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Learning Technologies: Bridging the Gap between Intention, Adoption and Routine Use*

DAVID M. BOURRIE
School of Computing, University of South Alabama, Shelby Hall, Room 1207. Mobile, AL 36688-0002, USA.
E-mail: dbourrie@southalabama.edu

L. ALLISON JONES-FARMER
Farmer School of Business, Miami University, Oxford, OH 45056, USA. E-mail: farmerl2@miamioh.edu

CHETAN S. SANKAR
Harbert College of Business, 413 Lowder Hall, Auburn University, Auburn, Alabama 36849, USA.
E-mail: sankacs@auburn.edu

Substantial funds are invested in developing educational technologies with the goal that faculty members adopt and routinely use these technologies. This research establishes that there is a gap between the development and widespread adoption/use of these technologies. This paper investigates (1) which critical success factors (CSF) influence faculty members to adopt and routinely use technologies, and (2) whether the CSFs moderate the adoption process. Based on surveys of 335 computer science and electrical engineering faculty members, the research findings pinpoint the factors that influence the adoption and routine use of educational technologies. These results can be used by developers of educational technologies to create and establish plans to increase faculty awareness of and create positive attitudes towards the technologies.

Keywords: adoption; critical success factors; faculty members; learning technologies; readiness

1. Introduction

Many for-profit companies and non-profit institutions are making significant investments in learning technologies. In the six-month period between January and June 2015, $2.51 billion was invested in learning technology companies across the globe. This is an astonishing amount considering the total global investments made in learning technology companies for the entire year of 2014 was $2.42 billion, which set a record in the industry [1, 2]. These learning technology companies develop instructional products directly involved in the learning process. The National Science Foundation (NSF), with its mission to advance science, engineering, and education, plans to invest over $100M in FY 2015 through coordinated investments across directorates within a coherent framework for improving undergraduate Science, Technology, Engineering and Math (STEM) learning [3]. A primary goal of this expenditure by the NSF is to learn whether theories of change from business or other sectors may be applicable to educational reform. In particular, NSF is interested in bringing about a shift in underlying cultural norms necessary to support the institution-wide embrace of effective teaching approaches and supports research on how to advance change [3, 4]. Despite the increased funding for pedagogical research in STEM fields, traditional lectures with PowerPoint slides are still used in the majority of STEM classrooms in the United States [5, 6].

The learning technology marketplace continually inundates educators with new hardware, software, methods, and techniques, whereas, a few of these technologies are routinely used in the classroom [7, 8]. Educators have a unique set of personal values, motivators, organizational policies and alliances that influence the adoption decision of these technologies [9]. Several studies have identified some of the factors that influence the adoption process but the body of research is still nascent [10–12]. Research regarding the dissemination and adoption of educational technologies is underdeveloped and can even appear to be somewhat of an afterthought to producing the new technologies [10, 13, 14]. Little empirical work has been done in identifying the critical success factors (CSFs) in the adoption process [11, 15]. We look to fill this gap in the literature by identifying the CSFs that influence successful adoption and use of educational technologies. Therefore, the goal of this paper is to investigate (1) which CSFs influence faculty members to adopt and routinely use educational technologies, and (2) whether the CSFs moderate the adoption process.

In section 2, we review the literature that leads to the development of a research model and hypo-

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theses. The research methodology is described in section 3 and includes development of a questionnaire and administration with faculty members. We describe the results of analyzing the data from the questionnaire in Section 4 and discuss the findings in Section 5. Section 6 concludes the paper with a discussion of the limitations and future research directions.

2. Theories of adoption and readiness of faculty members

The adoption process of educational technologies is well studied [16–18] and is influenced by the readiness of faculty members, students, and administrators to embrace the change [19]. Of these stakeholders, faculty members have been identified as the most important influencers of the adoption process [17, 18, 20]; therefore, we constrain our study to consider the readiness of faculty members to adopt the educational technologies.

2.1 Adoption

The adoption process includes creating awareness, followed by intention to adopt, actual adoption, and routine use of the innovation [16–18, 21–23]. *Intention to adopt* is defined as whether an individual, if given the opportunity, would adopt a technology in the foreseeable future [24]. *Adoption* is defined as a decision to make full use of a technology as the best course of action available [25]. *Routine use* of educational technologies is when individuals have mastered using the technology and have no plans to further adopt or change that technology [26, 27].

2.2 Readiness of faculty members to adopt educational technologies

The adoption process is influenced by the readiness of faculty members to embrace the change process [17, 18, 28]. Prior research based on a qualitative study (Delphi) of principal investigators of NSF education grants identified receptivity to change, attitude to innovation, awareness of innovations, care about student learning outcomes, and motivation to innovate as important factors that influence adoption success [17, 18]. The Delphi participants described receptivity to change as the degree of receptivity from faculty members toward the innovative technology. In organizational change literature, receptivity to change is synonymous with the concept of readiness for change [29–32]. These studies have identified faculty members' receptivity to change using multiple constructs including leadership support, openness to change, attitude to change, and characteristics of the change [31–33]. The leadership support includes aspects such as technology support and stability in the organization [34]. In education literature, receptivity to change is defined as one's internal attitudes that precede the behaviors that one takes when adopting or resisting change [35]. This construct includes CSFs identified in earlier literature [36] where they state IT competency, teaching style, attitude, and mindset are important factors influencing adoption of e-learning technologies.

