traits associated with growth mindset in faculty teaching online aided their adoption of instructional technologies. The ability to tolerate ambiguity has been found to be essential to an individual's approach to work in a range of work contexts (e.g., [26–29]). In fact, teachers with low tolerance for ambiguity have been found to be less likely to be comfortable with curriculum changes, including integrating new instructional technologies [30]. In essence, an individual's ambiguity acceptance, and how they perceive the technology as either reducing or increasing risk and ambiguity, can influence whether they adopt it. Finally curiosity has been found to be associated with the Perceived Ease of Use and Perceived Usefulness of information technologies [31] and has also been found to have a positive effect on consumers' Perceived Ease of Use of virtual reality hardware [32]. Oelhorn et al. [33] studied the impact of curiosity on use of social networking sites, finding that epistemic curiosity—wanting to obtain new knowledge or fill in gaps—positively influences users' perceived usefulness and perceived enjoyment of such sites, which both contribute to technology adoption.

2.4. Theoretical framing of the study

The UTAUT models provided an initial framework and lens for our work to understand faculty members' engineering technology adoption. The UTAUT was developed to understand technology adoption by professionals within industry and the UTAUT2 expanded this model to a consumer context. The application of these models to academic faculty has focused on faculties' adoption of instructional and communication technologies—not discipline-specific technologies. Thus, we theorized that some constructs from these models might not apply to the unique job motivations and concerns of engineering faculties' adoption of engineering technologies, while other constructs might need to be added.

In our review of the instructional technology literature prior to the study, we identified time, self-efficacy and student learning as additional constructs that may need to be included in a faculty-specific model for engineering technology acceptance. Thus, these constructs became part of our initial framework for the study. We acknowledged, however, that even the addition of these constructs may not account for all variability in technology adoption and use among faculty. Thus, we allowed for other codes to emerge from the data. The personal traits discussed in the prior section were such emergent codes and thus were not included in our initial coding framework.

3. Purpose

Venkatesh's own work has shown that the UTAUT2 does not account for all variability within either the Behavioral Intention to Use a technology or Use Behavior [34]. Additionally, although Behavioral Intention to Use is commonly used as a proxy for Use Behavior, it does not perfectly predict Use Behavior [10]. Thus, other factors that contribute to both the Behavioral Intention to Use and its translation into Use Behavior remain undiscovered. Although the UTAUT and UTAUT2 have been revised and expanded for multiple applications since its initial development, no models have been targeted to faculty adoption of *engineering technologies*. Faculty's adoption of industry-specific technology is critical, however, to maintaining the relevance of engineering programs. Thus, this research aims to both understand the extent to which constructs from prior models (e.g., UTAUT, UTAUT2) apply to engineering faculty technology adoption and identify additional constructs associated with such adoption. We do so by answering this research question: *What factors support or inhibit faculty members' adoption of new engineering technologies for their teaching or research?* Understanding what influences the adoption of engineering technologies can inform universities about what support they might provide to enable their engineering faculty to continue to update the engineering technologies they use in their research and teaching.

4. Methods

We adopted an interpretivist paradigm in our work as we aimed to understand the subjective experiences and beliefs of our participants [35] in the context of the adoption of engineering technologies. This approach acknowledges that reality is socially constructed, and thus emphasizes understanding the viewpoint of the participants as central to the work. Although we began with a coding framework that was drawn from prior research, we expected that some codes in the framework would not be relevant to our data and that additional codes would emerge from the data. Thus, to ensure that the viewpoint of the participants remained central in our analysis, we analyzed the data using analytic induction [36,37], which combines deductive and inductive methods. We also ensured that we were accounting for the viewpoints of the participants in the validation of our results. In the following, we provide additional details about our research approach.

4.1. Participants

Twenty-one engineering faculty at a Midwestern United States (US) engineering-centric university were interviewed about their engineering technology adoption. After soliciting a volunteer pool by email, interviewees were selected to represent faculty who were both tenure track and teaching track, in different academic career stages, with varying amounts of industry experience, and provided representation of faculty who identify as women as well as those with experience in academic administration. Table 1 provides a breakdown of the demographics of the faculty participants.

4.2. Data collection

An initial interview protocol was developed with feedback from the project's advisory board (see Trustworthiness section for more details on the board). Prior to conducting the faculty interviews, two pilot interviews were conducted and analyzed, after which the interview protocol was revised. The final protocol is presented in the Appendix. Due to

Table 1
Faculty Participant Demographics.

Faculty Track	Tenure Track (n=13)	Teaching Track (n=8)
Years in Academia	<7 years (23.1 %) 7-14 (46.2 %) >14 (30.8 %)	<7 years (25 %) 7-14 (62.5 %) >14 (12.5 %)
Years in Industry	0 (23.1 %) <5 years (30.8 %) 5-10 years (38.5 %) >10 years (7.7 %)	0 (12.5 %) <5 years (25 %) 5-10 years (25 %) >10 years (37.5 %)
Gender identity	Female (38.5 %) Male (61.5 %)	Female (12.5 %) Male (87.5 %)
Experience in Academic Administration	Yes (15.4 %) No (84.6 %)	Yes (0 %) No (100 %)

the COVID-19 pandemic, the approximately one-hour participant interviews were conducted via Zoom, all by the same member of the research team (the first author). During the interviews, participants were asked questions about their use of engineering-specific technologies, including (a) which technologies they teach to undergraduate students, (b) which technologies they use in their own work, (c) what motivates them to learn new technologies, and (d) barriers or challenges to using a new technologies.

4.3. Data analysis

The interview data were transcribed using Zoom. Consistent with user reports on automatic speech recognition generated transcripts, Zoom had difficulties recognizing discipline-specific jargon and non-American English dialects/accents [38]. To limit transcription error, a research team member manually checked and edited all the interview transcripts prior to coding.

After transcribing the interviews, the data were thematically coded for several factors related to faculty members' technology adoption: (1) factors that affect decisions about which technologies to learn and use in their courses, (2) factors that support adoption of new technologies, and (3) factors that inhibit technology adoption. The data was coded by idea unit [39], with the unit boundaries determined by a change in the idea being discussed. During this process, we allowed for multiple codes to be assigned to a unit of data as needed [40]. Both deductive and inductive coding methods were used [36,37]. We began with a coding framework that included constructs from the UTAUT [7,9] and drawn from the literature [12,15–17,19]. The initial (deductive) coding framework is provided in Table 2. Because we hypothesized that there might be additional constructs that are unique to engineering faculty, we also used inductive coding, allowing new codes to emerge from the data.

Table 2
Deductive codes from existing technology adoption models.

