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A taxonomy of factors affecting attitudes towards educational technologies for use with technology acceptance models

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Abstract

The aim of this theoretical review was to identify the important factors shown to affect attitudes towards use of educational technologies by students or educators in higher education institutions and organise them into broad, intermediate and narrow groupings. This was done to assist the construction of more objective measurement instruments used in the evaluation of educational technologies. A qualitative review of the influential factors that affect user attitudes, intentions and motivations to use educational technologies was conducted, first by interrogating the fundamental behavioural theories underpinning technology acceptance models, and then by exploring the findings of later and contemporary empirical research conducted in the educational context. Identified factors were grouped to produce an ordered taxonomy of measurement constructs. This taxonomy provides each construct's lineage back through tertiary, secondary and primary taxonomic groups and provides a greater scope of measurement than commonly used models. Seven primary and twenty two secondary and tertiary taxonomic groups were defined, which collectively comprise sixty one measurement constructs. The taxonomy is designed to reduce measurement bias within studies and also acts as a basis for consistent and objective benchmarking within and across institutions.

Introduction

Technology acceptance models (TAMs) are models that "provide an explanation of the determinants of computer acceptance that is general, capable of explaining user behaviour across a broad range of end-user computing technologies and user populations" (Davis, Bagozzi, & Warshaw, 1989, p. 985). The idea of TAMs was introduced by Davis (1986, 1989) who drew on behavioural models including the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), expectancy theory (see Snead & Harrell, 1994), self-efficacy theory (Bandura, 1981), cost-benefit decision processes (Beach & Mitchell, 1978), Innovation Diffusion Theory (IDT) (Tornatzky & Klein, 1982), and the Channel Disposition Model (Swanson, 1987). In doing so Davis concluded that a user's attitude to a technology is focused via the user's Perceived Usefulness and Perceived

Practitioner Notes

What is already known about this topic

- Technology acceptance models are derived from a number of foundational behavioural and motivational theories.
- The TAM and UTAUT are validated models that appraise attitude and/or behavioural intent to use an educational technology, which nonetheless do not cover the entire scope of what has been shown to be important in various studies.
- There is little consistency from study to study of measurement constructs used in technology acceptance models.

What this paper adds

- Collection and organisation of the salient measurement constructs into a flexible taxonomy.
- Establishment of a consistent measurement scope that is specifically suited to educational technology research.
- Establishment of construct lineage that clearly shows similarities and differences between the various constructs.

Implications for practice and/or policy

- The taxonomy supports robust instrument construction to improve both convergent and discriminant validity of measurement models.
- The taxonomy provides a recommended scope for higher education institutions to measure factors affecting use of various educational technologies.
- Consistent use of the taxonomy will provide an objective standard that can be used to compare across institutions or within institutions over time, which assist with benchmarking and management decisions.
- The taxonomy can be used as a framework for meta-analyses or to collate 'prior' data to use in Bayesian-type technology evaluation.

Ease of Use of the technology in question. Since that time, Davis' TAM has been expanded as the TAM2 (Venkatesh & Davis, 2000) and TAM3 (Venkatesh & Bala, 2008).

Venkatesh, Morris, Davis, and Davis (2003) conducted a revision of Davis' TAM, TAM2 (Venkatesh & Davis, 2000), C-TAM-TPB (Taylor & Todd, 1995), the TRA (Fishbein & Ajzen, 1975), Theory of Planned Behaviour (Ajzen, 1991), the Motivational Model (Deci, 1971; Vallerand, 1997), the Model of PC Utilization (Thompson, Higgins, & Howell, 1991), the IDT (Rogers, 1983) and Social Cognitive Theory (Bandura, 1986) in 2003, which resulted in the construction of the Universal Theory of Acceptance and Use of Technology (UTAUT). The UTAUT differs from Davis' original TAM in that it adds a Social Norm construct as a direct influencer of Behavioural Intent to Use, and a Facilitating Conditions construct as a direct influencer of Actual Use. The construction of the UTAUT included judgements about strength or value of some constructs, and so does not include, *inter alia*, attitude, affect or self-efficacy while recent research demonstrates the mediating role of attitude in some situations (López-Bonilla & López-Bonilla, 2017; Moreno, Cavazotte, & Alves, 2017; Park, Nam, & Cha, 2012) and the variance of self-efficacy in different contexts (Tarhini, Hone, & Liu, 2015). The UTAUT has been applied to both general and educational technologies and has internal reliability in various studies (Oye, Iahad, & Ab Rahim, 2014; Sumak, Hericko, Polancic, & Pusnik, 2010), although its utility has not been universal in contrast to the TAM's more flexible structure (Ros *et al.,* 2015).

More recently, the General Extended Technology Acceptance Model for E-Learning (GETAMEL) model was produced after extensive review in a broad variety of settings and covers a broad variety of educational technologies (Abdullah & Ward, 2016), and has been successfully used in over a hundred studies since its publication. The GETAMEL model comprises the five most-used constructs from reviewed research and so excludes constructs that have nonetheless been influential elsewhere.