Based on these studies, we selected the following factors to measure the readiness of faculty members toward educational technologies: (a) openness to change, (b) discrepancy (need for change), (c) appropriateness of change, (d) efficacy (ability) to change, (e) support by principals to change, (f) valence (perceive a gain), (g) attitude to innovation, (h) awareness of innovation, (i) care about student learning outcomes, and (j) motivation to innovate.

The adoption process and readiness of faculty members interact in multiple ways. We developed a research model (Fig. 1) that helps derive hypotheses by studying the:

- Relationship between intention to adopt and adoption (H1)
- Relationship between adoption and routine use (H2)
- Relationship between readiness of faculty members and the three elements of the adoption process (H3, H4, & H5), and
- The moderating relationships (H6 & H7)

2.3 Relationship between intention to adopt and adoption

Empirical research related to the theories of reasoned action [37, 38] and planned behavior [39] have indicated that intention to adopt is an antecedent to adoption. Moreover, theoretical and empirical research related to the different iterations of the Technology Acceptance Model (TAM) [40–42] support intention to adopt as a significant positive predictor of adoption. Therefore, we hypothesize (H1) a positive relationship between intention to adopt and adoption of educational technologies.

2.4 Relationship between adoption and routine use

For faculty members to routinely use a technology, they need to adopt it first [10, 17, 18, 37, 38]. Therefore, we hypothesize (H2) a positive relationship between adoption and routine use of educational technologies.

2.5 Relationship between readiness of faculty member and adoption process

Organizational change literature proposes that receptivity to change is a direct antecedent to

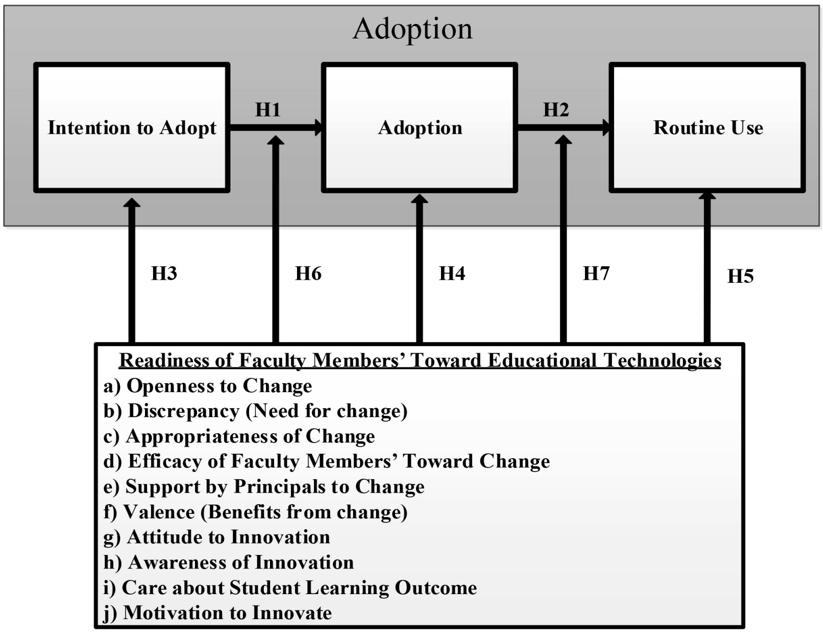


Fig. 1. Research Model.

intention to adopt, adoption and routine use [43]. Therefore, we hypothesize:

H3: A significant relationship between the readiness of faculty members and intention to adopt educational technologies.

H4: A significant relationship between the readiness of faculty members and adoption of educational technologies.

H5: A significant relationship between the readiness of faculty members and routine use of educational technologies.

2.6 Moderating relationships

Diffusion of innovation research [25] suggests that successful dissemination and adoption of new technologies is affected by the environment and culture in which the adoption is taking place (Fig. 1). B. T. Hazen, Y. Wu, C. S. Sankar and L. A. Jones-Farmer [44] proposed that characteristics of the adopter and characteristics of the environment moderate the dissemination and adoption process. For instance, readiness factors, such as efficacy and support for principals to change, have been found to moderate the relationship between intention to adopt and adoption [45]. Therefore, we hypothesize:

H6: Readiness of faculty members will moderate the relationship between intention to adopt and adoption of educational technologies.

H7: Readiness of faculty members will moderate the relationship between adoption and routine use of educational technologies.

3. Research methodology

The research methodology consisted of developing a questionnaire and administering it to a group of faculty members.

3.1 Questionnaire development

We divided the questionnaire into five sections: educational technologies, dissemination and adoption process, readiness of faculty members, demographic and control variables, and assessment of common method bias.

3.1.1 Educational technologies

We asked faculty members five questions about an educational innovation that they were currently using, would like to use, or planned to use in the future in an undergraduate course. The question allowed the faculty members to write about the innovation and describe the underlying educational technology.

3.1.2 Dissemination and adoption

This section of the questionnaire included 5 questions to address the dissemination and adoption process (intention to adopt, adoption, and routine use) at an individual level. *Intention to adopt* was assessed using a three-item scale by [24]. Intention to adopt was rated using a seven-point Likert scale where "1 = strongly disagree" and "7 = strongly agree". *Adoption* was assessed by using a single item based on the findings of C. Henderson and M. H. Dancy [46]. We asked the faculty member "Please select the best statement that best describes your use of this educational innovation." This item was measured using a four-point Likert scale where "1 = I have heard the name, but do not know much else about it" and "4 = I currently use all or part of it". We collapsed the responses for this question and created a dichotomous variable ranging from "0 = I have never used the innovation" and "1 = I have used the innovation". *Routine use* was assessed by using a single categorical measure based on the findings of C. Henderson and M. H. Dancy [46]. We asked faculty members "How often do you use all or part of this educational innovation?" This item was measured using a five-point Likert scale where "1 = I never use it" and "5 = "I always use it". We collapsed the responses for this question and created a dichotomous variable ranging from "0 = I rarely to never use it" and "1 = I always to sometime use it".