Code	Definition
Constructs from the UTAUT	
Performance Expectancy	"[T]he degree to which using a technology will provide benefits to consumers in performing certain activities" ([9], p.159)
Effort Expectancy	"The degree of ease associated with use of the system" ([8], p.450)
Social Influence	"The degree to which an individual perceives that important others believe [they] should use the [technology]" ([8], p.451)
Facilitating Conditions	"refer to consumers' perceptions of the resources and support available to perform a behavior." ([9], p.159; [8])
Moderating Variables from the UTAUT*	
Experience	"reflects an opportunity to use a target technology and is typically operationalized as the passage of time from the initial use of a technology by an individual." ([9], p. 161)
Voluntariness (dropped in UTAUT2)	Freely choosing to adopt the technology [8].
Constructs Added in the Formation of the UTAUT2	
Hedonic Motivation	"Fun or leisure derived from using a technology" ([9], p.161)
Price Value	"[C]ognitive tradeoff between the perceived benefits of the application and the monetary cost for using them" ([9], p.161; [41])
Habit	The automaticity of using a given technology, based on prior experience with it [9]
Constructs from Other Literature	
Self Efficacy	"individuals' beliefs about their competence or mastery in a particular domain" ([19], p.2).
Student Learning	Usefulness of the technology to aid in meeting learning objectives or enhancing student engagement.
Time	When faculty adopt new technologies, "time is a scarce resource and many other activities compete for faculty attention" (Moser, 200, p. 66).

* Note that the UTAUT also included age and gender, along with experience and voluntariness, as moderating the influence of the UTAUT constructs on Behavioral Intention to Use and Use Behavior. We did not code for age and gender because of our small sample size, but did make an effort to have a balanced interview pool based on gender and career stage (a proxy for age).

All of the data were individually coded by two members of the research team. After the individual coding was complete, they met to compare their coding and reconcile any differences. When a coding difference was identified, they discussed the instance to determine whether it fit into an existing coding category, or whether a new code needed to be created. A third member of the research team was brought into the discussion as needed to resolve coding differences if agreement could not be reached between the initial two coders. A codebook was maintained and updated throughout the coding process as new codes were added or code definitions were clarified [42]. Reflective memoing was used extensively throughout the coding process to record coding decisions made by the group [43].

After the initial coding was complete, data analysis focused on identifying themes in the data; during this process, codes were combined and further refined as needed to fully capture the ideas that emerged. Review of the preliminary themes was conducted by members of the project's advisory board to increase the trustworthiness of the themes that were identified [37,43]. Their feedback led to revisions of the themes within the data. Finally, three member checking focus groups [37] were conducted with six total participants who volunteered to provide additional feedback, including pairs of faculty in the following groups: self-identified high technology adopters, self-identified low technology adopters, and faculty with administration experience. Each group was presented with the results and asked for their opinion on the accuracy of the themes. They were also asked to provide additional details and insights as to how various constructs influenced their engineering technology adoption. After gathering feedback from the member checking groups, the results were further revised based on the focus group feedback to arrive at the final themes presented in this paper. The data collection, analysis and feedback process is shown below in Fig. 1.

4.4. Positionality statement

Recognizing the various positionalities of our research team provides an enhanced understanding of how our social identities and experiences influenced the way we designed the study and interpreted the data [44,45]. The first two authors are native to the US. The first author had extensive industry experience as a professional engineer before transitioning to academia, and even served on an industry advisory board for a university engineering program. These experiences resulted in her observations of the disconnect between the technologies taught in engineering programs and those relevant for practicing engineers. A resultant desire to understand how to better incentivize faculty adoption of relevant technologies motivates her research trajectory. The second author has been involved in the professional development of K-12 teachers and university faculty for more than two decades. This author has a strong commitment to supporting the continuous improvement of instruction, and has spent many years motivating teachers to adopt new ideas for teaching practice. The third author was an international PhD student (and now a faculty member in the US) who has experience having to learn a new technology in order to teach that technology to a research methods class. This author also has firsthand experience with distributive justice issues surrounding access to technologies. We acknowledge the possibility that these experiences influenced our study. Efforts to limit individual biases within the research are explained in the following Trustworthiness section.

4.5. Trustworthiness

Efforts to address the trustworthiness of the results focused on reducing individual biases of researchers and confirming the results with both research participants and experts in the field. As discussed in the Data Analysis section, investigator triangulation was employed where all data were coded separately by two members of the research team,

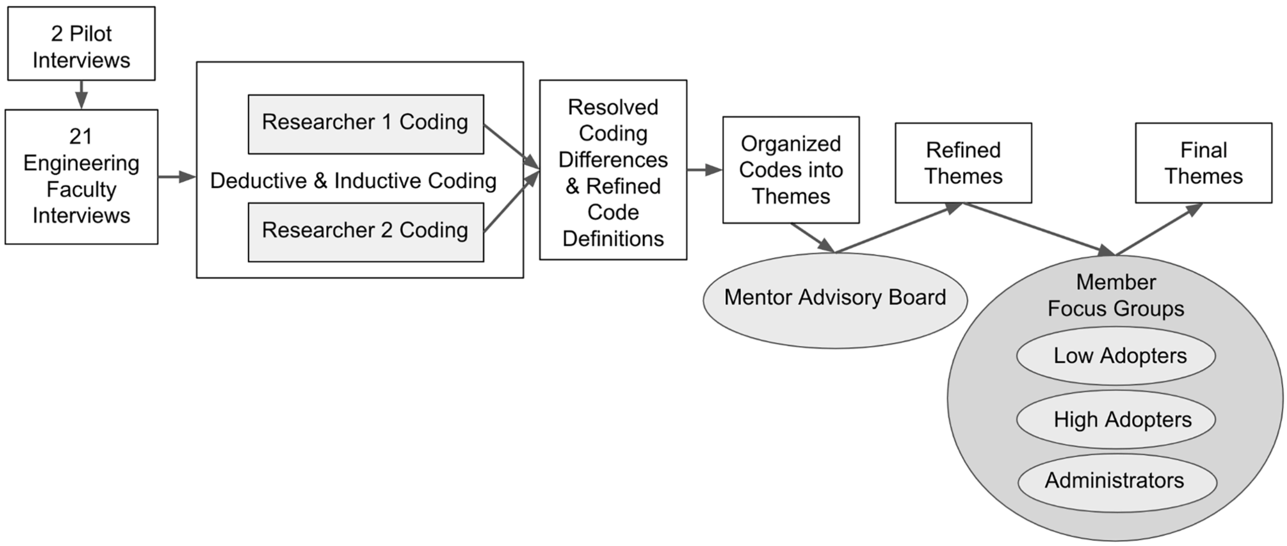

Fig. 1. Data collection and analysis process.

who then reconciled their coding differences through regular discussions. A third researcher was brought in to resolve coding differences when needed. Peer expert review and member checking were employed as means of analytical triangulation [37]. As noted previously, peer review of preliminary results was conducted by experts on the project's advisory board to increase the trustworthiness of the preliminary themes that were identified [43,37]. Advisory Board members included experts in human factors, engineering education, and qualitative methods. Additionally, as they were all university faculty in STEM fields, they were able to critique the results from the perspective of faculty who have adopted new technologies. Their feedback led to revisions of the themes within the data. Following these revisions, the communicative validity of the results was addressed through member checking with focus groups conducted with a subset of the research subjects [37,46].