The literature often reveals scant objective justification in how constructs are chosen or named and measurement models vary considerably. Moore and Benbasat relate that "inadequate definition and measurement of constructs have been identified as major causes" of mixed and inconclusive outcomes (Moore & Benbasat, 1991, p. 132). Considering further that structural equation modelling depends on calculating path coefficients concurrently, it stands to reason that variability in the number of paths and relationships alters the outcomes and inferences of models. It is therefore important that measurement models cover an inclusive scope and measure all likely factors in a way that brings consistency from study to study. We conjecture that this approach would improve validity and external reliability of study results, allowing for closer comparison of results across various settings. To this end, we propose a common lexicon and taxonomy to address this measurement problem.

The purpose of this review is to identify the important factors that influence intention to use educational technology and to organise them using a taxonomic structure. Noting Davis' point that "the size of the usage correlation varies greatly from one study to the next depending on the particular measures used" (Davis, 1989, p. 319) we should not forever exclude factors that have been shown to be less influential in other studies. *A priori* inclusion of all salient factors is important, because we cannot pre-empt technological developments or contextual influences which may elevate the importance of any factors. The taxonomy is an organised collection of such factors.

Methodology

Taxonomy formation

The taxonomy was formed adopting an 'empirical to deductive, deductive to empirical' approach (Nickerson, Varshney, Muntermann, & Isaac, 2009) with the aim of producing a taxonomy that is concise, inclusive, comprehensive and extendable (ibid.). Following the example of Walter, Nutley, and Davies (2003), we formed the taxonomy in stages using different source types.

In stage one, the theories that formed the basis of the TAM and UTAUT were interrogated to identify their included constructs and their associated authors' definitions to form the taxonomic root. The measurement intent of each construct was determined from the author definitions, which represents the "identify general distinguishing characteristics of objects" (Nickerson *et al.,* 2009) stage of the empirical to deductive process. Constructs sharing same or similar distinguishing characteristics (eg, a social factor, an attitude or feeling, a person's capacity, a technology attribute) were then collated into synonymous groups which became the primary groups of the taxonomic root. The deductive to empirical phase of taxonomy construction then began with re-examination of author definitions in the primary groups, which identified nuances allowing for the formation of secondary and, if required, tertiary levels. Tertiary levels were the limit of specificity in order to balance with parsimony, an approach adopted from Stoddard and Brownfield (2018). The co-authors were consulted to confirm the characterisation of the taxonomic groups and qualitative alignment of constructs within them.

The comprehensive review conducted by Abdullah and Ward (2016) was then used in stage two to expand the root by identifying additional constructs specifically relevant to educational technology. Only those which were not already represented, could form new taxonomic groups and which met the inclusion and exclusion criteria were added to the root. As a final check in stage three,

125 papers that cited the GETAMEL model were reviewed, as well as papers identified in a separate search using ["TAM" OR "UTAUT" OR "Technology Acceptance Model"] as the search term and higher education and 2016–2019 as the filters. Redundant measurement constructs were not included to support parsimony.

Inclusion criteria

- Higher education context or setting.
- Educational technology used for instruction, or the delivery of instruction.
- Research subjects are educators or students in the higher education sector.
- Research is peer reviewed, published in scholarly journals from 2004 onwards (the beginning of Web 2.0 capabilities).
- The construct is sufficiently defined to enable placement within the taxonomy.
- The presence of a significant ($p \leq .05$) regression co-efficient between the construct and either Behavioural Intent to Use (BI), or Attitude Towards Use (ATT), either directly or indirectly.

Exclusion criteria

- Research subjects are professional staff.
- Research conducted in a primary or secondary education setting.
- Redundant items.

As with the root taxonomy, the co-authors were consulted to confirm taxonomic structure and make adjustments as required.

Results

Stage one classified thirty-one constructs, stage two, twenty-one, and stage three another nine, bringing the total number of included measurement constructs to sixty-one.

Stage 1—Identification of the ontological foundations and formation of the taxonomic root

Table 1 lists the constructs described in the foundational behavioural theories that form the bases of the later major TAMs. It also lists the constructs from two major TAMs having causative relations with "Behavioural Intent to Use". The construct "Facilitating Conditions" from the Universal Theory of Acceptance and Use of Technology is not included because the UTAUT posits that it moderates the relationship between Behavioural Intent and Actual Use. That is, according to the UTAUT, facilitating conditions does not influence behavioural intent but is downstream of it. However, facilitating conditions is included from the Model of PC Utilization.

Formation of the taxonomic root using semantic groupings

The first step in building a taxonomy is to invert Table 1 so that constructs sharing a common or similar meaning or intention can be grouped using the authors' definitions as guides. Table 2 shows that there are five major common semantic groups that emerge naturally from the foundational behavioural theories. Closer consideration of definitions led to the creation of secondary and tertiary groupings, as shown in Tables 3–7.

