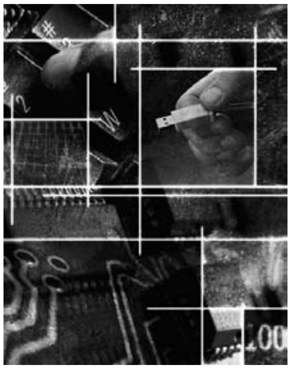

Construct Validity for the Teachers' Attitudes Toward Computers Questionnaire

Rhonda W. Christensen and Gerald A. Knezek

Abstract

Positive teacher attitudes toward computers are widely recognized as a necessary condition for effective use of information technology in the classroom (Woodrow, 1992). To measure attitudes toward technology, it is important to have valid and reliable instruments. In this study, the authors used confirmatory factor analysis to verify construct validity for the Teachers' Attitudes Toward Computers (TAC) Questionnaire, an instrument created from 32 well-validated scales, as a more parsimonious questionnaire covering areas assessed by previously existing instruments in the field. Since its creation as 284 items in 1997, this Likert- and Semantic Differential–based instrument has undergone two major refinements, each of which was designed to reduce the number of items while retaining subscale internal conshhhncy reliabilities in the range of .8–.9. The 51-item version of the TAC (v. 6.1) produced acceptable goodness-of-fit indices for its nine subscale constructs, based on analysis of 1,179 teacher responses from 2003. High internal consistency reliabilities were also verified for additional sets of 2006 teacher data and 2008 preservice teacher preparation data. This led the authors to conclude that the TAC is a well-validated, reliable instrument for teachers' self-appraisal of their attitudes toward computers, worthy of continued use in multiple language and cultural environments. (Keywords: construct validity, confirmatory factor analysis, teachers' attitudes, computers)

Instrument Development

Historical Foundations

The Teachers' Attitudes Toward Computers Questionnaire (TAC) was developed during 1995–1997 for a study of the effects of technology integration education on the attitudes of teachers and their students. Christensen and Knezek (1996) originally constructed the TAC as a 10-part composite instrument that included 284 items spanning 32 Likert and Semantic Differential subscales.

Context for Development

For more than two decades, positive teacher attitudes toward computers have been widely recognized as a necessary condition for effective use of information technology in the classroom (Woodrow, 1992). In the early 1980s, researchers reported that successful use of computers in the classroom was dependent on teachers' attitudes toward computers (Lawton & Gerschner, 1982). Educators have often been found to be resistant to using computer technology in the classroom, so changing teachers' attitudes has emerged as a key factor in fostering computer integration (Marcinkiewicz, 1993/1994). Several formal models have been created to address the issue of whether attitudes or skills are more important in achieving successful classroom technology integration, and recent studies (e.g., Morales, 2006) have reaffirmed that attitudes play a primary role.

At least 14 instruments with acceptable measurement properties had been reported in the literature prior to the development of the TAC (Woodrow, 1991; Chu & Spires, 1991; D'Souza, 1992; Francis, 1993; Gardner, Discenza, & Dukes, 1993; Kay, 1993; Knezek & Miyashita, 1993; Pelgrum, Janssen Reinen, & Plomp, 1993; Loyd & Gressard, 1984). However, few comprehensive studies had been carried out to determine which constructs measured by these instruments were redundant and which were unique. Administration of a battery of the well-validated existing instruments in this area at the time would have required well over an hour of an educator's time. A more parsimonious instrument was needed to cover the range of areas assessed by currently existing instruments in this field.

Initial Derivation of Constructs

For the initial development of the TAC, Christensen and Knezek (2000a) selected sets of items from 14 well-validated computer attitude survey instruments during the construction process. Items selected from the 14 instruments represented 32 unique subscales. Contributing instruments are listed in Table 1 (page 144).

Six hundred twenty-one K–12 and university educators in Texas, Florida, New York, and California completed the 284-item version of the TAC during 1995–1997. From this sample, 15% (n = 72) were male and 85% (n = 409) were female. An exploratory factor analysis (ULS, oblimin rotation) of the 284 individual items on the questionnaire, using the 621 sets of responses, indicated that between 4 and 22 different attributes were measured by the items collected from the 32 previously published subscales. Examination of the factor structures for 4–22 feasible solutions resulted in selections of 7-factor, 10-factor, and 16-factor structures as the most meaningful representations of the domain (Christensen, 1997). Additional content analysis of the items representing the alternative factor structures resulted in the judgment that the 7-factor structure could adequately represent the teachers' attitudes toward computers domain. Therefore, the authors selected the 7-factor structure as the most parsimonious foundation for further development of the TAC.

Table 2 (page 144) contains the names assigned to each of the factors identified and the measurement indices produced by summing the responses to items closely related to each factor. Post-hoc estimates of the internal consistency reliabilities for these constructs are also listed in Table 2. Reliability estimates (Cronbach's Alpha) for this group of educators ranged from .85 to .98, using between 10 and 30 items to form a subscale for each construct.