5. Results

Our data both confirmed some of the constructs associated with faculty engineering technology adoption found in the UTAUT and identified themes around which we propose new constructs that influence such adoption. In the following, we first discuss results that confirm prior findings, including an expansion of the Facilitating Conditions construct from the UTAUT. We then discuss new factors that influence faculty technology adoption identified in this study.

5.1. Results Consistent with the UTAUT Models

Themes identified within the interview data confirmed several constructs and variables associated with technology adoption that existed in the UTAUT models. These themes, along with an example from our data, are summarized in Table 3 and detailed in the sections that follow.

5.1.1. Performance expectancy

All of the interviewees ($n = 21$) discussed Performance Expectancy as influencing their decisions to adopt new engineering technologies. This construct relates to the usefulness of the technology in daily life by allowing the user to accomplish things faster or by increasing productivity [8]. The interviews revealed that faculty perceived engineering technologies as useful to them both for teaching ($n = 21$ interviewees; 100 %) and for research ($n = 20$; 95.24 %). Although some technologies were used in both contexts, faculty generally discussed adopting a new engineering technology specifically for either their teaching or their research. This dual purpose for adopting technologies seems to be

Table 3
Themes from The UTAUT.

Theme	Example of text coded with this theme
Performance Expectancy	"[I]t's kind of become one of my favorite tools…Because you can show things move around, and you know you can make a model of a person throwing a basketball and trying to get a basket because it's got a very visual output. And it represents all the physics, and I can calculate the forces of dribbling the basketball, throwing the basketball and having it hit the net and other aspects of objects moving. That's kind of my areas, noise and vibration, so seeing how things move and dynamics is my field."
Effort Expectancy	"The error messages…almost require an expert knowledge to understand the errors, even if the error you make would be a very novice kind of error. So, it's really hard, right. You won't make the error, if you know what you're doing, but if you make the error the way that they report it isn't helpful. You can't figure out what to do about it."
Social Influence	"I learned [LaTeX] when I was writing my PhD dissertation. My office mate told me, 'You Need to use LaTeX,' and then I learned by myself."
Price Value	" …if it was going to cost, you know, thousands of dollars per license… for this one class that they're going to take, that's not really worth it…"
Hedonic Motivation	"I enjoy learning it. If I have a problem to apply it to I really enjoy learning a tool that can help me. I enjoy learning a new thing about our tool..."
Habit	"You know, I, for me it's just habit, you know, from working in industry."
Experience	"I'm a MATLAB user…I've had several engineering jobs in addition to academia and almost all of them I used MATLAB in one form or another. And so to me it just was natural. So one reason why I'm using [it] is because I used it myself…"
Voluntariness	"...it wasn't really my choice, I guess. It was more a department [saying], 'We're going to use MATLAB, right, to kind of teach these' so …I started teaching [these classes], that was the software tool that was used, so we kind of use it. [demonstrating involuntariness]"
Facilitating Conditions	"...there seemed to be two types of introductory material that was available, whether it came from Chapel [a programming language] or from somebody else. And it was either here is something that's so enormously simplistic that you can't help but get it, or here's something that is supposedly introductory but…, even though I've written a number of programs in this language, still, I don't understand… and there was somehow not anything in the middle. And that's what I needed…that goldilocks level in the middle didn't exist. And online support also didn't exist, as well as even people around me, so I don't think that there's a single other person at [the university who] has ever written a line of Chapel."

related to the unique role of faculty. When it came to the utility of engineering technologies for teaching, faculty also took into account how the technology would help them meet their learning objectives ($n = 20$; 95.24 %) or increase student engagement ($n = 15$; 71.43 %). This faculty explains how using a simulation software in their engineering class benefits student learning:

> I like to use [that] software… for tying the principles of what the students are learning into something where they can actually see it, and where they're going to actually experience …it's just mainly to, number one, help them in their motivation to learn these things, and then number two, help them in the learning process.

Overall, faculty were motivated to adopt engineering technologies that made either their teaching or research (or both) more efficient.

5.1.2. *Effort expectancy*

All of the interviewees also indicated that Effort Expectancy influenced their decision to adopt new technologies. Effort Expectancy is "the degree of ease associated with the use of the system" ([8], p. 450). Effort expectancy could be a barrier to adoption when users perceive it to be high or a motivator for the adoption of a specific technology when users perceive the effort to adopt it as very low. Faculty within the focus group of low technology adopters indicated that Effort Expectancy significantly influenced their decisions around which technologies to utilize in their research as well as in their teaching. These faculty indicated they were more likely to teach technologies they already know or those that do not release new versions as often, which would require re-learning components of the technology. Faculty also wanted to adopt technologies they perceived as easy for themselves and students to learn. Concerns regarding the time invested in learning technologies were expressed by 17 (80.95 %) of the interviewees. (We also found another time theme related to time pressures of faculty schedules as will be discussed under Facilitating Conditions). Faculty noted that the trade-off of the time invested in learning an engineering technology had to be worth the gain they would achieve by adopting the technology. One focus group used the phrase "time value" to describe this concept.

5.1.3. *Social influence*

All of the interviewees indicated a Social Influence upon their decision to use specific engineering technologies. Social Influence accounts for the influence of other people's opinions about a technology on an individual's use [8]. The opinions of other researchers (as expressed in journal articles, at conferences, and in personal interactions), affected which engineering technologies faculty utilized for their own research and teaching. Faculty decisions were particularly influenced by the opinions of engineers working within industry (as communicated through departmental advisory boards, trade publications, colleagues in industry), who were described as having a great influence on faculty perceptions of which engineering technologies had job relevance for their students entering industry.

Members of the low adopters member checking focus group, however, clarified that Social Influence was not a consideration when They decided which technologies to teach students. They indicated that it only influenced their choice of technologies for their own professional use. In contrast, the high adopters indicated that they were affected by Social Influence in both the selection of engineering technologies to incorporate into their teaching as well as their research.

5.1.4. *Price value*

All 21 faculty interviewed indicated that Price Value associated with a technology influenced whether they would adopt it. Price Value is a sense of the user's tradeoff of the money they spend to use a technology and the gains they will realize from using it [9]. Faculty explained that cost was a major factor in whether they would adopt a technology for the purpose of teaching it to students. In fact, faculty indicated a preference for technologies with absolutely no cost at all, as discussed in the section on Access.

5.1.5. *Hedonic motivation*

Although some of the interviewees ($n = 7$; 33.33 %) did mention enjoying using certain technologies, or playing around to experiment with their use, Hedonic Motivation was not found to be a major motivator for the majority of faculty interviewed. Hedonic Motivation occurs when pleasure associated with using a technology motivates one to learn it [9]. However, for those who did experience Hedonic Motivation, faculty discussed the joy of learning or experimenting with a new technology that aligned with a subject area of passion for them

5.1.6. *Habit*

We anticipated that habit might be an important construct related to faculty technology adoption, but only 4 of the 21 interviewees (19.05 %) discussed defaulting to a technology out of habit rather than adopting a new one. Habit is the automaticity of using a given technology based on prior experience with it [9]. Without prior experience, a habit cannot develop.