Ajzen's (1991) "Perceived Behavioural Control" was considered as its child constructs "Capability & Effort" and "Environmental & Situational" for clear construction of the taxonomic root, although it can be considered to precede both in Tables 6 and 7. Even though Ajzen did not specifically include "Ease of Use" as a component of "Perceived Behavioural Control", it is closely related to a person's self-efficacy and therefore contributes to Ajzen's intention of

Table 1: The constructs that comprise the foundational behavioural intention models

Ontological root	*Included constructs*	*Authors' definitions*
TRA—Theory of Reasoned Action (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975)	Attitude Toward Behaviour	"the individual's positive or negative evaluation of performing the behaviour" (Ajzen & Fishbein, 1980, p. 6)
	Subjective Norm	"the person's perception of the social pressures put on him to perform the behaviour" (Ajzen & Fishbein, 1980, p. 6)
TPB—Theory of Planned Behaviour (Ajzen, 1991)	Attitude Toward Behaviour	Same as above as "The theory of planned behaviour is an extension of the theory of reasoned action" (Ajzen, 1991, p. 181)
	Subjective Norm	Same as above as "The theory of planned behaviour is an extension of the theory of reasoned action" (Ajzen, 1991, p. 181)
	Perceived Behavioural Control	people's "confidence in their ability to perform" a behaviour (Ajzen, 1991, p. 184)
MM—Motivational Model (Deci, 1971; Vallerand, 1997)	Extrinsic Motivation	Motivation to "performing a behaviour in order to achieve some separable goal" (Vallerand, 1997, p. 271)
	Intrinsic Motivation	Behaviour "performed for itself, in order to experience pleasure and satisfaction inherent in the activity" (Vallerand, 1997, p. 271), not for any external reward or results that come from it (Deci, 1971)
MPCU—Model of PC Utilization (Thompson *et al.,* 1991)	Job-fit	"the capabilities of a PC to enhance an individual's job performance" (Thompson *et al.,* 1991, p. 129)
	Complexity	"the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers & Shoemaker, 1971, p. 154)
	Long-term Consequences	"outcomes that have a payoff in the future [as opposed to] addressing current needs" (Thompson *et al.,* 1991, p. 129)
	Affect Towards Use	"the feelings of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act" (Triandis, 1980, p. 211)
	Social Factors	"the individual's internalization of the reference groups' subjective culture, and specific interpersonal agreements that the in- dividual has made with others, in specific social situations" (Triandis, 1980, p. 210)
	Facilitating Conditions	"objective factors…that…make an act easy to do" (Triandis, 1980, p. 205)
IDF—Innovation Diffusion Theory (Rogers, 1983)	Relative Advantage	"the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 1983, p. 213)
	Complexity	"The degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 1983, p. 230)
	Trialability	"the degree to which an innovation can be experimented with on a limited basis" (Rogers, 1983, p. 231)
	Observability	"the degree to which the results of an innovation are visible to others" (Rogers, 1983, p. 232)
	Compatibility	"the degree to which an innovation is perceived as being consistent with the existing values, past experiences and needs of potential adopters" (Rogers, 1983, p. 223)

Table 1: (Continued)

Ontological root	*Included constructs*	*Authors' definitions*
AITI—Adoption of Information Technology Innovation (Moore & Benbasat, 1991)	Image	"the degree to which use of an innovation is perceived to enhance one's image or status in one's social system" (Moore & Benbasat, 1991, p. 195).
	Voluntariness of Use	"the degree to which use of the innovation is perceived as being voluntary, or of free will" (Moore & Benbasat, 1991, p. 195)
	Results Demonstrability	Relates to whether an innovation can be measured, observed and communicated. (Moore & Benbasat, 1991)
	Visibility	Relates to how immediately visible an innovation is, such as a hardware innovation. (Moore & Benbasat, 1991)
	Ease of Use	A renamed version of 'Complexity' (Rogers, 1983).
SCT—Social Cognitive Theory (Bandura, 1977, 1981, 1986) and adaptation to use of computers (Compeau & Higgins, 1995)	Outcome Expectations (Performance)	"a person's estimate that a given behaviour will lead to certain outcomes" (Bandura, 1977, p. 193)
	Outcome Expectations (Personal)	The "personal consequences of the behaviour" (Venkatesh *et al.,* 2003, p. 432) in terms of esteem and accomplishment
	Self-Efficacy	"Peoples' judgements of their capabilities to organize and execute courses of action required to attain designated types of performances. It is concerned not with the skills one has but with judgements of what one can do with whatever skills one possesses" (Bandura, 1986, p. 391)
	Affect	"liking for particular behaviours" (Compeau & Higgins, 1995, p. 196)
	Anxiety	"Evoking anxious or emotional reactions when it comes to performing a behaviour" (Venkatesh *et al.,* 2003, p. 432)
TAM-O (Davis, 1986)	Perceived Usefulness	"the user's subjective probability that using a specific application system will increase his or her job performance within an organizational context." (Davis *et al.,* 1989, p. 985)
	Perceived Ease of Use	"the degree to which the prospective user expects the target system to be free of effort." (Davis *et al.,* 1989)
	Attitude Towards Use	Davis relates that the TAM was extended from the Theory of Reasoned Action. Accordingly, we adopt the definition for Attitude from the TRA: "the individual's positive or negative evaluation of performing the behaviour" (Ajzen & Fishbein, 1980, p. 6)
UTAUT (Venkatesh *et al.,* 2003)	Performance Expectancy	"the degree to which an individual believes that using the system will help him or her to attain gains in a job performance" (Venkatesh *et al.,* 2003, p. 447)
	Effort Expectancy	"the degree of ease associated with the use of the system" (Venkatesh *et al.,* 2003, p. 450)
	Social Influence	"the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh *et al.,* 2003, p. 451)