Parallel Forms Development (Resulting in Form A = 106 Items)

During 1996–1997, the authors produced Form A and Form B editions of the seven-factor version of the TAC by dividing items from each of

Table 1: Survey Instruments Serving as Sources of Items for the Teachers' Attitudes Toward Computers Questionnaire (TAC)

Survey Instrument	Author(s)	Year	Computer-Related Constructs
1. The Computer Usefulness Attitude Scale (CAS)	Gressard & Loyd	1986	Confidence, liking, anxiety, and usefulness
2. The Computer Use Questionnaire	Griswold	1983	Awareness
3. Attitudes Toward Computers Scale	Reece & Gable	1982	General attitudes toward computers
4. The Computer Survey Scale	Stevens	1982	Efficacy and anxiety
5. The Computer Anxiety Rating Scale (CARS)	Heinssen, Glass, & Knight	1987	Technical capability, appeal of learning and using computers, being controlled by computers, learning computer skills, and traits to overcome anxiety
6. Attitudes Toward Computers (ATC)	Raub	1981	Computer usage, computer appreciation, and societal impact
7. The CAIN (Computer Anxiety Index)	Maurer & Simonson	1984	Avoidance of, negative attitudes toward, caution with and disinterest in computers (anxiety and comfort)
8. The Blombert-Erickson-Lowery Computer Attitude Task (BELCAT)	Erickson	1987	Attitudes toward learning about computers and toward computers themselves
9. The Attitude Toward Computer Scale	Francis	1993	Affective domain
10. The Computer Attitude Measure (CAM)	Kay	1993	Cognitive (student, personal, general), affective, behavioral (classroom and home), and perceived control components of computer attitudes
11. The Computer Attitude Questionnaire (CAQ)	Knezek & Miyashita; Knezek & Christensen	1993 1996	Computer importance, computer enjoyment, computer anxiety, and computer seclusion
12. The Computer Attitude Items	Pelgrum, Janssen Reinen, & Plomp	1993	Computer relevance and computer enjoyment
13. The Computer Attitudes Scale for Secondary Students (CASS)	Jones & Clarke	1994	Avoidance of, negative attitudes toward, and caution with computers, as well as cognitive, affective, and behavioral attitudes
14. E-mail	D'Souza	1992	Attitudes toward classroom use of electronic mail

Table 2: Internal Consistency Reliability for Seven-Factor Structure of the TAC

Factor	Alpha	Number of Items
F1 (Enthusiasm/Enjoyment)	.98	30
F2 (Anxiety)	.98	30
F3 (Avoidance/Acceptance)	.90	13
F4 (Email for Classroom Learning)	.95	11
F5 (Negative Impact on Society)	.85	11
F6 (Productivity)	.96	30
F7 (Semantic Perception of Computers)	.94	10

the three factors with 30 strong items into two groups of 15. In general this process proceeded by ordering the items according to strength of factor loadings and then placing the even items on one form and the odd items on the other form. Several items were then switched from Form A to B and vice versa to avoid placing near duplicates on the same form. In addition, some items were switched in order to balance the discriminating power of each form. The resulting reliability estimates for Form A were: (a) .96 for F1—Enjoyment, (b) .96 for F2—Anxiety, (c) .90 for F3—Avoidance, (d) .95 for F4—E-mail, (e) .85 for F5—Negative Impact, (f) .93 for F6—Productivity, and (g) .94 for F7—Semantic Perception of Computers. The comparable reliabilities for Form B were: (a) .95 for F1, (b) .95 for F2, (c) .90 for F3, (d) .95 for F4, (e) .85 for F5, (f) .93 for F6, and (g) .94 for F7. A more detailed description of the process employed to produce Form A and Form B of the TAC has been published elsewhere (Christensen & Knezek, 1998). Reliability increments due to increasing numbers of items for each of the seven subscales on Form A are reported in Table 3. The researchers selected these 90 items plus 16 others selected for the purpose of comparing teacher attitudes on selected sets of items to identical sets of items completed by their students (Knezek & Miyashita, 1993; Knezek & Christensen, 1996) to comprise Form A of the TAC (106 items total).

First Refinement Phase

Replication Study

During 1997–1998, 1,296 educators from 16 of 1,046 Texas school districts completed Form A of the TAC. This convenience sample represented urban/suburban and rural schools from across the state. The respondents were 18.9% (n = 239) male and 81.1% (n = 1,027) female educators in the K–12 educational environment. The authors performed an exploratory factor analysis (ULS, oblimin rotation, seven factors specified) on the 106 items included on Form A of the TAC Questionnaire using 1997–1998 replication study data as well as the 1995–1997 data set. Structure matrix factor loadings for these two analyses are listed in Table 4 (pages 146–147).

As shown in Table 4, among the 74 items that were selected as loading on the seven anticipated factors using the 1998 data, 72 had also been selected from the 1995–1997 data set analysis because they fulfilled the criteria of: (a) the items loaded most highly on the factor they were selected to represent, (b) they were judged by the authors to have high content validity, and (c) the items maintained their corresponding factor location in the initial and in the replication study analysis. For each of the seven foundation constructs, the six strongest items selected to represent a factor remained intact for the replication study as well as the initial analysis. This led the authors to conclude that the factor structure derived from the 1995–1997 data was also present in the independent data sample gathered 2 years later.

As shown in Table 3, post-hoc reliability estimates based on just the top five items in the confirmed factor structure were quite high. These tabled values might aid future researchers in determining acceptable cut points for the most appropriate tradeoffs between subscale reliability

Table 3: Internal Consistency Reliability Indices for TAC Seven-Factor Structure, Form A

	5 Items	6 Items	7 Items	8 Items	9 Items	10 Items	11 Items	12 Items	13 Items	14 Items	15 Items
F1 (Enjoyment)	0.91	0.91	0.92	0.93	0.93	0.94	0.95	0.94	0.94	0.95	0.95
F2 (Anxiety)	0.92	0.92	0.93	0.92	0.93	0.94	0.95	0.95	0.95	0.95	0.95
F3 (Avoidance)	0.80	0.80	0.82	0.84	0.86	0.87	0.88	0.88	0.89		
F4 (E-mail)	0.96	0.95	0.95	0.95	0.96	0.95	0.95				
F5 (Negative Impact)	0.83	0.83	0.84	0.85	0.85	0.86	0.87				
F6 (Productivity)	0.87	0.87	0.88	0.90	0.91	0.91	0.92	0.92	0.93	0.93	0.93
F7 (Semantic Perception)	0.92	0.93	0.93	0.94	0.94	0.94					