5.1.7. *Experience*

Experience was mentioned by 20 interviewees (95.24 %). Prior Experience using a technology has been found to contribute to the intent to use it further [7]. Faculty explained how prior experiences with a given technology made them more likely to use that technology, or made it easier for them to use. Additionally, a new concept emerged with regard to Experience—experience with one technology was sometimes easily applicable to a similar technology. For example, faculty using one CAD software might find it easy to learn and adopt a different CAD software, which positively influenced their decision to adopt. This Transferable Experience was specifically mentioned by 15 interviewees (71.43 %).

5.1.8. *Voluntariness*

Our data indicated a majority of the faculty ($n = 13$, 61.9 %) adopted technologies involuntarily. During their own graduate studies, faculty often adopted technologies because they were being used within a research project they joined. Faculty assigned to teach a class new to them were often told which technology was used in the course, either because the department had agreed upon it or later courses required students to know that technology. Overall, only 5 (23.8 %) faculty discussed adopting an engineering technology voluntarily. Within teaching, two faculty (9.5 %) discussed selecting which engineering technologies to teach as part of their membership on a curriculum committee, which means the decision could be influenced but was not the free choice of the individual faculty member. Three faculty (14.3 %) indicated they liked to give their students choice in which engineering technology to use on an assignment (such as choosing a favorite programming language or solid modeling software), indicating they were comfortable allowing a range of technologies to be used in their course.

5.1.9. *Facilitating conditions: An expansion of a prior construct*

The Facilitating Conditions construct was included in the UTAUT models [8,9], but our results extend what is known about this construct by identifying specific supports for engineering faculty technology adoption. Our inductive coding of the data revealed five Facilitating Conditions that support faculty adoption of new engineering technologies: Other People, Time, Digital Resources, Non-Digital Resources, and Formal Training [4]. In addition, we found that faculty often leveraged or further developed these facilitating conditions as a means of overcoming difficulties learning a technology, as will be discussed in the Persistence section below. As these emergent themes are the result of inductive coding, their definitions were not provided in Table 2. Thus, code definitions, along with example quotes from the data are shown in Table 4.

Table 4
Facilitating conditions.

Themes	Definition	Example of text coded with this theme
Other People	Who faculty approach to help them adopt new technologies, including faculty peers, mentors, students, and industry colleagues.	"[T]here's also a couple of faculty in the department that have taken...training classes...I would get stuck, but send it to them and they'd say, 'Oh, do this'...because they've used it so extensively that it would be an easy solution. Or if they'd say, 'Well, I don't know', then they have contacts at [software company]...that they would pass it along [to]."
Digital Resources	Electronic sources faculty leverage when adopting technologies, such as videos, internet, discussion forums, and technology documentation centers.	"[W]hen you're not able to meet with somebody right then…you can dig around more broadly, and so [it's] more time intensive but just like more [of a] range of material available."
Non-Digital Resources	Print materials faculty leverage to adopt new technologies, such as books, manuals, and journals.	"For me, I have to sit down with a manual or a book and read it like from the beginning, because I can't jump in."
Time	Temporal concerns related to general faculty time pressures, including balancing their workload and carving out the time to teach technologies within courses.*	"[T]hat it would be time on my part because in our job we don't have a lot of time to learn new skills. Our time is taken up with committee work and various other things…so I guess there's so many things that I should learn that I just don't feel like I have time to."
Formal Training	Structured learning opportunities that faculty seek out to adopt new technologies, such as classes, workshops, short courses, and seminars.	"[T]here's not always that incentive to continue to develop your skills. There's no funding for that, there's no reward mechanism for that necessarily and, failing that, it's hard to come up with the incentive..internally."

* This definition is revised from our previous work [4]. We now include faculty concerns about the time involved to learn a technology in the Effort Expectancy theme.

5.1.9.1. Other people. All of the interviewees discussed seeking assistance from Other People—peers, industry colleagues, students and technology support personnel—as facilitating their learning and using engineering technologies. Some faculty relied on others in ways that are counter to traditional educational hierarchies, noting that they ask their graduate or undergraduate students to learn a new technology and then teach them just enough to use the technology in their work. Others indicated that they partnered with colleagues and included members on research teams to ensure they had access to technology proficiencies they themselves were lacking. Some faculty discussed having their graduate students learn to use new technologies without any intent to use the technology themselves. In this case, the students were used as surrogate technology adopters.

5.1.9.2. Digital resources. All of the interviewees discussed leveraging digital learning resources, including YouTube videos, Google, discussion forums, and documentation centers within the technologies, to facilitate their adoption of a new engineering technology. The faculty indicated that they found digital resources to be particularly useful because they allowed targeted searches and are always accessible, unlike other people. Some of the interviewees also said that they typically like to first try to figure out a technology themselves before asking someone else for help, which was supported by the use of digital resources.

5.1.9.3. Non-digital resources. Non-Digital Resources like books and manuals were also discussed by a majority of the engineering faculty interviewees ($n = 20$; 95.24 %) as resources to help them adopt new engineering technologies. In fact, a few faculty indicated that they preferred non-digital resources over digital resources, and that they could not learn new things without a physical manual. Journal articles were described as useful by some faculty for adopting new laboratory-based technologies. Faculty also discussed additional benefits of journals, such as learning which technologies their colleagues were using and how they were using those technologies. We note that although some faculty were likely accessing articles digitally, we included them in the non-digital resource category due to the original print format of most journals.

5.1.9.4. Time. The majority of faculty highlighted that learning new engineering technologies requires time and effort—a challenge given that faculty time is limited. In the interviews, 18 faculty (85.71 %) specifically discussed time pressures and time restrictions of faculty work, or the time it would take away from other instructional activities to incorporate a new technology into their class as considerations for technology adoption. Faculty of all ranks discussed work time pressures ($n = 17$ faculty; 80.95 %); for teaching track faculty, this was related to high teaching loads and for tenure track faculty, it was related to balancing teaching and research expectations. Thus, faculty discussed time as a resource that was very limited. The data suggest that when faculty have available time, they are more willing to learn new engineering technologies, but this was a significant barrier for many interviewees. When the adoption process demands more time than they can give, faculty may choose to assign a surrogate adopter, as discussed in the Other People section.

Faculty also discussed the difficulty of fitting everything into a course necessary to cover the learning objectives. These faculty were concerned about the time they would have to carve out of already packed courses to utilize a new technology in class ($n = 11$; 52.38 %). These concerns were different from those expressed under Effort Expectancy surrounding the student time involved in learning. These faculty framed their class time as a limited resource, and were concerned about content they might not be able to include if they introduced a new technology. Thus, both faculty time and class time were included as facilitating conditions.