Table 2: Semantic groupings of the constructs derived from foundational theories vis-à-vis use of educational technology

Primary construct group and semantic intent	*Identified construct*
Attitude and Affect A person's attitude towards using the educational technology and the associated affectual state	Attitude Towards Behaviour (TRA, TPB) Attitude Towards Use (TAM-O) Intrinsic Motivation (MM) Affect Towards Use (MPCU) Affect (SCT) Anxiety (SCT) [negative]
Social Factors Perceptions of others' opinions on the use of the educational technology, including agreements and how one is perceived by others	Subjective Norm (TRA, TPB) Social Influence (UTAUT) Social Factors (MPCU) Voluntariness of Use (AITI) Image (AITI) Outcome Expectations (Personal) (SCT)
Usefulness and Visibility The value of using the educational technology in terms of meeting an operational need and the visibility to others	Relative Advantage (IDF) Extrinsic Motivation (MM) Job-fit (MPCU) Long-term consequences (MPCU) Outcome Expectations (Performance) (SCT) Perceived Usefulness (TAM) Performance Expectancy (UTAUT) Compatibility (IDF) Results Demonstrability (AITI) Visibility (AITI) Observability (IDF)
Capability and Effort The ease or difficulty of using the educational technology given one's abilities	Complexity (IDF, MPCU) [negative] Ease of Use (AITI) Perceived Ease of Use (TAM) Effort Expectancy (UTAUT) Self-efficacy (SCT)
Environmental and Situational The systemic or situational factors that affect the ability to use the educational technology	Facilitating Conditions (MPCU) Facilitating Conditions (Triandis, 1977) Context of Opportunity (Sarver, 1983) Trialability (IDF)

Perceived Behavioural Control. The final taxonomy combines both "Capability & Effort" and "Environmental & Situational" groups as secondary beneath "Perceived Behavioural Control". Rogers' (1983) 'Trialability' was placed alongside Sarver's (1983) 'Opportunity' as both relate to the opportunity to engage with an educational technology in a situational or access sense.

The inductive process represented in Tables 2–7 resulted in four primary groups: Attitude & Affect, Social Factors, Usefulness & Visibility, and Perceived Behavioural Control as represented in Table 8.

Table 3: Semantic groupings of the Attitude & Affect primary taxonomic group

Attitude & Affect	
Secondary construct group and definition	Member constructs and definitions
Attitude The individual's positive or negative evaluation of using the educational technology	*Attitude Towards Behaviour (TRA, TPB); Attitude Towards Use (TAM-O)* The individual's positive or negative evaluation of using the educational technology
Affect The emotional or affectual state associated with the use of the educational technology	*Intrinsic Motivation (MM)* The motivation to use the educational technology deriving from the expected pleasure or satisfaction thereof *Affect Towards Use (MPCU); Affect (SCT)* The positive or negative feelings towards use of the educational technology *Anxiety (SCT) [negative]* A state of unease, nervousness or apprehension with respect to using an educational technology

Table 4: Semantic groupings of the Social Factors primary taxonomic group

Social Factors	
Secondary construct group and definition	Member constructs and definitions
Social Influence The effect of a group's culture, norms and direct influences with respect to use of an educational technology	*Subjective Norm (TRA, TPB); Social Factors (MPCU); Social Influence (UTAUT)* The person's perception of the social pressures to use the educational technology in terms of culture and norms *Voluntariness of Use (AITI)* The degree to which use of the educational technology is voluntary.
Image & Esteem How one is/will be perceived by others as a result of using the technology	*Image (AITI); Outcome Expectations (Personal) (SCT)* The degree to which use of the educational technology will augment the esteem or image of the user within a social group

Stages 2 and 3—Incorporating subsequent research into the root taxonomy

The root taxonomy in Table 8 serves only as a foundational base that needs to be extended to cover contemporary and educational scope. In this section we incorporate new salient factors uncovered by later educational research to arrive at a full taxonomy.

Affect, attitude and motivation

The TRA and TPB relate the importance of attitude as an influencer of behaviour, and Davis' original TAM ("TAM-O") (1986) placed it as a precursor to behavioural intent. However, Davis' revised TAM ("TAM-R") (1989) removed it because "attitudes do not fully mediate the effect of perceived usefulness and perceived ease of use on behaviour" (Davis, 1989, p. 335). The TAM2 (Venkatesh &

Table 5: Semantic groupings of the Usefulness & Visibility primary taxonomic group

Usefulness & Visibility	
Secondary construct group and definition	Member constructs and definitions
Usefulness The degree to which use of an educational technology meets an operational need	*Relative Advantage (IDF); Extrinsic Motivation (MM) Job-fit (MPCU); Long-term Consequences (MPCU); Outcome Expectations (Performance) (SCT); Perceived Usefulness (TAM); Performance Expectancy (UTAUT); Compatibility (IDF);* The degree to which use of an educational technology meets an operational need more than alternatives
Visibility The degree to which use of the educational technology is observable to others	*Results Demonstrability (AITI); Visibility (AITI); Observability (IDF)* The degree to which use of the educational technology is observable to others