3.1.3 Readiness of faculty members

In this section of the questionnaire, 52 items measured the ten readiness of faculty members factors using a seven-point Likert scale ("1 = strongly disagree" and "7 = strongly agree"). Openness to change was measured using the eight-item scale by Miller, Johnson, and Grau [47]. Discrepancy, appropriateness of change, support by principals to change, and valence were measured using 18 items from Armanakis et al.'s [28, 50] Organizational Change Recipients' Beliefs (OCRBS) assessment tool (e.g., This educational innovation is the right ones for my students). Change efficacy was measured using the six-item measure by Holt, Armenakis, Feild, and Harris [48]. Attitude to innovation was measured by the four item scale developed by Agarwal and Prasad [49]. Awareness of innovations was measured by the six-item scale others' use developed by Compeau et al. [50]. Others' use referred to the degree to which potential adopters were aware of other people using the innovation [50] (e.g., Several colleagues in my university use this educational innovation). Care about student learning outcomes was measured used the five-item scale *Concern about Student Learning* developed as part of the Concerns-Based Adoption Model (CBAM) [26, 51]. Motivation to innovate was assessed using the five-item scale by Alpkan, Bulut, Gunday, Ulusoy, and Kilic [52] called performance-based reward systems.

3.1.4 Demographics and control variables

This section of the questionnaire included 19 items to gather demographic information. Five items were used as control variables (gender, race, department, tenure status, and percentage of teaching load) based on past research [11].

3.1.5 Assessment of common method bias

The final section of the questionnaire included a marker variable. Richardson, Simmering and Sturman [53] suggested using a marker variable as a proxy for method variance. If the marker variable did not correlate with any of the other variables in the study, it indicated that faculty members were carefully reading the questions and not marking the same rating for all of the answers (e.g., yea-saying). We adapted the four-item scale by Miller and Chiodo [54] called attitude toward a particular color.

3.2 Pilot study

A pilot study was conducted to validate the questionnaire and ensure the user-friendliness of the web-based survey tool. Participants included eleven faculty members attending the Annual National Engineering Mathematics Consortium. Based on the feedback provided by the participants, the wording of some items were modified slightly for contextual clarity.

3.3 Participants

The study participants included faculty members in computer science and electrical engineering programs in the United States. An invitation email to complete the questionnaire was sent to 4,352 faculty members at ABET accredited programs [55]. The final response rate was 7.98% with 335 participants. The respondents averaged 15.73 years teaching experience (SD = 11.87), and had been at their current school for 12.71 years (SD = 10.56).

3.4 Categorization of types of learning technologies

Past literature lists the types of learning systems as online learning systems, intelligent tutors, educational software applications and games, simulation systems for education and training, collaborative learning tools, devices, and interfaces for learning, interactive techniques for learning, personalized and adaptive learning systems, tools for formative and summative assessment, ontologies for learning systems, standards and web services that support learning, authoring tools for learning materials, computer support for peer tutoring, learning via discovery, field and lab work, learning with mobile devices, social learning techniques, social networks and infrastructures for learning and knowledge sharing, and the creation and management of learning objects [56, 57]. A researcher read through each of the response and categorized it into one of the learning technologies mentioned above. When a response could fit two or more learning technologies, he/she chose the one that was most emphasized by the respondent.

3.5 Data analysis methodology

We conducted all of our statistical analysis using SPSS 22. Following the guidelines of Kutner, Nachtsheim, Neter, and Li [58], hierarchical linear regression was used to analyze the study data and test the hypotheses when intention to adopt was our dependent variable because the measure was collected using a seven-point Likert scale. Following the guidelines of Menard [59], hierarchical logistic regressions were used to analyze the study data and text hypotheses when adoption and routine use were our dependent variables because we collapsed these measures due to their dichotomous nature. We used mean-centered scale averages for all the independent factors and intention to adopt to aid the interpretation of potential moderating effects [60]. In the first step of the analysis (model 1), control variables were entered in the model. Retaining the control variables, the hypothesized main effects for H1 and H2 were entered into the model where applicable (only for the variables adoption and routine use). Next, any significant main effects were retained and the readiness of faculty members factors (H3-H5) were added to the model (model 2). Finally, the significant main effects were retained and a series of interaction terms (consisting of the cross products of the significant items identified in earlier steps) were added as predictors of the dependent variables (models 3 and 4). Interactions were only considered noteworthy if they had significant coefficients, and statistically improved the fit of the model.

4. Results

A categorization of the specific educational technology used or planned to be used by the 335 respondents into a type of learning technology is provided in Appendix I. For example, 113 of the respondents chose online learning systems such as use of web resources, flipped classes, video maker, or You Tube as the learning technology of interest to them. The appendix shows that online learning systems were the top choice of the faculty members followed by project/lab work, intelligent tutors, collaborative training tools, devices for learning systems, and creation of new learning objects. Despite their perceived popularity, few faculty chose social networks and infrastructures for learning and knowledge sharing.

Table 1 presents the Cronbach's alphas, means, standard deviations, and intercorrelations among the study variables. The lack of significant correlations among the marker variable (variable 14) and the study variables indicates no evidence of common method variance.