5.1.9.5. Formal training. Formal Training (i.e., classes, workshops, and seminars) was mentioned by 19 (90.48 %) of the interviewees as a facilitating condition for learning about or updating their knowledge of engineering technologies. Many of the engineering faculty discussed courses they had taken as part of their graduate program but some had enrolled in classes as a faculty member, taking advantage of education benefits at their university. Many faculty indicated that Formal Training facilitated technology adoption by providing structure that was necessary to allow them to learn new technologies. Some faculty who had spent time in industry contrasted the support their previous work places had provided to fund training for new engineering technologies with the lack of time and incentives for such learning in academia.

5.2. Technology adoption themes absent from the UTAUT models

In addition to verifying and elaborating previously existing constructs within the UTAUT models, this study also identified two new themes related to faculty adoption of engineering technologies, Access to the technology and Personal Traits. New themes uncovered in this work are included in Table 5 and discussed in the following sections.

5.2.1. Access

Access to technologies was discussed by 15 (71.43 %) of the interviewees as influencing their decisions about which technologies to

Table 5
Themes uncovered within this study.

Themes	Definition		Example of text coded with this theme
Access	Free and unfettered access to a technology.		"It's a government freeware right, so there's no support. But the nice thing is it's free so you can download it, and all the students can have it on their own computer. That's the good part."
Personal Traits	Persistence	"The personal tendency to endure through hardships to achieve goals" ([22], p.77).	"...it certainly was hard, but you know you just grind it over time so eventually it's such a long process that you become proficient."
	Humility	The degree to which faculty recognize their ideas about a technology might be wrong (based on [47])	"[I]t's so hard to admit you don't know something, and some [faculty] are really okay with that. They're so happy to say, 'I don't know'…"
	Self Efficacy	What an individual believes about whether their actions can have a meaningful positive result [48].	"So earlier in my career, I was a software programmer and then later just before coming here, I was the technology program manager for a large company. And so my working with technology, the tools to use, I'm very, very comfortable with using them just because in my previous life, I've learned so many new tools and technologies at a faster rate. This is actually not a problem for me at all."
	Growth Mindset	Growth mindset is believing that cognitive abilities can be developed through learning and effort. Fixed mindset is a belief that differences in ability are determined, or fixed, by genetics. [49]	"I teach myself, I expect myself to be able to learn these things right, I mean we want our students to learn them, we should be learning them too. So I think it's just part of the job right."
	Ambiguity Acceptance	An individual's tendency to view ambiguous situations or those with uncertainty as desirable [50].	"It was like, you know… you made me learn the software. I know it. And why are we changing now? And it's getting used to change is an important thing…"
	Curiosity	"[T]he desire to seek and obtain new information" [32], p. 506)	"I'm always looking at that and I'm like, 'What's that? That's interesting.' And then I looked it up … and found out about it, and I'm like, 'Oh, that might work for this thing.'"

teach students. In the interviews, faculty expressed that they did not want to burden students with paying for technologies used in their courses, and thus selected technologies that were freely available to students, such as open source or university licensed software. The theme of Access is related to, but different from, the construct of Price Value, in which a user considers the gain from using a technology against its cost of purchase [9]. The faculty in this study focused on finding and using technologies with *zero* cost for their students. In fact, both the focus groups of high- and low-technology adopters confirmed that free access to a technology was among the most important factors they considered when determining which engineering technologies to teach to their students.

When it came to faculty adoption of technologies for their own research, Access was both a motivator and a barrier. As with teaching, faculty mentioned adopting technologies for use in research because they were free. One interviewee indicated that using such technologies often meant that the pool of other people to go for help would be wider. Interviewees noted that some instruments needed for faculty research are expensive and hard to access, depending on the funding source under which they were purchased and whether they have been formally established as a university-wide resource. Proprietary behavior of faculty towards their labs and lack of communication about shared resources also provided barriers to technology use by faculty.

5.2.2. *Personal traits*

Although existing models for technology adoption do include constructs that account for individual variation in the user's perception of technologies, such as Performance Expectancy and Effort Expectancy, they do not account for variation in the personalities of users that might influence adoption. In our study, several Personal Traits emerged from the data as influences on faculty's adoption of engineering technologies. Although further study of these traits is needed, we propose that these traits might be among the missing factors that contribute to the translation of Behavioral Intention to Use into Use Behavior.

5.2.2.1. Persistence. Persistence was the most commonly identified personal trait influencing technology adoption, with 20 interviewees (91.25 %) discussing situations in which persistence was important as they struggled to learn or use new technologies. Persistence is "the personal tendency to endure through hardships to achieve goals" ([22], p.77). We coded instances of Persistence where faculty discussed continuing with their efforts to adopt a technology in the face of obstacles.

Many faculty explained that they just stuck with a difficult technology until they figured it out. Persistence was discussed by faculty when adopting technologies in both their teaching and research to overcome struggles that were primarily caused by lack of time or other facilitating conditions. Thus, the presence or leveraging of facilitating conditions can help faculty to persist in their technology adoption. One faculty explained how they persisted through the difficulty of adopting computer aided design (CAD) software, despite never having been formally taught it: "Again, brute force, because I never had a CAD class. They did not have it in the curriculum and so, at some point … I had to figure out drafting as a whole. And so I just had to go find books and again, other smart people and say okay, how do you do this?... so I just had to tinker and play." This faculty leveraged the facilitating conditions of Other People and Non-Digital Resources to make up for the lack of another facilitating condition, Formal Training, as they persisted to adopt a new technology.

5.2.2.2. Humility. Instances of Humility were coded in nine (46.82 %) of the faculty interviews. Leary et al. [47] define intellectual humility as "the degree to which people recognize that their beliefs might be wrong" (p.793). We extended this definition to operationalize our definition of Humility in this study as the degree to which faculty recognize their ideas about a technology might be wrong or incomplete. We see Humility being related to the TAM2 construct of image, since Humility required letting go of image concerns. Humility showed up in the data when faculty discussed having to overcome their fears about using a new engineering technology in class, where they might have wrong answers or may not be able to answer all student questions. These fears were intricately tied to their perceived expectation of the professor having all the answers for students, as explained by one faculty member:

> So the students will ask me, "Professor, how do you do this in SewerCAD?" And I won't know the answer. So I send them to the support people for SewerCAD…but part of [the] thing that might stop me is what if I'm embarrassed to admit I don't know? Like as a professor I should know everything, or I feel like at least a student should think I know everything, but I'm only human I don't know everything. And so, I might refuse to use SewerCAD because I would be embarrassed to admit that I don't know everything.

In relation to leveraging other people to support the adoption process, faculty indicated that learning new technologies especially required Humility when in a position where they needed to learn from students. Humility allowed faculty to ask students for help, setting aside their own expectation of always being in the role of expert. Some faculty were able to let go of their expectation that they had to be the expert to the extent that they were able to task students with learning a technology and teaching it to them, as discussed in the Facilitating Conditions section. In this sense, Humility made them better project managers, able to delegate and learn from their subordinates.