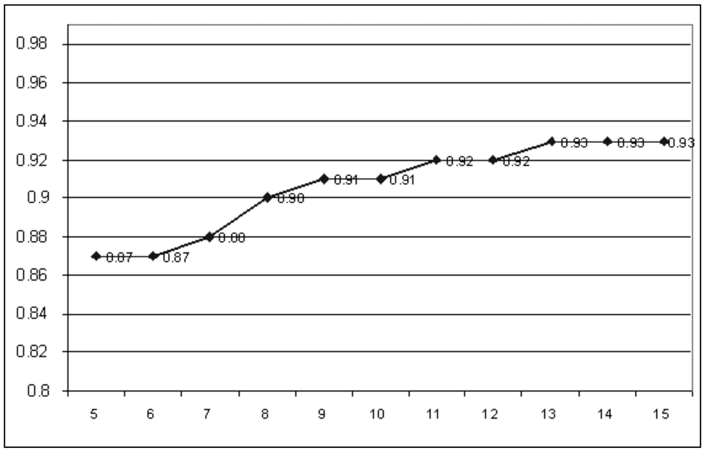

Figure 1: Factor 6 (Productivity) Reliability Estimates Based on Number of Items Included in Scale

and expected completion time in their specific situations. The authors' recommended cut points for individual items composing a scale, based on analysis of the 1995–1997 and 1997–1998 data, are shown by dotted lines (----) in Table 4.

The procedure for establishing the recommended cut points shown in Table 4 was as follows:

The researchers first selected a base set of five items by choosing those with the highest (strongest) factor loadings from among those available for a subscale.

The researchers plotted the reliability of this five-item subscale, and then added the next strongest loading item and plotted the new six-item subscale reliability estimate.

The researchers repeated this procedure until there was negligible increase in the slope of the curve due to new items, or until the pool of significantly related items ($p < .01$) that they judged to be content-valid was exhausted.

The resulting reliability curves were typically similar to the one shown for Factor 6 (Productivity) in Figure 1. Christensen and Knezek (2000b) reported reliability curves for all seven foundation factors in a separate publication.

Development of 95-Item TAC (Version 5)

The authors established the recommended cut points shown in Table 4 in the interest of creating a new version of the TAC that was as parsimonious as possible. However, the authors also recognized the need to have the TAC instrument maintain ties (via marker variables and crossover scales) to historically significant measurement indices in the field. Thus, the six additional indices[1] of Loyd and Gressard's Confidence (Gressard & Loyd, 1986), Pelgrum and Plomp's Enjoyment (Pelgrum, Janssen Reinen, & Plomp, 1993), Pelgrum and Plomp's Relevance (Pelgrum, Janssen Reinen, & Plomp, 1993), Miyashita and Knezek's Importance (Knezek & Miyashita, 1993), and Knezek and Miyashita's Anxiety (Knezek & Christensen, 1996), were merged with each other and the seven TAC foundation scales to produce a nine-part instrument. The authors included eight individual marker items from related U.S. nationwide studies (Becker & Anderson, 1998; Norris & Soloway, 1999), as well.

As shown in Table 5 (page 148), reliability estimates for each part of the TAC version 5.0, when viewed as a composite scale, ranged from .84 to .95 for two sets of Texas data. As researchers began using subsets of the original pool of 284 well-validated items in various parts of the world to compare findings from different nations, the authors conjectured that the subscales making up several of the parts might preserve their historical identities in a multinational context. Researchers reported findings that generally confirmed this conjecture for a Spanish translation of the TAC used in Mexico (Morales, 2006), and a Dutch translation of the TAC used in the Netherlands (Moonen, 2001).

Second Refinement Phase

Development of 51-Item TAC (Version 6)

Increasing use of the TAC for international studies during the late 1990s, as well as the adoption of the TAC as an evaluation instrument for a large-scale Technology Innovation Challenge Grant involving 50 Texas school districts and spanning 1999–2004 (Knezek & Christensen, 2000; Christensen & Knezek, 2001; Knezek & Christensen, 2002), prompted the development of a shorter version of the TAC that was robust across languages and cultures, stable with respect to the established nine-factor structure, and more efficient with regard to completion time. The authors carried out a series of exploratory factor analyses and reliability cross-checks on fall 1999 and spring 2000 data gathered with the TAC version 5 with the goal of producing a shorter form. By late spring 2001, the authors had reconfirmed the stability of the nine-factor structure shown in Table 6 (pages 148–149) across two large sets of K–12 teacher data. Tabled values are based on analysis of data gathered during the spring of 2000 from 546 elementary, middle school, and high school teachers in a large suburban public school district north of Dallas, Texas, USA (nine factors specified, principal components extraction, oblimin rotation; nine factors with eigenvalues >= 1.14 accounted for 72% of the variance). TAC version 6 was constructed as a 51-item instrument by ordering the presentation of the items in the order of the factor loadings shown in Table 6 for the appropriate scale. A copy of TAC version 6 is provided in the Appendix.

Table 7 (page 150) contains Cronbach's Alpha indices for the 546 teachers used to produce the factor loadings listed in Table 6. As shown in Table 7, reliability estimates for spring 2000 teacher data ranged from .84 to .96 for individual scales. Similar results (not shown) were also found for the fall 1999 teacher data set, based on the same items.