4.1 Stage 1: Intention to adopt

Table 2 presents the results of the hierarchical linear regression analysis with intention to adopt educational technologies as the dependent variable. The control variables were not significantly related to intention to adopt (Model 1). The only additional hypothesized antecedents to intention to adopt include the factors relating to readiness of faculty members. The results from Model 2 suggests that four out of the ten readiness of faculty members' factors were empirically supported: efficacy of the faculty member toward change; valence, attitude to the innovation, and care about student learning outcomes.

4.2 Stage 2: Adoption

Table 3 presents the results of the hierarchical

Table 1. Correlation Matrix

Variable	Cronbach's alpha	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Openness to change	.91	5.62	0.87													
2. Discrepancy	.86	5.48	0.99	.60**												
3. Appropriateness of change	.87	5.96	0.77	.35**	.37**											
4. Efficacy of faculty members' toward change	.87	5.66	0.91	.36**	.25**	.54**										
5. Support of principal to change	.87	4.78	1.15	.27**	.14*	.18**	.21**									
6. Valence	.74	5.60	0.93	.38**	.36**	.66**	.53**	.19**								
7. Attitude to innovation	.91	5.75	0.99	.40**	.35**	.68**	.62**	.20**	.72**							
8. Awareness of Innovation	.86	4.10	1.35	.01	.01	.00	.09	.20**	.00	.01						
9. Care about student learning outcomes	.81	4.99	1.20	.16**	.18**	.01	-.08	.07	.10	.08	.03					
10. Motivation to innovative	.85	3.92	1.34	.15**	.08	.05	.12*	.53**	.12*	17**	.16**	.08				
11. Intention to adopt	.88	6.06	1.00	.28**	.27**	.50**	.53**	.17**	.54**	.58**	.10	.15**	.08			
12. Adoption	N/A	0.80	0.40	.19**	.13*	.31**	.35**	.08	.28**	.41**	.14**	.01	.10	.33**		
13. Routine use	N/A	0.86	0.35	.20**	.14**	.28**	.35**	.11*	.29**	.40**	.16**	-.04	.14*	.32**	.69**	
14. Attitude toward color green	.72	3.72	1.06	-.03	-.04	-.02	-.05	-.01	-.03	-.03	-.08	.10	-.05	.00	.02	.02

Note: N = 335. *p < 0.05. **p < 0.01.

Table 2. Regression Analysis with Intention to Adopt as the Dependent Variable

	Model 1		Model 2	
Variables	*b*	*se*	*b*	*se*
Constant	0.06	(0.12)	.07***	(0.09)
Control Variables				
Female	0.20	(0.154)	0.09	(0.12)
Asian	0.02	(0.146)	-0.24*	(0.12)
Other Nationalities	-0.23	(0.179)	0.04	(0.14)
Electrical Engineering	-0.04	(0.117)	0.02	(0.09)
Dept. Other	0.03	(0.250)	0.08	(0.19)
Not Yet Tenure	-0.18	(0.143)	-0.13	(0.11)
Non-Tenure Track	-0.09	(0.141)	-0.14	(0.11)
Less than Half time Teaching	0.01	(0.118)	-0.01	(0.09)
Theorized Effects				
Readiness of Faculty Members' Toward Educational Innovations				
Openness to Change			-0.02	(0.07)
Discrepancy			0.02	(0.06)
Appropriateness of Change			0.12	(0.08)
Efficacy of Faculty Members' Toward Change			0.27***	(0.06)
Support from Principals to Change			0.04	(0.05)
Valence			0.19**	(0.07)
Attitude to Innovation			0.24***	(0.07)
Awareness of Innovation			0.06	(0.03)
Care About Student Learning Outcomes			0.11**	(0.04)
Motivation to be Innovative			-0.02	(0.04)
Adjusted R^2	0.90%		40.70%	

Notes: N = 335. * = Significant at 0.05 level. ** = Significant at 0.01 level. *** = Significant at 0.001 level. Standard errors are reported in parentheses.

logistic regression analysis with adoption as the dependent variable. Model 2 indicates that H1 was supported with significant association between intention to adopt and adoption of educational technologies (b = 0.75, Wald χ^2 = 25.49, p < 0.001). The odds ratio suggested that faculty members who *intended to adopt* educational technologies were 2.11 times more likely to *actually adopt* educational technologies when all model variables were held constant. This model overall was able to classify 81.5% of those who adopted educational technologies and accounted for between 12.3% and 19.5% of the variance.

Once the readiness of faculty members factors were entered in Model 3, H1 was no longer supported (b = 0.23, Wald χ^2 = 1.44, p = 0.23). Mixed support for H4 was indicated with significant coefficients for the faculty member's attitude toward the innovation and their awareness of the innovation. This model was able to classify 83.3% of those that adopted educational technologies and between 22.5% and 35.8% of the variance. Partial support was indicated for H6, with a significant moderating effect between a faculty member's intention to adopt an innovation and his/her attitude toward the innovation (b = 0.96, Wald χ^2 = 5.80, p = 0.016).

4.3 Stage 3: Routine use

Table 4 presents the results of the hierarchical logistic regression analysis with routine use as the dependent variable. In Model 2, a significant relationship between adoption and routine use of educational technologies was indicated (b = 4.44, Wald χ^2 = 70.42, p < 0.001), lending support for H2. The odds ratio suggested, when holding all other variables constant, faculty members that have adopted educational technologies were 84.55 times more likely to routinely use them compared to those who have not adopted the innovations. Model 2 was able to classify 92.8% of faculty members that routinely used educational technologies and accounted for between 35.4% and 63.8% of the variance.