5.2.2.3. Self efficacy. A majority of faculty respondents (n = 14; 66.67 %) discussed Self Efficacy with regard to adopting and utilizing technologies. Self Efficacy is an individual's beliefs about whether their actions can have a meaningful positive result [48]. Faculty in our study generally expressed good Self Efficacy surrounding the implementation of engineering technologies both within their teaching and research. This Self Efficacy was often evident in domains where faculty believed in their natural ability, such as programming or learning new software in their subject area. For example, one faculty explained that their adoption of a CAD software "came naturally." However, this same faculty member had mastered other CAD software previously. Mastery experiences are known to contribute to the development of Self Efficacy [51, 52]. Self Efficacy was also expressed by faculty with mastery experiences in a related domain, indicating that even non-technology mastery experiences could influence Self Efficacy about technology adoption. For example, this faculty member explained how experience learning a foreign language supported the ability to learn new programming languages:

> I think that I tend to approach computer languages the same way that you would approach a foreign spoken language. So, looking at a lot of examples and making connections, trying to figure out in my mind how I would translate what I know how to write in language X to turn it into language Y and…just learning that translation and using that as much as I need to until I can start thinking fluently in the new language.

5.2.2.4. Growth mindset. Among the faculty interviewees, 12 (57.14 %) expressed belief about their ability to learn new technologies, indicating a Growth Mindset. Those with a Growth Mindset believe that intelligence or cognitive abilities can develop through learning and experience, while those with a fixed mindset believe intelligence is static [24, 49,53]. Growth Mindset is related to, but different from, Self Efficacy. Self Efficacy can be thought of as one's belief in their ability to perform a task, while a Growth Mindset encompasses the belief that said ability can improve with learning and effort.

Faculty exhibited a Growth Mindset with regard to technology adoption in both their teaching and their research, expressing confidence about learning new technologies, trusting that they would get better with time and effort, and often approaching the learning process with a sense of playfulness. Faculty confidence in their ability to learn a new technology was tied to confidence in their ability to leverage facilitating conditions, especially other people, to learn new technologies. Past experiences learning technologies (mastery experiences) often contributed to faculty's sense that they could learn new technologies; in this sense, Experience, Growth Mindset, and Self Efficacy are related concepts.

Only two faculty interviewees (9.52 %) indicated a fixed mindset with regard to learning a new engineering software. In both cases, the faculty members leveraged other people as surrogate technology adopters. As discussed previously, for example, one faculty member assigned students to learn the technology and teach them only the parts they needed to know. This faculty member characterized leveraging others as good project management.

Among those expressing a growth mindset about technology adoption, five faculty (23.8 %) also expressed a fixed mindset in some other domain. These faculty often indicated using technologies to help them in areas where they expressed fixed mindsets. For example, one faculty member explained why they used Mathematica to help them avoid learning math, "I used it because I'm not good at math. Truthfully, I like the fact that it didn't hold me back … I could use that as the tool to help me solve the mathematical relationships."

5.2.2.5. Ambiguity acceptance. Ambiguity Acceptance was identified as a factor related to faculty engineering technology adoption by 12 (57.14 %) interviewees. The acceptance or tolerance of ambiguity refers to an individual's tendency to view ambiguous situations or those with uncertainty as desirable [50]. Our data indicates that Ambiguity Acceptance supports faculty technology adoption within both their teaching and research. Faculty discussed being comfortable with, or at least resigning themselves to, the ambiguity of not knowing what might come next with regards to technological change:

> [I]n my particular field of computer engineering everything is always changing….new things are being added, software is changing and it's almost a requirement in my discipline to be adopting new technologies, because anything less is a disservice to the students. So it's both a joy and a frustration…I remember one day…I wrote a whole bunch of material on a particular technology. I got done with it and the very next day, there was an announcement online, "look the next version is now released" and I was like "No, I just got done with the previous one." It's not fair. But that's necessary in my line of work and I'm both okay with that and excited by it, but sometimes it can be frustrating.

Those faculty comfortable with ambiguity expressed willingness to let go of the certainty of fully knowing a technology, particularly when dealing with student questions about a technology new to them. In fact, instances coded as Ambiguity Acceptance were often found in conjunction with those coded for Humility. For example, some faculty expressed discomfort with the ambiguity surrounding not knowing what questions students might ask about technologies within the classroom; those who accepted this ambiguity addressed this issue head on by turning the questions around to the students.

5.2.2.6. Curiosity. Instances of curiosity were coded in five (23.81 %) of the faculty interviews. Curiosity is defined as wanting to find and learn new information (e.g., [32,54]) and can be driven by either interest to learn or desire to mitigate a deprivation of information [54]. Faculty expressed Curiosity about the technologies as they learned them, wanting to find applications and abilities of the technologies, as well as new abilities in revised software and programming languages and how these might be used, especially with their students. Among our interviewees, Curiosity was often linked to information seeking behaviors that support technology adoption. For example, this faculty explains how curiosity in learning can consume time, but ultimately results in deeper learning.

> But if I'm learning something new, I will tend to take more time than most to do … And it's usually because in addition to learning one

thing … I would also learn several things around the periphery… it's a double edged sword. So, I'll take a whole bunch of time, and sometimes it might not be worth the time. But other times, you know, usually I'll develop a system and then…be able to do things much quicker and usually better.

Conversely, when Curiosity about a technology is lacking, faculty may have less incentive to learn that technology and may instead partner with others who will implement the technology as surrogate technology adopters. One faculty interviewee who was particularly adept at utilizing students as surrogate technology adopters specifically cited lack of interest in learning more about that technology.

6. Discussion

The results of this study contribute to the field's understanding of engineering faculty's adoption of engineering technologies in four important ways. First, the results confirmed that all of the constructs and variables in the UTAUT2 [9] included in Table 2 are also relevant to understanding the adoption of engineering technologies by university faculty. Our findings provide new insights on two of the constructs: Performance Expectancy and Effort Expectancy. Related to the first, the results showed that in addition to considering how a technology would enhance their own work, faculty also considered a technology's impact on student engagement and its ability to help meet learning objectives when selecting technologies to teach students. This finding is consistent with the literature indicating a technology's usefulness to student learning influenced technology adoption [19,15]. With regard to Effort Expectancy, the time involved in learning an engineering technology was an important consideration in technology adoption, as it has been shown to be with faculty adoption of instructional technologies [12–15]. Although survey items inquiring about the time involved in learning a technology were considered within Effort Expectancy when developing the UTAUT, time did not make it into the final model [8]. Thus, faculty-specific models might add survey items for time involved in learning under Effort Expectancy.