Numerous studies have used the TAC version 6 since its creation in 2001. Subjects have included preservice as well as inservice educators.

1 These additional indices were selected from the 16-factor structure of the TAC.

Table 4: TAC Seven-Factor Form A with Factor Loadings for Items on Seven-Factor Structure of the TAC (Form A)

Var #	Item	1995–1997	1997–1998
	Factor 1—Enthusiasm/Enjoyment	Factor	Loadings
186	I think that working with computers would be enjoyable and stimulating.	.82	.69
103	I want to learn a lot about computers.	.79	.73
211	The challenge of learning about computers is exciting.	.78	.71
180	Learning about computers is boring to me.	.71	.60
181	I like learning on a computer.	.74	.67
195	I enjoy learning how computers are used in our daily lives.	.71	.57
249	I would like to learn more about computers.	.70	.63
53	I would like working with computers.	.69	.69
101	A job using computers would be very interesting.	.69	.69
270	I enjoy computer work.	.67	.68
266	I will use a computer as soon as possible.	.67	.58
65	Figuring out computer problems does not appeal to me.	.66	.42
224	If given the opportunity, I would like to learn about and use computers.	.66	.60
191	Computers are not exciting.	.65	.62
102	Computer lessons are a favorite subject for me.	.66	.65
	Factor 2—Anxiety		
263	I get a sinking feeling when I think of trying to use a computer.	.87	.75
230	Working with a computer makes me feel tense and uncomfortable.	.88	.84
182	Working with a computer would make me very nervous.	.83	.76
227	Computers intimidate and threaten me.	.87	.79
264	Computers frustrate me.	.80	.76
88	I have a lot of self-confidence when it comes to working with computers.	.80	.80
153	I sometimes get nervous just thinking about computers.	.78	.71
112	A computer test would scare me.	.77	.64
141	I feel apprehensive about using a computer terminal.	.78	.79
231	Computers are difficult to understand.	.77	.77
177	I feel at ease when I am around computers.	.77	.81
157	I sometimes feel intimidated when I have to use a computer.	.75	.78
15	I feel comfortable working with a computer.	.75	.77
20	Computers are difficult to use.	.72	.76
51	Computers do not scare me.	.71	.68
	Factor 3—Avoidance		
150	If I had a computer at my disposal, I would try to get rid of it.	.53	.60
192	Studying about computers is a waste of time.	.52	.52
74	I can't think of any way that I will use computers in my career.	.51	.53
154	I will probably never learn to use a computer.	.51	.60
123	I see the computer as something I will rarely use in my daily life as an adult.	.43	.52
262	Not many people can use computers.	.41	.45
214	Learning to operate computers is like learning any new skill—the more you practice, the better you become.	.46	.50
94	Knowing how to use computers is a worthwhile skill.	.44	.47
*84	I do not think that I could handle a computer course.	.41	.50
272	I would never take a job where I had to work with computers.	.41	.53
224	If given the opportunity, I would like to learn about and use computers.	.40	.53
261	You have to be a "brain" to work with computers.	.40	.45
164	Someday I will have a computer in my home.	.39	.42

** Recommended omission of this item due to lack of content validity.*

Table 4 (Continued)

Var #	Item		1995–1997	1997–1998
	Factor 4—E-mail			
282	The use of e-mail makes the student feel more involved.		.88	.88
284	The use of e-mail helps provide a better learning experience.		.88	.89
281	The use of e-mail makes the course more interesting.		.87	.86
283	The use of e-mail helps the student to learn more.		.86	.85
280	The use of e-mail increases motivation for the course.		.85	.86
276	More courses should use e-mail to disseminate class information and assignments.		.80	.77
278	The use of e-mail creates more interaction between students enrolled in the course.		.78	.84
279	The use of e-mail creates more interaction between student and instructor.		.78	.83
277	E-mail provides better access to the instructor.		.76	.76
274	E-mail is an effective means of disseminating class information and assignments.		.67	.64
275	I prefer e-mail to traditional class handouts as an information disseminator.		.66	.69
	Factor 5—Negative Impact on Society			
142	Computers are changing the world too rapidly.		.48	.74
215	I am afraid that if I begin to use computers I will become dependent upon them and lose some of my reasoning skills.		.46	.47
138	Computers dehumanize society by treating everyone as a number.		.44	.75
135	Our country relies too much on computers.		.43	.76
144	Computers isolate people by inhibiting normal social interactions among users.		.43	.72
176	Use of computers in education almost always reduces the personal treatment of students.		.40	.49
134	Computers have the potential to control our lives.		.40	.57
241	Working with computers makes me feel isolated from other people.		.46	.59
218	I dislike working with machines that are smarter than I am.		.42	.39
257	Using a computer prevents me from being creative.		.41	.49
251	Working with computers means working on your own, without contact with others.		.36	.53
	Factor 6—Productivity			
202	Computers would increase my productivity.		.72	.70
204	Computers would help me learn.		.73	.68
226	I feel computers are necessary tools in both educational and work settings.		.68	.70
175	Computers can be a useful instructional aid in almost all subject areas.		.66	.77
207	Computers improve the overall quality of life.		.65	.62
94	Knowing how to use computers is a worthwhile skill.		.63	.59
149	Having a computer available to me would improve my general satisfaction.		.63	.61
162	Computers will improve education.		.63	.73
163	Someday I will have a computer in my home.		.61	.69
137	I will use a computer in my future occupation.		.61	.54
147	If I had to use a computer for some reason, it would probably save me some time and work.		.57	.57
170	Computers can be used successfully with courses which demand creative activities.		.57	.69
168	Teacher training should include instructional applications of computers.		.57	.71
66	I'll need a firm mastery of computers for my future work.		.54	.48
12	I believe that it is important for me to learn how to use a computer.		.54	.54
	Factor 7—Semantic Perception of Computers			
44	Computers are: Unpleasant	Pleasant	.79	.88
50	Suffocating	Fresh	.75	.86
49	Dull	Exciting	.72	.81
41	Unlikable	Likable	.72	.79
46	Uncomfortable	Comfortable	.69	.83
43	Bad	Good	.68	.75
42	Unhappy	Happy	.70	.80