Table 6: Semantic groupings of the Capability & Effort primary taxonomic group

Capability & Effort	
Secondary construct group and definition	Member constructs and definitions
Ease of Use The degree to which the user perceives an educational technology to be easy to use	*Complexity (IDF, MPCU) [negative]; Ease of Use (AITI); Perceived Ease of Use (TAM); Effort Expectancy (UTAUT)* The degree to which the user perceives an educational technology to be easy to use in terms of the interface and system that deploys it
Self-efficacy A person's perceived capability to use various attained computer skills to successfully engage with educational technology	*Self-efficacy (SCT)* A person's perceived capability to use various attained computer skills to successfully engage with educational technology

Table 7: Semantic groupings of the Environmental & Situational primary taxonomic group

Environmental & Situational	
Secondary construct group and definition	Member constructs and definitions
Facilitating Conditions The degree to which the user perceives that external factors assist use of an educational technology	*Facilitating Conditions (MPCU); Facilitating Conditions (Triandis)* The degree to which the user perceives that external factors assist use of an educational technology
Opportunity The degree to which a person perceives that opportunity and access to the educational technology are present	*Context of Opportunity (Sarver); Trialability (IDF)* The degree to which a person perceives that opportunity and access to the educational technology are present

Davis, 2000), TAM3 (Venkatesh & Bala, 2008) and UTAUT (Venkatesh *et al.*, 2003) models likewise do not feature attitude as a mediatory construct because it was found to be non-significant in the presence of usefulness and ease of use, and Teo (2009a) later demonstrated that attitude did not

Table 8: The taxonomic root that emerges from semantic alignment of the fundamental behavioural theories, Davis' TAM and Venkatesh et al's UTAUT

Primary taxonomy group	*Secondary taxonomy group*	*Tertiary taxonomy group*	*Measurement construct*
Attitude & Affect	Attitude		Attitude Towards Behaviour (TRA, TPB) Attitude Towards Use (TAM)
	Affect	Intrinsic Motivation Affect Towards Use	Intrinsic Motivation (MM) Affect Towards Use (MPCU) Affect (SCT)
		Anxiety	Anxiety (SCT) [Neg]
Social Factors	Social Influence	Subjective Norm	Subjective Norm (TRA, TPB) Social Factors (MPCU)
			Social Influence (UTAUT)
		Voluntariness	Voluntariness of Use (AITI)
	Image & Esteem		Image (AITI) Outcome Expectations (Personal) (SCT)
Usefulness & Visibility	Usefulness		Relative Advantage (IDF) Extrinsic Motivation (MM)
			Job-fit (MPCU)
			Long-term Consequences (MPCU)
			Outcome Expectations (Performance) (SCT)
			Perceived Usefulness (TAM)
			Performance Expectancy (UTAUT)
			Compatibility (IDF)
	Visibility		Results Demonstrability (AITI) Visibility (AITI)
			Observability (IDF)
Perceived Behavioural Control	Capability & Effort	Ease of Use	Complexity (IDF, MPCU) [negative] Ease of Use (AITI)
			Perceived Ease of Use (TAM)
			Effort Expectancy (UTAUT)
		Self-efficacy	Self-efficacy (SCT)
	Environmental & Situational	Facilitating Conditions	Facilitating Conditions (MPCU, Triandis)
		Opportunity	Context of Opportunity (Sarver) Trialability (IDF)

affect total variance of behavioural intent, confirmed by Nistor and Heymann (2010). However, attitude was influential as a distinct mediatory factor in a voluntary setting (López-Bonilla & López-Bonilla, 2011) and when PLS-SEM was used as the analysis method (López-Bonilla & López-Bonilla, 2017; Yang & Su, 2017). Chau also demonstrated "significant positive impacts" (Chau, 2001, p. 30) when attitude was a precursor to both usefulness and ease of use and Teo *et al.,* (2017) found that teacher experience can impact attitude directly. Attitude can also relate to personal bearing instead of being directed to a technology, and Hao *et al.* have shown the significant influence of personal innovativeness ("an individual's willingness to take a risk and try a new technology") (Hao, Dennen, & Mei, 2017, p. 107) on ease of use and thus to behavioural intent. Thus, attitude can sometimes be subsumed by other constructs, while in other settings, and measured in certain ways, it can appear distinctly. As such we retain the attitude construct within the taxonomy.

Affect has generally not had as high an impact on behavioural intent as other constructs, and for this reason it was not included in the UTAUT model (Venkatesh *et al.,* 2003). However, user enjoyment ("the extent to which the activity of using the computer is perceived to be enjoyable in its own right" Martinez-Torres *et al.,* 2008, p. 498) has been shown to have "significant effect on intentions" (Davis, Bagozzi, & Warshaw, 1992, p. 1111) and so we retain it. User satisfaction, defined as "the degree to which users are satisfied and pleased with their prior use of an information system" (Lee & Lehto, 2013, p. 195) is simply an affectual state, and so we place satisfaction in the affect group. Learning motivation, defined as "learner motivation to learn" (Huang & Liaw, 2018, p. 95), and learning goal orientation, defined as "an achievement-oriented motivation via task learning process" (Cheng, 2011, p. 275) have a drive element that pure affect does not and so we have placed learner motivation and learning goal orientation in a group called 'Intrinsic Motivation' parallel to affect. In recognising the implicit pleasure aspect of intrinsic motivation (Vallerand, 1997), we posit that motivation must be associated with affect, although its directional element is a distinguishing feature. In light of these considerations we modify the "Attitude & Affect" primary taxonomic group from the root taxonomy in Table 8 to "Attitude, Affect & Motivation" (Table 9).