There are some also potentially unique aspects of our findings that are important to highlight with regard to the variables in the UTAUT models. Recall that Vekatesh dropped Voluntariness when revising the UTAUT to the UTAUT2 for consumer settings [9]. In our data, Voluntariness surfaced when faculty discussed their *involuntarily* adoption of new technologies that are used department-wide in the courses they teach or utilized by an existing research group. These results indicate that Voluntariness (or rather involuntariness) influences technology adoption in this workplace setting. Additionally, a variation of Experience, *Transferable Experience* with similar technologies, was also found to aid faculty in their technology adoption. Transferable Experience may be especially important as new technologies evolve over time.

Second, our findings extend the field's understanding of the Facilitating Conditions construct by categorizing five conditions that faculty discussed as facilitating their adoption of engineering technologies. Three of these supports—Other People, Formal Training and Time—have previously been found to support the adoption of instructional technologies. Related to Other People, several researchers [55–58] have found that social supports aid faculty adoption of instructional technologies. One finding from our work that may be unique to university faculty is that they often discussed learning from other people in non-hierarchical ways—leveraging their graduate and undergraduate students to support their learning of a new technology. Other research has also found that a lack of support or access to Formal Training can be a barrier to faculty adoption of instructional technologies [13,14], which aligns with our findings that such training facilitates engineering technology adoption. In addition to influencing Effort Expectancy, time also emerged as an important resource for faculty engineering technology adoption. Time is a well documented barrier to faculty instructional technology adoption [12–15] and faculty schedules are notoriously time limited due to competing demands of teaching, service and scholarship. Thus, providing time for faculty to learn new technologies is important to support their adoption.

We also identified two additional facilitating conditions, Digital and Non-Digital resources. As a sign of our times, all of the faculty in the study reported using Digital Resources in learning new engineering technologies. All but one of the faculty indicated also using Non-Digital Resources to aid in their technology adoption. However, those faculty who indicated a preference for Non-Digital Resources over Digital tended to be more experienced faculty who learned how to learn prior to the explosion of the internet. In general, understanding the Facilitating Conditions that are necessary to support faculty technology adoption can inform universities as they develop programs and other support structures to assist engineering faculty in continuously updating the technologies they use in their courses to ensure that they are best preparing students for the technologies they will use in industry.

Third, we found that Access influenced faculty's adoption of new technologies for their research, as well as those that they taught to their students. In both contexts, faculty preferred to adopt technologies that were freely available, both because this increased the chance that others would also be using the technology (and thus a Facilitating Condition would be in place) and because they were keenly aware of the cost of higher education to their students and wanted to minimize that burden. Prior models of technology adoption did not address varying levels of access to technologies because they focused on the adoption within workplace settings where access is provided by the employer [6–8], or in consumer settings, where access is available, but Price Value matters [9]. The UTAUT2 did acknowledge that access to the facilitating conditions that support technology adoption increases the intention to use a technology [9], but did not address Access to the technology as either a construct or variable in the model.

Fourth, this study identified six Personal Traits that may influence the progression from Behavioral Intention to Use to actual Use Behavior: Self Efficacy, Persistence, Humility, Growth Mindset, Ambiguity Acceptance and Curiosity. Although prior research has examined relationships between some of the individual personal traits that emerged in our work and technology adoption, this research has not been focused on engineering technology adoption by university faculty. Thus, these traits are an important contribution of this study. As noted previously, Self Efficacy was originally proposed for inclusion in the UTAUT, but was removed because it was believed to be captured by Effort Expectancy [8]. As we anticipated, however, Self Efficacy emerged as a theme within our data. Self Efficacy might be a critical personal trait for technology adoption, as it is not only important on its own, but is also related to other personal traits identified in this study. For instance, prior Experience with a positive outcome has been found to contribute to the development of Self Efficacy around similar tasks [51,52] and high levels of Self Efficacy have been found to enhance Persistence [59].

In relation to the Persistence trait, Howard and Crayne [22] identified two dimensions of persistence: (a) Persistence Despite Difficulties—striving towards goals in spite of problems and (b) Persistence Despite Fear —not allowing fear to turn one away from efforts towards goals. Persistence Despite Difficulties has been found to significantly influence organizational outcomes [22], indicating that persistence matters for workplace activities. In the age of Industry 4.0 that is characterized by technology increasingly becoming embedded in work [60], the learning of new technologies is a core workplace activity. Thus, the role of persistence in helping users overcome technology anxiety should be explored in future work. Related to Howard and Crayne's [22] Persistence Despite Fear, we also found that Humility was essential for faculty to overcome their fears about how students would perceive them when using new technologies in the classroom or asking others for help adopting the technology.

Our findings related to the other personal traits also add support to prior research findings. For example, research findings that mindset influences technology adoption [23,25] align with our finding that having a Growth Mindset about their ability to learn new technologies is an important influence on faculty's adoption of engineering technologies. Likewise, the theme of Ambiguity Acceptance aligns with research that has found the ability to tolerate ambiguity is related to making changes to instruction, including adopting new instructional technologies [30]. Finally, Curiosity has been found to be associated with both Perceived Ease of Use and Perceived Usefulness of information technologies [32,31]. Our research similarly found that epistemic curiosity of faculty towards new engineering technologies promoted adoption. Although further study of these personal traits is needed, including how to cultivate and capitalize upon them to support faculty's technology adoption, our findings indicate that these personal traits might contribute to the translation of Behavioral Intention to Use into Use Behavior.

To incorporate the expanded Facilitating Conditions, as well as the new findings related to Access and Personal Traits, we propose a new theory for faculty technology adoption that expands upon the constructs and variables in the UTAUT models. Our proposed theory suggests additional constructs be overlaid with the existing UTAUT2 model; we note that this is not a replacement of the constructs and variables within the UTAUT2. The Theory of Faculty Adoption of Engineering Technologies theorizes that, in the presence of Access to an engineering technology, the progression from Behavioral Intention to Use to actual Use Behavior is influenced by various Facilitating Conditions and by Personal Traits. The proposed model is shown in Fig. 2. We acknowledge the various Facilitating Conditions identified may also influence Behavioral Intention to Use, but faculty in this study discussed Facilitating Conditions primarily in the context of how they supported Use Behavior. Thus, our suggested changes focus on Facilitating Conditions as supporting the transition from Behavioral Intention to Use to Use Behavior. We emphasize that this work was qualitative study designed to reveal additional possible influences on engineering faculty technology adoption, and as such, our findings have resulted in a theory as opposed to a model. The following section suggests additional work necessary to develop this theory into a model.

7. Limitations and directions for future research

We recognize that a major limiting factor of the applicability of the Theory of Faculty Adoption of Engineering Technologies is that it was developed based on 21 engineering faculty interviews at a single predominantly White, STEM-focused R2 institution in the United States. Thus, the findings may not account for all factors that impact faculty technology adoption, such as cultural and societal factors, the varying policies and practices of institutions of higher education in the US and worldwide, and additional personal factors such as language barriers that impact the use of technology support materials. Future work will explore the applicability of the model in a wider range of contexts. We also acknowledge that the self-reported interview data could be subject to social desirability bias [61], so future research might include other data collection methods such as surveys or observation.