Table 5: Reliabilities for Texas Teachers on Nine Scales of the TAC Version 5.0

Scale/Part Name	# Items	Standard Item Code	Alpha for Texas 1995–1997 (n = 621)	Alpha for Texas 1998–1999 (n = 1,296)
1. Interest	9	186, 103, 211, 180, 181, 10, 9, 12, 4	.88	.90
2. Comfort	8	263, 230, 17, 227, 18, 15, 20, 13	.94	.92
3. Accommodation	11	150, 192, 74, 154, 123, 164, 257, 292	.86	.86
Interaction (E-mail)	10	282, 284, 281, 283, 280, 276, 278, 279, 277, 274	.95	.95
5. Concern	10	142, 215, 138, 135, 144, 176, 134, 241, 251, 218	.84	.86
6. Utility	10	202, 204, 226, 175, 207, 163, 168, 162, 170, 149	.89	.92
7. Perception	7	44, 50, 49, 41, 46, 43, 42	.92	.93
8. Absorption	10	98, 193, 85, 100, 57, 69, 99, 60, 54, 104	.89	.88
9. Significance	10	96, 95, 172, 97, 199, 198, 214, 62, 216, 173	.84	.86
Number of Items	85			

Table 6: Factor Loadings Forming Basis of TAC Version 6 (n = 546, April 2000 Teacher Data)

	F1	F2	F3	F4	F5	F6	F7	F8	F9
V162	.79	-.17	.42	-.34	.30	.24	-.59	-.32	.37
V175	.78	-.30	.36	-.38	.42	.27	-.39	.39	.53
V204	.77	-.24	.42	-.35	.45	.28	-.34	-.46	.57
V202	.77	-.24	.45	-.48	.44	.41	-.40	-.39	.30
V168	.76	-.22	.38	-.35	.29	.23	-.46	-.35	.37
V163	.76	-.13	.34	-.40	.34	.33	-.52	-.34	.22
V226	.75	-.34	.42	-.35	.42	.29	-.33	-.43	.57
V207	.70	-.17	.45	-.38	.36	.35	-.53	-.28	.21
V17	-.26	.93	-.43	.33	-.40	-.38	.20	.46	-.24
V230	-.25	.92	-.44	.35	-.40	-.39	.21	.45	-.25
V263	-.23	.90	-.41	.30	-.41	-.38	.18	.49	-.24
V227	-.23	.89	-.42	.29	-.38	-.41	.18	.46	-.21
V18	-.15	.77	-.44	.35	-.37	-.45	.21	.32	-.21
V41	.38	-.36	.94	-.38	.48	.40	-.40	-.41	.28
V50	.39	.33	.92	-.41	.47	.43	-.44	-.38	.27
V49	.41	-.32	.91	-.38	.49	.40	-.44	-.38	.27
V46	.35	-.49	.91	-.34	.44	.45	-.37	-.43	.27
V44	.36	-.39	.90	-.36	.44	.39	-.41	-.41	.29
V138	-.40	.20	-.42	.82	-.33	-.25	.27	.35	-.24
V135	-.40	.25	-.40	.81	-.30	-.35	.28	.35	-.18
V144	-.32	.24	-.38	.80	-.29	-.29	.28	.24	
V241	-.42	.29	-.41	.76	-.37	-.21	.32	.36	-.23
V134	-.29	.21	-.24	.75	-.20	-.23	.24	.21	
V176	-.41	.23	-.32	.74	-.39	-.31	.30	.37	-.37
V142	-.19	.30	-.26	.71	-.33	-.28	.17	.25	-.25
V215	-.27	.40	-.26	.61	-.32	-.19	.23	.37	-.46
V186	.26	-.33	.47	-.29	.87	.36	-.23	-.38	.18
V181	.35	-.35	.38	-.31	.86	.39	-.26	-.31	.20
V10	.35	-.29	.37	-.32	.85	.39	-.32	-.34	.27
V103	.28	-.20	.37	-.28	.85	.37	-.25	-.38	.21
V211	.25	-.32	.50	-.29	.83	.48	-.31	-.42	.19
V85	.24	-.29	.35	-.26	.41	.85	-.26	-.27	.24
V193	.21	-.33	.45	-.24	.44	.84	-.25	-.26	.20

Table 6 (Continued)