For the third step of the analysis (Model 3), we added readiness of faculty members toward educational technologies variables to the model containing the control variables and adoption. None of the readiness of faculty members' factors influenced the relationship between adoption and routine use. With no significant main effects of readiness factors, the analysis was terminated without considering moderating effects. Fig. 2 shows the research model with the hypotheses that were supported, the value of *b*, and the level of significance.

Table 3. Regression Analysis with Adoption as the Dependent Variable

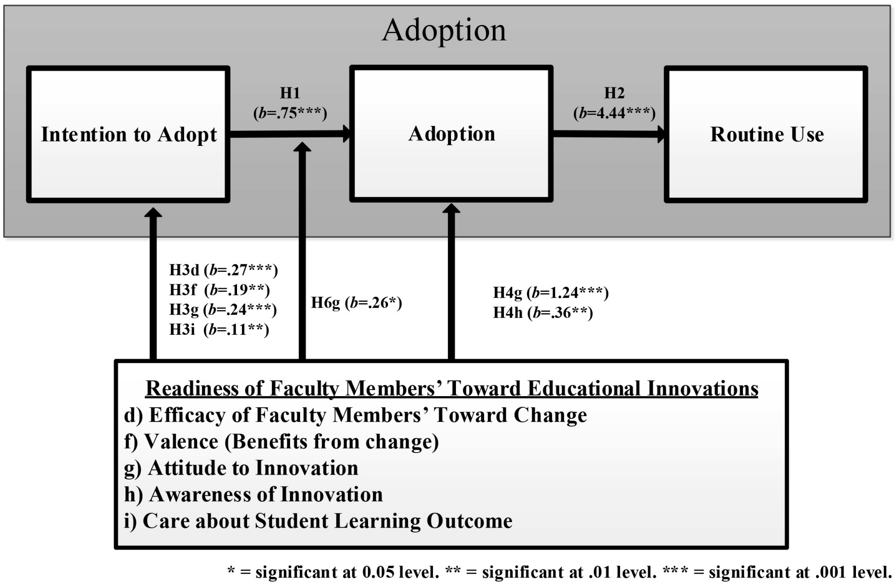
	Model 1			Model 2			Model 3			Model 4		
Variables	*b*	SE *b*	e^{β} *(odds ratio)*	*b*	SE *b*	e^{β} *(odds ratio)*	*b*	SE *b*	e^{β} *(odds ratio)*	*b*	SE *b*	e^{β} *(odds ratio)*
Constant	0.09	(0.97)	1.10	0.11	(1.00)	1.12	0.07	(1.15)	1.07	-0.28	(1.11)	0.75
Control Variables												
Female	-0.40	(0.43)	0.67	-0.27	(0.45)	0.76	-0.15	(0.49)	0.86	-0.05	(.48)	0.95
Asian	-0.49	(0.42)	0.61	0.49	(0.45)	0.61	0.02	(0.50)	1.02	-0.01	(.48)	1
Other Nationalities	0.44	(0.42)	1.55	0.31	(0.45)	1.36	-0.05	(0.51)	0.95	0.17	(.49)	1.18
Electrical Engineering	0.57	(0.31)	1.77	0.66*	(0.33)	1.93	0.69	(0.37)	2.00	0.65	(.36)	1.91
Dept. Other	0.34	(0.63)	1.41	0.50	(0.65)	1.64	0.36	(0.75)	1.43	0.31	(.75)	1.37
Not Yet Tenure	0.77*	(0.35)	2.17	0.73*	(0.36)	2.07	0.85*	(0.42)	2.34	0.96*	(.40)	2.62
Non-Tenure Track	0.46	(0.36)	1.59	0.42	(0.38)	1.52	0.62	(0.43)	1.87	0.63	(.42)	1.87
Less than Half time Teaching	0.27	(0.29)	1.31	0.31	(0.31)	1.36	0.35	(0.34)	1.42	0.35	(.34)	1.41
Theorized Effects												
Intention to Adopt				.75***	(0.15)	2.11	0.23	(0.19)	1.26	0.38	(.22)	1.46
Readiness of Faculty Members' Toward Educational Innovations												
Openness to Change							0.21	(0.27)	1.24			
Discrepancy							-0.24	(0.22)	0.78			
Appropriateness of Change							0.10	(0.32)	1.11			
Efficacy of Faculty Members' Toward Change							0.34	(0.24)	1.40			
Support from Principals to Change							-0.18	(0.19)	0.84			
Valence							-0.18	(0.27)	0.83			
Attitude to Innovation							1.06***	(0.27)	2.90	1.24***	(.22)	3.45
Awareness of Innovation							0.37**	(0.14)	1.45	0.36**	(.14)	1.44
Care About Student Learning Outcomes							0.04	(0.16)	1.04			
Motivation to be Innovative							0.08	(0.15)	1.08			
Moderating Effects												
Intention to Adopt x Attitude to Innovation										.26*	(.11)	1.3
Intention to Adopt x Awareness of Innovation										-0.05	(.12)	0.95
Log likelihood		319.31			288.68			247.07			245.17	
Chi-squared (χ^2)		13.15			43.80***			85.41***			87.31***	
Hit ratio (%)		80.30%			81.50%			83.30%			85.10%	
Cox & Snell R^2		3.80%			12.30%			22.50%			22.90%	
Nagelkerke R^2		6.10%			19.50%			35.80%			36.50%	

Notes: N = 335. * = Significant at 0.05 level. ** = Significant at 0.01 level. *** = Significant at 0.001 level. Standard errors are reported in parentheses.