System and learning usefulness

Educational compatibility has been defined as "the degree to which an e-learning system is perceived as being congruent with a student's learning expectancy" (Chen, 2011, p. 1504). It is a reflection of learning usefulness, which we define as the ability of the learning resource to deliver desired learning outcomes. This is conceptually a different type of usefulness than system usefulness, which we define as the ability of the technology to produce a learning resource, and so we propose that an

Table 9: Modifications to "Attitude & Affect"

Attitude, Affect & Motivation	Attitude		Attitude Towards Behaviour (TRA, TPB) Attitude Towards Use (TAM)
			Personal Innovativeness
	Intrinsic Motivation		Intrinsic Motivation (MM) Learner Motivation
			Learning Goal Orientation
	Affect	Affect Towards Use	Affect Towards Use (MPCU) Affect (SCT)
			Perceived Enjoyment
			User Satisfaction
		Anxiety	Anxiety (SCT) [Neg]

educational technology is useful only if it performs the double function of producing a learning resource that then helps the student achieve their learning goals. Another way that educational technology has been shown to be useful in a system sense is in 'quality of work life' (Tarhini *et al.,* 2015), which has been defined "in terms of students' perception and belief that using the technology will improve their quality of work life such as saving expenses when downloading e-journals, or in communication when using email to communicate with their instructors and colleagues." (Tarhini, Hone, Liu, & Tarhini, 2017, p. 311). This may be important in voluntary situations and so we include it addressing system usefulness. In light of the above considerations we therefore suggest that the usefulness construct be explicitly applied as both system and learning usefulness in educational technology research, and so we have modified Rogers' "compatibility" (1983) to "educational compatibility" in the final taxonomy and renamed "Usefulness" to "System and Learning Usefulness".

Instructional attributes

Learning usefulness is itself supported by instructional design factors such as feedback, defined as "an important mechanism that helps to modify and reinforce those factors that assist in altering perceptions" (Martinez-Torres *et al.,* 2008, p. 498), which can be adaptive (Tobing, Hamzah, Sura, & Amin, 2008). Instructor-learner interaction ("the degree of online interaction between instructors and learners via the e-learning system" Cheng, 2013, p. 75) and learner-learner interaction ("the degree of online interaction between learners and other learners via the e-learning system" Cheng, 2013, p. 75) rely on the ability of the technology to enable these forms of social interaction important to learning. Collaboration, defined as "using features of cloud-based applications to facilitate students' collaboration" (Yadegaridehkordi, Shuib, Nilashi, & Asadi, 2019, p. 85) has been shown to influence usefulness and ease of use and naturally sits alongside student-student interaction but has a groupwork emphasis. Teaching materials (Rajak *et al.,* 2018) can be represented by both content features ("the characteristics and presentation of course content and information" Tran, 2016, p. 257) and content richness ("the abundance of learning resources that users can access to enrich their learning activity" Lee & Lehto, 2013, p. 196) which have both been found influential in attitude formation in the above studies. Rajak *et al.,* (2018) also provide evidence that design of learning contents is influential and because this represents how materials are assembled and presented we add it to the taxonomy. Finally, there is evidence that lecturers' positive attitudes to e-learning "contributes to the acceptance of [it]" (Rajak *et al.,* 2018, p. 2343) by supporting usefulness (Lee, Yoon, & Lee, 2009). In addition, technological pedagogical content knowledge ("TPCK"), defined as "a large body of sophisticated knowledge to understand how to use technology to improve the teaching" (Teo *et al.,* 2017, p. 813) has influenced usefulness and behavioural intent (Teo *et al.,* 2017). Both lecturers' characteristics and their knowledge are related and contribute to the successful deployment of a learning resource. Accordingly we have formed a primary taxonomic group called 'Instructional Attributes' to house lecturer attributes, feedback, interaction and content attributes as per Table 10, which could be considered in support of learning usefulness.

Perceived Behavioural Control

Abdullah & Ward (2016) demonstrated that experience is the fifth most measured construct and they related it to users' growth of skills, implying that prior experience influences perceived ease of use or the self-efficacy that results from those skills thereby improving attitude. Another study showed that actual use of a wiki system positively influenced continued use (Yueh, Huang, & Chang, 2015). Because there is more solid evidence that experience is related to skills growth, we have included it within the Ease of Use taxonomic group as an associated factor of perceived ease of use.