	F1	F2	F3	F4	F5	F6	F7	F8	F9
V100	.27	-.27	.33	-.29	.37	.81	-.37	-.18	
V98	.36	-.32	.50	-.40	.47	.77	-.41	-.36	.22
V69	.20	-.40	.31	-.22	.32	.77	-.20	-.20	.18
V281	0.46	-0.17	0.41	-0.30	0.32	0.33	-0.93	-0.28	0.27
V283	0.45		0.41	-0.29	0.28	0.30	-0.90	-0.23	0.25
V280	0.42	-0.11	0.38	-0.20	0.29	0.29	-0.90	-0.25	0.29
V284	0.46	-0.19	0.40	-0.31	0.30	0.30	-0.90	-0.27	0.25
V282	0.38	-0.11	0.37	-0.24	0.25	0.27	-0.82	-0.28	0.24
V74	-0.38	0.45	-0.39	0.34	-0.40	-0.22	0.35	0.88	-0.41
V123	-0.27	0.39	-0.37	0.29	-0.39	-0.22	0.20	0.83	-0.27
V150	-0.38	0.36	-0.37	0.33	-0.33	-0.23	0.24	0.82	-0.38
V154	-0.23	0.46	-0.33	0.25	-0.34	-0.22	0.22	0.81	-0.40
V192	-0.29	0.21	-0.41	0.30	-0.40	-0.31	0.26	0.75	-0.25
V172	0.43	-0.28	0.34	-0.28	0.30	0.29	-0.32	-0.41	0.86
V95	0.39	-0.24	0.35	-0.31	0.31	0.21	-0.30	-0.47	0.86
V96	0.44	-0.26	0.30	-0.28	0.30	0.27	-0.40	-0.36	0.80
V199	0.47	-0.22	0.44	-0.35	0.33	0.30	-0.41	-0.37	0.73
V97	0.44	-0.13	0.39	-0.16	0.29	0.22	-0.32	-0.44	0.72

Factor Correlation Matrix

	F1	F2	F3	F4	F5	F6	F7	F8	F9
F1	1.00								
F2	-0.15	1.00							
F3	0.36	-0.34	1.00						
F4	-0.36	0.27	-0.35	1.00					
F5	0.32	-0.32	0.45	-0.33	1.00				
F6	0.25	-0.33	0.40	-0.28	0.43	1.00			
F7	-0.46	0.12	-0.40	0.28	-0.28	-0.30	1.00		
F8	-0.33	0.38	-0.40	0.31	-0.40	-0.24	0.25	1.00	
F9	0.37	-0.21	0.25	-0.21	0.24	0.16	-0.25	-0.37	1.00

For these studies, the TAC version 6 has typically produced reliability estimates in the range of .84 to .97. For example, in a study involving 786 preservice educators in 2003, the authors found that subscale reliabilities ranged from .84 to .94, and in a study involving 306 inservice educators in 2001, the authors found that subscale reliabilities ranged from .86 to .97 (Christensen & Knezek, 2001). The authors gathered data from 273 preservice educators in Texas and Maine during 2008 that yielded subscale reliability estimates ranging from .87 to .95. Educators from other nations have also used the TAC in translated forms (e.g., Moonen, 2001; Liao, 2003; Morales, 2006). These investigations often verified significant differences among groups being studied, indicating (through high discriminant validity) acceptable reliabilities among the translated forms. For the study in Mexico, Morales (2006) calculated TAC subscale reliability estimates ranging from .74 to .98.

Confirmatory Factor Analysis

The authors conducted confirmatory factor analysis (CFA) on a 2003 data set gathered from 1,176 elementary school (49 %), middle school (22 %), and high school (29%) teachers in the Dallas-Fort Worth metroplex of Texas, USA, to determine whether data gathered since the development of the 51-item version of the TAC (v. 6.1) replicated the expected factor structure. They used the statistical modeling package LISREL (Joreskog & Sorbom, 1998) for this procedure. Because the TAC was constructed from several previous instruments in which the subscales were theoretically correlated (Christensen & Knezek, 1996; Christensen & Knezek, 2000b), latent factors were allowed to correlate in the confirmatory procedure. The model specified to carry out the confirmatory analysis is shown in Table 8 (page 150).

Testing Model Fit

The Chi Square statistic is a common measure of how well a model fits the data. Predictions from the model are compared to the actual data, and if there is no significant difference between the two, the fit is said to be good. However, this measure is strongly influenced by sample size and thus is rarely found to be nonsignificant in samples sufficiently large to legitimately be used as the basis for confirmatory factor analysis (Thompson & Daniel, 1996). Therefore goodness-of-fit was evaluated for the nine-factor model using the standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), and the test of the comparative fit index (CFI). Guided by suggestions provided in Hu and Bentler (1999), acceptable model fit was defined by the following criteria: RMSEA (≤ .06), SRMR (≤ .08), and CFI (≥ .95). When used together, these criteria provide a conservative approach to evaluation of goodness-of-fit of a confirmatory solution.

Table 7: Reliability Estimates for TAC Version 6 Subscales Based on April 2000 Teacher Data

Part	# Items	Standard Item Code	Alpha for Texas 2000 (n = 546)
1. Interest	5	186, 103, 211, 181, 10	.90
2. Comfort	5	263, 230, 17, 227, 18	.94
3. Accommodation	5	150, 192, 74, 154, 123	.88
4. Interaction (E-mail)	5	282, 284, 281, 283, 280	.94
5. Concern	8	142, 215, 138, 135, 144, 176, 134, 241	.89
6. Utility	8	202, 204, 226, 175, 207, 163, 168, 162	.90
7. Perception	5	44, 50, 49, 41, 46,	.96
8. Absorption	5	98, 193, 85, 100, 69	.89
9. Significance	5	96, 95, 172, 97, 199	.84
Number of Items	51		

Each of the criterion goodness-of-fit indices produced by LISREL suggested that the nine-factor model fit the data well: RMSEA = .048 (desirable is < .06), SRMR = .0452 (desirable is <= .08), and CFI = .984 (desirable is >= .95) (Hu & Bentler, 1999). As shown in Table 9, post hoc estimates of subscale reliabilities for the 2003 data set fell in the range of .87 to .95. The authors computed additional reliability estimates for the nine TAC version 6.1 constructs for two sets of data gathered in 2006 that were similar to the 1995–1997 and 1997–1998 as well as 2001–2003 teacher groups. As shown in Table 9, the 2006 reliability estimates in the USA compared favorably with those computed 3–5 years earlier, while the 2008 reliability estimates were higher still. Even the data that Morales (2006) gathered through a Spanish-language version in Mexico produced acceptable reliability estimates after removing three items with translation difficulties. These findings, when viewed collectively, led the authors to conclude that the nine-factor structure incorporated into TAC version 6 was successfully confirmed.