Table 4. Regression Analysis with Routine Use as the Dependent Variable

	Model 1			Model 2			Model 3		
Variables	*b*	SE *b*	e^{β} (odds ratio)	*b*	SE *b*	e^{β} (odds ratio)	*b*	SE *b*	e^{β} (odds ratio)
Constant	3.11*	(1.54)	22.50	1.81**	(1.97)	514.57	1.46*	(2.22)	230.65
Control Variables									
Female	-1.08	(.64)	0.34	-0.87	(0.84)	0.42	-0.73	(0.99)	0.48
Asian	-2.44*	(1.03)	0.09	-2.73*	(1.15)	0.07	-2.36	(1.30)	0.10
Other Nationalities	0.42	(.46)	1.52	0.15	(0.69)	1.16	0.200	(0.71)	1.22
Electrical Engineering	0.64	(.36)	1.89	0.440	(0.53)	1.55	0.55	(0.59)	1.73
Dept. Other	0.12	(.83)	1.13	0.02	(1.17)	1.02	-0.06	(1.28)	0.94
Not Yet Tenure	0.37	(.42)	1.45	-0.33	(0.61)	0.72	-0.22	(0.66)	0.80
Non-Tenure Track	0.49	(.41)	1.63	0.22	(0.62)	1.25	0.68	(0.73)	1.97
Less than Half time Teaching	.85*	(.34)	2.33	1.06*	(0.50)	2.88	1.29*	(0.55)	3.63
Theorized Effects									
Adoption				4.44***	(0.53)	84.55	3.98***	(0.60)	53.72
Readiness of Faculty Members' Toward Educational Innovations									
Openness to Change							.20	(.46)	1.22
Discrepancy							-.09	(.37)	0.92
Appropriateness of Change							-.57	(.52)	0.57
Efficacy of Faculty Members' Toward Change							.40	(.35)	1.50
Support from Principals to Change							.12	(.30)	1.13
Valence							.28	(.43)	1.32
Attitude to Innovation							.56	(.39)	1.76
Awareness of Innovation							.22	(.21)	1.25
Care About Student Learning Outcomes							-.34	(.25)	0.71
Motivation to be Innovative							-.02	(.28)	0.98
Log likelihood		242.78			125.14			111.82	
Chi-squared (χ^2)		28.91***			146.55***			159.87***	
Hit ratio (%)		86.00%			92.80%			93.70%	
Cox & Snell R^2		8.30%			35.40%			38.00%	
Nagelkerke R^2		14.90%			63.80%			68.30%	

Notes: N = 335. * = Significant at 0.05 level. ** = Significant at 0.01 level. *** = Significant at 0.001 level. Standard errors are reported in parentheses.



Supported Hypotheses:

- **H1: There is a positive relationship between intention to adopt and adoption of educational technologies.**
- **H2: There is a positive relationship between adoption and routine use of educational technologies.**
- **H3d: There is a positive relationship between efficacy of faculty members toward change and intention to adopt educational technologies.**
- **H3f: There is a positive relationship between valence and intention to adopt educational technologies.**
- **H3g: There is a positive relationship between attitude to innovation and intention to adopt educational technologies.**
- **H3i: There is a positive relationship between care about student learning outcomes and intention to adopt educational technologies.**
- **H4g: There is a positive relationship between attitude to innovation and adoption of educational technologies.**
- **H4h: There is a positive relationship between awareness of innovation and adoption of educational technologies.**
- **H6g: Attitude to innovation positively moderates the relationship between intention to adopt and adoption of educational technologies.**

Fig. 2. Supported Research Model and Hypotheses.

5. Discussion and implications

Analysis of the results leads to the following findings:

1. Intention to adopt an educational technology was influenced by four CSF: faculty members' efficacy (ability) to change, valence (perceive a gain), attitude to innovation, and care about student learning outcomes.
2. Adoption of a technology was based on
   (a) faculty members' attitude to educational technology.
   (b) faculty members' awareness of others using an educational technology.
3. The only study variable that was shown to significantly relate to routine use was whether the faculty members adopted the technology.

We discuss each of these findings and its implications next.

5.1 Intention to adopt an educational technology was influenced by four csf: faculty members' efficacy toward change, valence, attitude to innovation, and care about student learning outcomes

5.1.1 Findings

Table 2 shows faculty members who believe that they are capable of implementing the educational technologies (efficacy) increase their intention to adopt such innovations. Faculty members have been shown to learn by doing [61] and gain a feeling of efficacy as they assess the effect of the innovation on students [62]. In addition, Table 2 shows faculty members who perceive a gain from using the proposed educational innovation (valence) increase their intention to adopt such innovations. Such a change is reported in the organizational change literature [28, 43]. The attitude toward innovations by faculty members influenced their intention to adopt the innovations. The study also found that faculty members who care about student learning outcomes are more likely to intend to adopt educational technologies (Table 2). This finding is consistent with findings from past literature [17, 18].

5.1.2 Implications

These results indicate that University administration and funding agencies should design and implement strategies so that faculty members develop confidence in adopting educational technologies. The administration needs to reexamine its reward system as emphasized by Walczyk et al., [6] who found many faculty members are unmotivated to use educational technologies since they are not tied to rewards. In many Universities, faculty members are penalized for adopting and using innovative educational technologies that do not produce peer-reviewed scholarly publications [6, 20, 63]. Faculty members need to feel it is in their professional self-interest to increase adoption of educational technologies [6, 64, 65]. The American Society for Engineering Education [66, 67] and the President's Council of Advisors on Science and Technology [68] have already suggested that promotion and tenure requirements in academic disciplines need to recognize pedagogical innovations by use of educational technologies in the classroom [6, 69].