The review revealed that self-efficacy is a targeted, rather than general, concept that deals with how a person uses their skillset as opposed to the level of skills themselves (Bandura, 1981). For example, computer self-efficacy, defined as "a user's assessment of his or her capability to use a computer" (Teo, 2009b, p. 304) is different to e-learning self-efficacy ("the personal confidence in finding information

Table 10: Formation of the "Instructional Attributes" taxonomic group

Instructional Attributes	Lecturer Attributes	Lecturer Characteristics Technological Pedagogical Content Knowledge (TPCK)
	Content Attributes	Content Features Content Richness
		Design of Learning Contents
	Feedback	Feedback System Adaptability
	Social Interactivity	Learner-Learner Interaction Instructor-Learner Interaction
		Collaboration

and communicating with an instructor within the e-learning system and the necessary skills for using the system" Park, 2009, p. 152). Due to the variety of technological targets, we have modified the root taxonomy to include self-efficacy of various forms in their own section. As well as e-learning self-efficacy, students need accessibility ("the degree of ease with which a university student can access and use a campus e-learning system as an organizational factor" Park, 2009, p. 153) and mobility ("the ability of using cloud applications via mobile devices freely without any time or place limitation" Yadegaridehkordi *et al.,* 2019, p. 85), which we see as forming part of the opportunity taxonomic group, and training ("effort to teach and train their students to acquire E-learning skills" Alenezi, Karim, & Veloo, 2011), which we have placed within the facilitating conditions group. These modifications complete the Perceived Behavioural Control taxonomic group as per Table 11.

Cognitive engagement

Our review noted the effects of cognitive absorption ("a state of deep involvement" Saade & Bahli, 2005, p. 320) and flow ("the state in which people are so involved in an activity that nothing else seems to matter" Saade & Bahli, 2005, p. 318) on attitudes, in addition to concentration ("degree to which users maintain exclusive, focused attention on their activity" Liu, Liao, & Pratt, 2009, p. 602), which we saw as sufficiently related to place in a taxonomic group called "Absorption". Alongside this, the concept of vividness ("the ability of a technology to produce a sensorially rich mediated environment" Steuer, 1992, p. 80) was discussed in terms of sensorial richness,

Table 11: Modifications to "Perceived Behavioural Control"

Perceived Behavioural Control	Capability & Effort	Ease of Use	Complexity (MPCU, IDF) [negative] Ease of Use (AITI)
			Perceived Ease of Use (TAM)
			Effort Expectancy (UTAUT)
			Experience
		Self-efficacy	Self-efficacy (SCT) (various forms)
	Environmental & Situational	Facilitating Conditions	Facilitating Conditions (MPCU, Triandis) Training
		Opportunity	Context of Opportunity (Sarver) Trialability (IDF)
			Accessibility
			Mobility

Table 12: Formation of the "Cognitive Engagement" taxonomic group

Cognitive Engagement	Absorption	Cognitive Absorption Concentration Flow
	Playfulness	Perceived Playfulness
	Vividness	Vividness

relating it to cognitive processes and so is separate from content richness, which relates to media variety. Lee *et al.* (2009) discuss playfulness in terms of focussing attention and engaging curiosity and so has been used as a measure of flow. Together, absorption, vividness and playfulness therefore relate to the focus, attention and absorption of the learner and we have formed a primary taxonomic group called "Cognitive Engagement" (Table 12).

System attributes

"System Attributes" is a proposed primary taxonomic group related to how the system itself performs as a separate consideration to the learning it produces—we relate this to 'system usefulness' as distinct from 'learning usefulness' of the resources so-produced. The advent of cloud computing brings with it considerations of security and privacy ("the degree to which students believe that cloud services are secure platforms for storing and sharing sensitive data" Arpaci, Kilicer, & Bardakci, 2015, p. 94) of student information, which can affect student attitudes towards the technology. System usefulness depends on its function ("the perceived ability of an e-learning system to provide flexible access to instructional and assessment media" Pituch & Lee, 2006, p. 225), response to user inputs ("the degree to which a learner perceives that the response from the e-learning system is fast, consistent, and reasonable" Pituch & Lee, 2006, p. 225), and system interactivity ("learner-environment interaction consists of learners making use of a range of mechanisms for creating and modifying virtual worlds" Huang & Liaw, 2018, p. 94). There is evidence that personalisation, defined as "the process of changing interface, functionality, information content, or distinctiveness of a system to improve personal relevance" (Yadegaridehkordi *et al.,* 2019, p. 86) also influences perceived ease of use in cloud systems. Function, response, interactivity and personalisation have been placed in a secondary taxonomic group called "System Function & Response". Information security and privacy is slightly different and may not necessarily relate to usefulness directly, although could certainly influence attitudes and intention to use a voluntary technology if a user was sensitive to such concerns. Table 13 shows the resultant system attributes primary taxonomic group (see Table 13).

The final taxonomy

The final taxonomy is presented in Table 14.

Table 13: Formation of the "System Attributes" taxonomic group

System Attributes	Information Security & Privacy System Function & Response	Information Security & Privacy System Functionality System Interactivity System Response Personalisation