Discussion

The authors have removed many highly-quality items from the TAC as it evolved from its original 284-item form to the 51-item version used for the confirmatory factor analysis reported in this paper. These items are not necessarily inferior to those that have been retained and could be further developed by interested researchers. Especially noteworthy in this category are items just beyond the cut points selected (for the purpose of brevity) in Table 4, plus the entire selection of approximately 90 items validated for TAC Form B that has not been further developed since the late 1990s.

Because reliabilities for the nine subscales of TAC version 6 have remained sufficiently high to be classified as "very good" (DeVellis, 2003) for more than half a decade in the USA, the prospect exists for further reduction in the number of items used in many of the subscales. However, additional research is needed to determine if shorter versions would be sufficiently robust to be stable in a multicultural, global environment. The study by Morales (2006) with a Spanish translation of the TAC in Mexico, where three items were not used (see Table 6, pages 148–149) because of translation inconsistencies identified at the pilot test stage, serves to remind us that some reliability can be lost in translation.

A final point of technical discussion is that each subscale of the TAC is independent and can stand alone. Therefore researchers or evaluators may choose to use only some of the scales and not others.

Table 8: Lisrel Model for Confirmatory Factor Analysis

Latent Variables	Pt1	Pt2	Pt3	Pt4	Pt5	Pt6	Pt7	Pt8	Pt9
Relationships:	V186	V263	V150	V282	V142	V202	V44	V98	V96
	V103	V230	V192	V284	V215	V204	V50	V193	V95
	V211	V17	V74	V281	V138	V226	V49	V85	V172
	V181	V227	V154	V283	V135	V175	V41	V100	V97
	V9	V18	V123	V280	V144	V207	V46	V69	V199
					V176	V163			
					V134	V168			
					V241	V162			

Note: Sample size = 1,179

The TAC has been used in many preservice as well as in service teacher education activities. Curriculum and/or professional development coordinators have found it useful for: (a) providing a snapshot of computer attitudes across a school to establish a baseline for targeting teacher professional development, or (b) administering the instrument as a pre–post assessment in technology integration preservice teacher preparation classes. Studies have also shown the instrument functions well as a cornerstone indicator for research in technology integration (Morales, 2006; Hancock, Knezek, & Christensen, 2007). The authors have developed a formal model that includes teacher maturity in three areas as critical for the higher levels of classroom technology integration to take place: will, or positive attitudes toward technology; skill in the use of technology for professional productivity and teaching; and access to tools for teachers' own development and curricular delivery, as well as for student learning (Knezek, Christensen, Hancock, & Shoho, 2000; Christensen & Knezek, 2008) The TAC instrument has become the primary indicator of teacher attitudes or will in the Will, Skill, Tool (WST) Model of Technology Integration shown in Figure 2. Studies using the WST Model have shown that up to 90% of the level of technology integration in the classroom can be explained by will, skill, and tool measures (Morales, 2006).

Conclusion

Analysis of educator data sets from 1995–1997, 1998–1999, 1999–2000, 2003, 2006, and 2008 have reconfirmed that the Teachers' Attitudes Toward Computers Questionnaire (TAC) has retained superior psychometric properties as it evolved from its original 284 items to the 51 items comprising the version featured in this paper. Confirmatory factor analysis verified acceptable goodness-of-fit indices in the form of RMSEA = .048 (desirable is < .06), SRMR = .0452 (desirable is <= .08), and CFI = .984 (desirable is >= .95). Internal consistency reliability estimates for 2006 K–12 teacher data in the USA ranged from .89 to .95 among subscales representing the nine TAC constructs. Reliability estimates for 2008 preservice teacher data ranged from .87 to .95. These can be classified as "very good" according to established guidelines. Data reported in 2006 for a Spanish-language translation of the instrument indicates that reliabilities for the subscales of the TAC can be expected to remain in the range of at least "respectable" (DeVellis, 2003) in translated forms. This evidence collectively indicates that the TAC version 6 is worthy of continued use in a multicultural, global environment.

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Table 9: Calendar Years 2003, 2006, and 2008 Internal Consistency Reliability Estimates for Data Gathered Through TAC Version 6

	Items	2003 Alpha English	2006 Alpha English	2006 Alpha Spanish	2008 Alpha English
Sample Size (n)		1,169	973	100	273
Part 1—Interest	5	.90	.90	.89	.90
Part 2—Comfort	5	.95	.95	.96 (4 items)	.95
Part 3—Accommodation	5	.90	.91	.98	.95
Part 4—Interaction	5	.94	.95	.90 (4 items)	.94
Part 5—Concern	8	.89	.89	.92 (4 items)	.92
Part 6—Utility	8	.90	.92	.88	.92
Part 7— Perception	5	.94	.95	.91	.94
Part 8— Absorption	5	.89		.82	.91
Part 9— Significance	5	.87		.74	.87

Note: Items not used in Spanish-language edition (Mexico) due to low translation integrity at the pilot test stage were item 247 from part 2, item 280 from part 4, and item 142 from part 5. See Appendix for item wordings (pages 153–155).