5.2 Adoption of an educational technology was based on primarily the faculty members' attitude, and secondarily on faculty members' awareness of others using it

5.2.1 Findings

Primarily, the attitude toward technologies by faculty members was responsible for their intention to adopt or adopting the technology. This is seconded by Borrego et al., [20] who found faculty members' attitude toward innovations was an important part of peers' willingness to adopt new technologies. Prior research has suggested poor attitudes to innovations are often the result of a lack of time, training, motivation, and technological naïveté [69–71]. Secondarily, an awareness of peers using an educational technology was important in adopting the technologies (Table 3). This finding is consistent with [6] who found that discussions with colleagues was the most influential source before adopting educational technologies. Likewise, Borrego et al., [20] found faculty attitudes play an important role in peer willingness to adopt new pedagogies.

5.2.2 Implications

This finding implies developers, department chairs, and deans need to find ways to overcome negative attitudes. If department chairs and college deans changed promotion and tenure guidelines to include innovative uses of educational technologies in the classroom as an important criteria, it will definitely have a profound impact on faculty members' attitudes toward educational technologies [72]. Faculty members need to show support for their colleagues through more open discussions of teaching, which will influence the dissemination of educational technologies [73, 74]. In addition, faculty members should be encouraged to attend seminars and meetings where educational technologies are showcased and disseminated [61].

5.3 Routine use was dependent on whether the faculty members adopted the technology

5.3.1 Findings

This study shows that routine use of technologies was dependent on adoption decision and not on any of the readiness of faculty members' factors. A reason for this might be that the faculty members have formed strong opinions about the technology during the adoption decision and that influences whether they routinely adopt it. Those faculty members who have not adopted a technology may not routinely use it even if the system pressurizes them to do so.

5.3.2 Implications

This finding shows that developers of technologies have to consider the intention to adopt and adoption decisions of faculty members and influence them in those stages. Educational technology developers, text book publishers, and grant agencies need to develop and implement appropriate strategies to promote these technologies in such manner so that the faculty members intent to adopt and adopt those technologies.

6. Limitations and future research

This study has several limitations. The first limitation of this study is that the data was collected from faculty members in computer science and electrical engineering departments across the United States. Future research should validate and extend our model using samples from other departments. Such investigations may use the methodology outlined in this paper to find similarities and/or differences that may arise among departments, undergraduate institutions, research institutions, and community colleges.

Second, the findings cannot be generalized for all educational technologies. Appendix I shows that the respondents used many of the educational technologies, but some of the educational technologies (such as social networks) was not emphasized by the respondents. The respondents identified online learning systems and flipped classrooms as the major educational technology in this study and the results might be more representative of these technologies. Nicholls & Restuauri [75] discuss the difficulties in assessing the effectiveness of focused e-learning modules. Hung, Chang, & Lin [76] study hybrid instructional methods. Future research needs to extend our study by looking at one specific educational technology or look at additional educational technology categories.

The third limitation is that the purpose of this research was not to investigate whether differences in demographics (such as race, gender, or tenure status) influenced the successful dissemination of educational technologies. Future research should investigate what influence these factors have on the dissemination and adoption process.

The fourth limitation stems from collecting self-reported data from faculty members. Since the dissemination and adoption of educational technologies unfolds over time, future research needs to validate this model using longitudinal data. We also allowed faculty members to self-select educational technologies, which may have added bias; future research should experiment with different questionnaire designs that could prevent the self-selection bias.

The fifth limitation is that the study was confined to responses from faculty members. It is possible that the CSFs might be different if looked at from the perspective of students or administrators. For example, Selim [34] show that eight categories of critical CSFs were important in e-learning as perceived by students. These included: instructor characteristics (attitude towards and control of the technology, and teaching style), student characteristics (computer competency, interactive collaboration, and e-learning course content and design), technology (ease of access and infrastructure), and support.

Finally, the questionnaire was long since we wanted to use validated scales with excellent psychometric properties. With such a long survey instrument it could be argued that only the committed would respond in full, thus respondents may well be a technology supportive sample of the population. If that were the case, it would be disappointing, as the implications for the faculty members who avoid technology or reluctant to use technology are then hard to assess. Future research might create compressed scales that may help shorten the questionnaire and potentially improve the response rate.

7. Conclusions

This study makes several important contributions to the research literature and to investors in educational technologies. This study shows that awareness of an educational technology, attitude, and intent to adopt are direct antecedents to adoption that is a direct antecedent to routine use. Furthermore, this study finds that faculty members' attitude to technology is the most important CSF that influences intention to adopt and adoption and also moderates the relationship between intention to adopt and adoption. Advancement of knowledge in this area will enable decision makers of the educational technology companies to be better prepared about CSFs to consider and challenges to anticipate while planning strategies for marketing these technologies.