We see several other directions for future research that could build on these findings. For example, we theorize that many of the constructs we identified might apply to university faculty's adoption of technologies specific to other disciplines, or even to their adoption of instructional technologies. Further work is needed to understand similarities and differences in technology adoption for various faculty groups, and for different types of technologies. Related to this, we also see the potential for studies with larger sample sizes that could compare technology adoption practices for engineering faculty (or faculty more generally) with varying levels of industry experience, academic career stages, and demographic characteristics. Such work has the potential to reveal nuances in faculty technology adoption among faculty subgroups. Our own ongoing and future work will explore potential university supports that could help faculty more easily adopt new technologies, as well as develop individual reflective inventories to help faculty leverage their personality traits and available support structures to facilitate their technology adoption. Finally, it is important to note that this qualitative study was focused on identifying potential themes missing in the current models. Future quantitative work should develop and validate items and scales to measure each of these new constructs, as well as explore and

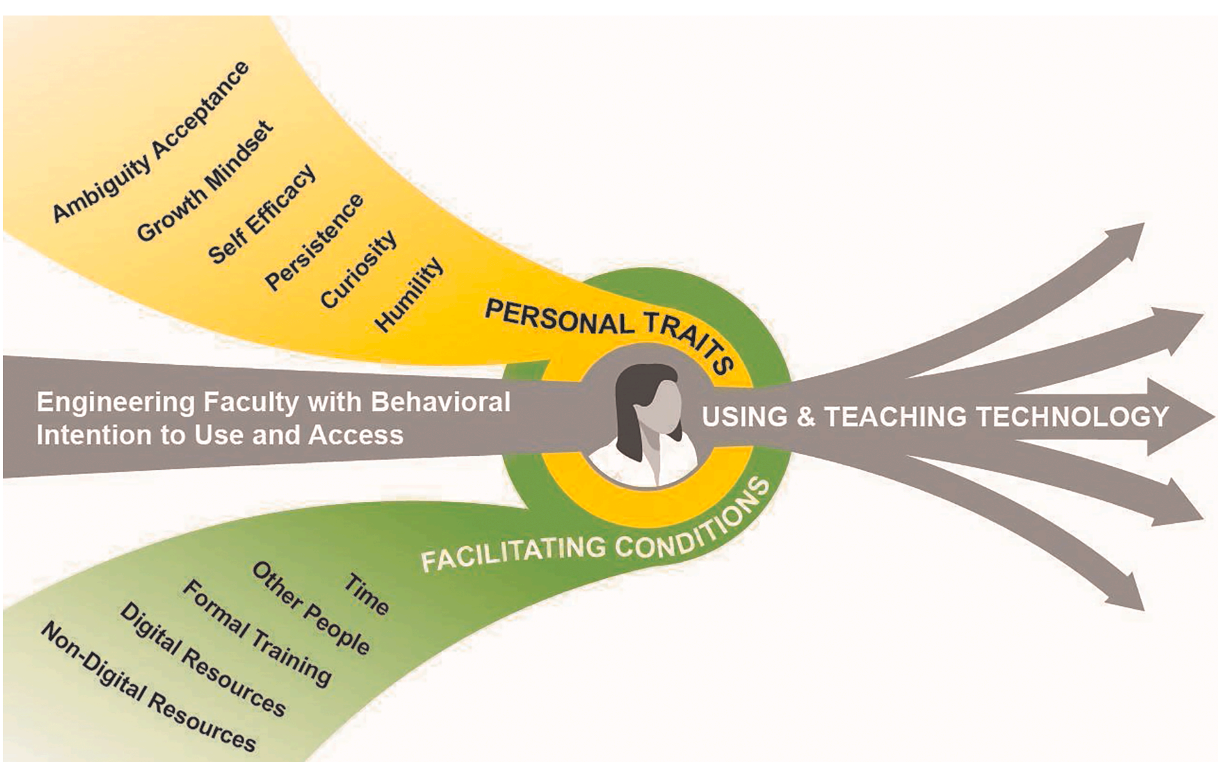

Fig. 2. Theory of faculty adoption of engineering technologies.

confirm the relationships between the proposed and existing constructs and variables.

8. Conclusion

Since technology is developing and changing at a faster rate than ever before, it is imperative that engineering faculty continually adopt and teach new technologies in their engineering courses to ensure that students are prepared for future positions in industry. Our model contributes to what is known about technology adoption by illuminating constructs specific to faculty's engineering technology adoption. Our proposed Theory of Faculty Adoption of Engineering Technologies has the potential to help universities figure out how to effectively support faculty in providing their students with relevant technological skills for entry into the engineering workforce. Understanding potential interventions and their viability within an academic setting is the focus of ongoing work [4,62–64].

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CRediT authorship contribution statement

Michelle Jarvie-Eggart: Writing – original draft, Visualization, Formal analysis, Data curation, Conceptualization, Validation, Project administration, Methodology, Software, Investigation. **Shari L. Stockero:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Alfred Owusu-Ansah:** Writing – review & editing, Software, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Michelle Jarvie-Eggart, Shari Stockero, and Alfred Owusu-Ansah reports financial support was provided by National Science Foundation. Michelle Jarvie Eggart & Shari Stockero reports a relationship with National Science Foundation that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

Interview protocol

1. What technologies (e.g., programming languages, software, apps, etc) do you teach to undergraduate students? Why do you teach these specific technologies to students? (What motivated you to learn each technology? Why this one?) When did you learn each technology? How did you learn it? What challenges, if any, did you encounter in learning it? How did you overcome these?
2. Sometimes faculty use very specific technologies in their research or consulting work that they don't teach to undergraduates. Are there any technologies (e.g., programming languages, software, apps, etc) that you use as an engineering faculty utilize in your own work beyond what you are teaching to students? What are these technologies? Why did you decide to learn each of these? What motivated you to learn each technology? Why this one? When did you learn each technology? How did you learn it? What challenges, if any, did you encounter in learning it? How did you overcome these?
3. Whsat was the last new technology you learned for your research or teaching? Why did you decide to learn this? When did you learn it? How did you go about learning it? What challenges, if any, did you encounter in learning it? How did you overcome these? What resources or supports do you wish you would have had?
4. Tell me about a time when you decided to replace the technology you were using in class. How did you decide which new engineering technology to use or teach in your classes? How did you know when it was time to replace one of these technologies or learn something new? How do you learn about new technologies that are out there in their fields (what's new)? What factors might make you decide not to learn or teach an engineering technology that is used in industry?
5. Tell me about an experience where learning a new technology was hard. What resources did you use to learn to use new technologies? What made it hard? -What would have made it easier?
6. What are your biggest barriers to learning new technologies?
7. How could the university better support your ability to adopt and learn these new technologies? What institutional policies and programs might aid faculty in the adoption of new engineering technologies?

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