Table 14: The final taxonomy after reviewing all considerations

Primary taxonomy group	*Secondary taxonomy group*	*Tertiary taxonomy group*	*Measurement construct*
Attitude, Affect & Motivation	Attitude		Attitude Towards Behaviour (TRA, TPB) Attitude Towards Use (TAM) Personal Innovativeness
	Intrinsic Motivation		Intrinsic Motivation (MM) Learner Motivation Learning Goal Orientation
	Affect	Affect Towards Use	Affect Towards Use (MPCU) Affect (SCT) Perceived Enjoyment User Satisfaction
		Anxiety	Anxiety (SCT) [Neg]
Social Factors	Social Influence	Subjective Norm	Subjective Norm (TRA, TPB) Social Factors (MPCU) Social Influence (UTAUT)
		Voluntariness	Voluntariness of Use (AITI)
	Image & Esteem		Image (AITI) Outcome Expectations (Personal) (SCT)
Usefulness & Visibility	System and Learning Usefulness		Relative Advantage (IDF) Extrinsic Motivation (MM) Job-fit (MPCU) Long-term Consequences (MPCU) Outcome Expectations (Performance) (SCT) Perceived Usefulness (TAM) Performance Expectancy (UTAUT) Educational Compatibility (IDF) Quality of Work Life
	Visibility		Results Demonstrability (AITI) Visibility (AITI) Observability (IDF)
Instructional Attributes	Lecturer Attributes		Lecturer Characteristics Technological Pedagogical Content Knowledge (TPCK)
	Content Attributes		Content Features Content Richness Design of Learning Contents
	Feedback		Feedback System Adaptability
	Social Interactivity		Learner-Learner Interaction Instructor-Learner Interaction Collaboration

Table 14: Continued

Primary taxonomy group	*Secondary taxonomy group*	*Tertiary taxonomy group*	*Measurement construct*
Perceived Behavioural Control	Capability & Effort	Ease of Use	Complexity (IDF, MPCU) [negative] Ease of Use (AITI) Perceived Ease of Use (TAM) Effort Expectancy (UTAUT) Experience
		Self-efficacy	Self-efficacy (SCT) (various forms)
	Environmental & Situational	Facilitating Conditions	Facilitating Conditions (MPCU, Triandis) Training
		Opportunity	Context of Opportunity (Sarver) Trialability (IDF) Accessibility Mobility
Cognitive Engagement	Absorption		Cognitive Absorption Concentration Flow
	Playfulness		Perceived Playfulness
	Vividness		Vividness
System Attributes	Information Security & Privacy		Information Security & Privacy
	System Function & Response		System Functionality System Interactivity System Response Personalisation

Discussion

Building a reliable measure of factors affecting attitudes, intentions and behaviours required the incorporation of all factors shown or theorised to be influential. The inductive process initially identified a root taxonomy based on the foundational behavioural and motivational theories that underpin the TAM and UTAUT that had four primary groups: Attitude & Affect, Social Factors, Useability & Visibility and Perceived Behavioural Control. Consideration of more contemporary research slightly modified some of these groups and identified additional constructs, which were organised into three additional primary taxonomic groups: Instructional Attributes, Cognitive Engagement and System Attributes.

The taxonomy is as parsimonious as possible and does not include every synonymous measurement construct identified in reviewed research. In operationalisation it is recommended to include at least the primary taxonomic groups in research instruments, although the secondary and tertiary taxonomic groups provide for more targeted research, and within them, measurement constructs can be carefully chosen. For example, in the Usefulness & Visibility group, "Relative Advantage" may be used when comparing two or more technologies, however "Job Fit" could be more appropriate when appraising a single technology. The Usefulness & Visibility primary group can also be operationalised according to whether the research is measuring system usefulness or learning usefulness.

A second benefit of the use of the taxonomy is to manage convergent and discriminant validity of the measurement model. Referring to the taxonomy, it can be seen that "Anxiety" and "Self-efficacy" could conceivably co-vary. The taxonomy offers either "User Satisfaction" or "Perceived

Enjoyment" within the "Affect" group as alternatives to "Anxiety". In this way the taxonomy is a useful tool in the construction of a robust measurement model both in terms of operationalising the model to a particular context and also to improve discrimination between latent constructs.

We believe that the taxonomy is a tool to reduce measurement bias because it was constructed to include a comprehensive collection of factors, as recommended by Nickerson *et al.,* (2009), applicable to all educational technologies surveyed. It is intended that by including a fuller suite of relevant measurement constructs that a larger variance of Behavioural Intent may be accounted for, although individual research will demonstrate to what extent this occurs. A limitation of the taxonomy is that it may be appropriate to extend it as new technologies or contexts emerge.

The taxonomy is architecturally neutral in that while it is useful in advising what to measure, it leaves open the question of structure, which is the topic of further research. While structural model architecture is outside the scope of this paper, it is sufficient to say that closer review of each of the taxonomy's taxonomic groups could provide guidance on structural model construction.

Conclusion

A qualitative review was conducted of the precursor behavioural, motivational and attitudinal theories that underpinned the creation of both Davis' TAM and Venkatesh's UTAUT models, as well as of more recent educational technology research. Semantic alignment of the identified constructs allowed them to be grouped according to measurement intent. Arrangement of the constructs into primary, secondary and tertiary taxonomic groups produced seven primary and twenty two secondary and tertiary taxonomic groups, which collectively organise sixty one measurement constructs. The taxonomy is larger in scope than many of the currently used acceptance models because it includes and organises the variety of factors that the foundational behavioural theories and later empirical studies indicate are important in human decision making vis-à-vis educational technology use. It is intended that using this to operationalise measurement models could increase variance accounted for in measurement and structural models, and improve external validity of studies by introducing consistency and reducing measurement bias.

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Statements on open data, ethics and conflict of interest

All of the data are available within this article and the journals referenced.

We declare that no human participants were involved in this study.

We declare no conflict of interest concerning this study.

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