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Appendix A. Examples of learning technologies used/plan to use by respondents

Learning Technologies	Number of respondents	Examples Mentioned by Respondents
Online learning systems	113	• Use web resources for learning materials in lieu of textbooks • All class notes put on web • Flip class on algorithmic problem solving • Use Prezi • Video maker for YouTube
Learning via discovery, field, and lab work	28	• Project-based learning • Lab-immersion based approach to teach microwave circuit design • Use company-sponsored and integrated laboratory activities • Projects in the classroom which are publishable • Hands-on lab for network security course • Platform-based system development labs

Intelligent tutors	24	• Online review quizzes • Use Gradiance which creates and administers class exercise. • Online tutors • Project Euler as a source of practice problems • Use WebWork to assign online homework
Collaborative training tools	22	• Have student from two classes teach each other on parallel computing • Collaborative learning where seniors grade juniors' papers • Studio based learning • Peer reviews of projects • Learning by discovery in digital logic design
Devices and interfaces for learning	22	• Use white boards for written demonstrations • Instrumentation installed in pipes and use this data for lab exercises • Use iClickers • Integrate Smart Board into presentations • Small portable instrumentation allows me to bring the construction and testing steps into the classroom • A Phase Lock Loop development board • Use robot to teach embedded devices
Creation and management of learning objects	19	• Develop a module on ethics • Create a security-first engineering curriculum • Embedded systems • Agile programming techniques
Interactive techniques for learning systems	16	• Use challenge-based learning • Student-led design of computer architecture • Use book/ movie reviews on AI • Think pair share strategies • Scavenger hunts to teach encryption and loop constructs • Use research to drive class discussions
Learning with mobile devices	14	• Use tablet computer to record lectures which then put on web • Conduct projects on mobile devices using open source software • Use applets on transmission lines • Use iPython to do mathematical manipulation • Use Smartphones for programming courses • Mobile devices for online learning
Educational software applications and games	9	• Remote lab experience • Integrated automatically generated static and dynamic software visualization into introductory course • Multimedia case study and smart scenarios • Gamified learning approach • Use virtual machine software
Simulation systems for education and training	9	• Annotate animated slides • Teach intro to computer programming with humanoid robots • Use Mathematic symbolic equation solving and graphics for electromagnetic problems • Simulation in project management • Use High Tech Tools & Toys lab
Tools for formative and summative assessment	8	• Implement faculty course assessment report in the course • Develop Active and Learning system • Online assessment of study habits • CATME, a high-quality tool for assessing the effectiveness of individual team members • Concept inventory
Personalized and adaptive learning systems	7	• Conduct a variety of labs using a MEMS chips • Mobile lab in electric circuits allows students to learn not limited by time, space, or equipment
Ontologies for learning systems	7	• Curriculum development for GPU based Parallel Programming course • Student centered learning • Guest lectures • Use reflective writing
Standards and web services that support learning	4	• Allow faculty to share files and folders using a server • Use Microsoft OneNote as the mandatory option of note taking in class
Authoring tools for learning materials	3	• Develop new labs using Labview • Use open source Real-Time Operating System (RTOS) for lab exercises

Social networks and infrastructures for learning and knowledge sharing	3	• Use local multicast wireless/ wired hybrid networks • Use student texting for Q&A
Computer support for peer tutoring	1	• Use a sequence of labs that finally results in large piece of software that is used to tutor each other
None of the above	26	• Supplemental instruction • Use basic slides and notes • Blackboard and chalk
Total	335	

David M. Bourrie (Ph.D. Auburn University) is an Assistant Professor of Information Systems and Technology in the School of Computing at the University of South Alabama. His research interests include big data security, health informatics, innovation diffusion, and innovations dissemination. He is a Hortonworks University academic partner and a member of the Data Science Ensemble (DSC) and Computing Education Research Group (CERG) at the University of South Alabama. His research has appeared in international journals including Decision Sciences Journal of Innovative Education, Information Systems Management, International Journal of Engineering Education, International Journal of Information Systems and Change Management, and Knowledge Management and E-Learning.

L. Allison Jones-Farmer is the Van Andel Chair of Analytics, the founding director of the Miami University Center for Analytics and Data Science, and a Professor in the Department of Information Systems and Analytics at Miami University in Oxford, Ohio. Her research focuses on developing practical methods for analyzing data in industrial and business settings. She is on the editorial review board of *Journal of Quality Technology*, a former Associate Editor of *Technometrics*, and was recently awarded the Lloyd Nelson Award (2014) for the paper in *Journal of Quality Technology* with the most immediate impact to practitioners. Dr. Jones-Farmer enjoys developing innovative curricula and teaching analytics and statistics to both undergraduate and graduate students. She is the 2005 recipient of the Colonial Company Teaching Excellence Award, the 2008 recipient of the MBA Teacher of the Year Award, and the 2012 recipient of the Outstanding Teaching Award at Auburn University. In 2016, Dr. Jones-Farmer received the Faculty Service Excellence Award in the Farmer School of Business at Miami University. Prior to joining Miami University of Ohio, Dr. Jones-Farmer was on the faculty at the University of Miami in Coral Gables, Florida, and at Auburn University in Auburn, Alabama. She has consulted with numerous organizations and enjoys working with companies to improve their analytics capabilities.

Chetan S. Sankar is the Harbert College of Business Advisory Council Professor of Management Information Systems at Auburn University. He has received more than three million dollars from several National Science Foundation grants to develop exceptional instructional materials that bring real-world issues into classrooms. He has won awards for research and teaching excellence from the Society for Information Management, NEEDS, Decision Sciences Institute, American Society for Engineering Education, American Society for Mechanical Engineering, International Network for Engineering Education & Research, Computer World, Campus Technology, and the Project Management Institute. He was the editor-in-chief of the Decision Sciences Journal of Innovative Education and is the managing editor of the Journal of STEM Education: Innovations and Research. He is certified as a Project Management Professional.