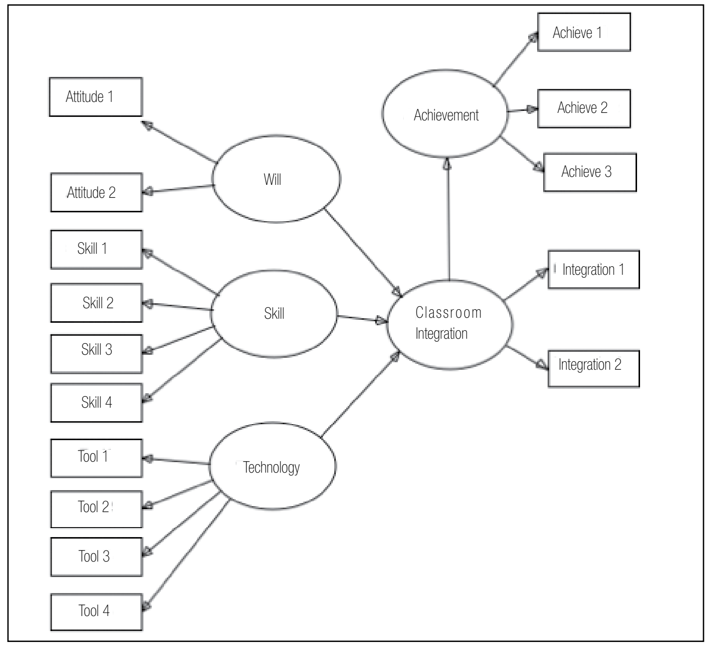

Figure 2: Will, Skill, Tool Model of Technology Integration

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Appendix

Teachers' Attitudes Toward Computers

This questionnaire is derived from well-validated portions of several attitudinal surveys that have been used with teachers in the past. We will use your responses to help develop a profile of how teachers view technology. Please complete all items even if you feel that some are redundant. This should require about 10 minutes of your time. Usually it is best to respond with your first impression, without giving a question much thought. Your answers will remain confidential.

ID: ________________ **Group:______________**	**Use the ID assigned to you or if there is no assigned ID, use the last four digits of your social security #**

Part 1

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	I think that working with computers would be enjoyable and stimulating. (186)	1	2	3	4	5
2.	I want to learn a lot about computers. (103)	1	2	3	4	5
3.	The challenge of learning about computers is exciting. (211)	1	2	3	4	5
4.	I like learning on a computer. (181)	1	2	3	4	5
5.	I can learn many things when I use a computer. (9)	1	2	3	4	5

Part 2

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	I get a sinking feeling when I think of trying to use a computer. (263)	1	2	3	4	5
2.	Working with a computer makes me feel tense and uncomfortable. (230)	1	2	3	4	5
3.	Working with a computer makes me nervous. (17)	1	2	3	4	5
4.	Computers intimidate me. (227)	1	2	3	4	5
5.	Using a computer is very frustrating. (18)	1	2	3	4	5

Part 3

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	If I had a computer at my disposal, I would try to get rid of it. (150)	1	2	3	4	5
2.	Studying about computers is a waste of time. (192)	1	2	3	4	5
3.	I can't think of any way that I will use computers in my career. (74)	1	2	3	4	5
4.	I will probably never learn to use a computer. (154)	1	2	3	4	5
5.	I see the computer as something I will rarely use in my daily life. (123)	1	2	3	4	5

Part 4

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

Appendix continued on p. 154

Appendix continued from p. 153

		SD	D	U	A	SA
1.	The use of electronic mail (E-mail) makes the student feel more involved. (282)	1	2	3	4	5
2.	The use of E-mail helps provide a better learning experience. (284)	1	2	3	4	5
3.	The use of E-mail makes a class more interesting. (281)	1	2	3	4	5
4.	The use of E-mail helps the student learn more. (283)	1	2	3	4	5
5.	The use of E-mail increases motivation for class. (280)	1	2	3	4	5

Part 5

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	Computers are changing the world too rapidly. (142)	1	2	3	4	5
2.	I am afraid that if I begin to use computers I will become dependent upon them. (215)	1	2	3	4	5
3.	Computers dehumanize society by treating everyone as a number. (138)	1	2	3	4	5
4.	Our country relies too much on computers. (135)	1	2	3	4	5
5.	Computers isolate people by inhibiting normal social interactions among users. (144)	1	2	3	4	5
6.	Use of computers in education almost always reduces the personal treatment of students. (176)	1	2	3	4	5
7.	Computers have the potential to control our lives. (134)	1	2	3	4	5
8.	Working with computers makes me feel isolated from other people. (241)	1	2	3	4	5

Part 6

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	Computers could increase my productivity. (202)	1	2	3	4	5
2.	Computers can help me learn. (204)	1	2	3	4	5
3.	Computers are necessary tools in both educational and work settings. (226)	1	2	3	4	5
4.	Computers can be useful instructional aids in almost all subject areas. (175)	1	2	3	4	5
5.	Computers improve the overall quality of life. (207)	1	2	3	4	5
6.	If there was a computer in my classroom it would help me to be a better teacher. (163)	1	2	3	4	5
7.	Computers could enhance remedial instruction. (168)	1	2	3	4	5
8.	Computers will improve education. (162)	1	2	3	4	5

Part 7

Instructions: Choose one location between each adjective pair to indicate how you feel about computers.

Computers are:

1.	unpleasant	1	2	3	4	5	6	7	pleasant	(44)
2.	suffocating	1	2	3	4	5	6	7	fresh	(50)
3.	dull	1	2	3	4	5	6	7	exciting	(49)
4.	unlikable	1	2	3	4	5	6	7	likeable	(41)
5.	uncomfortable	1	2	3	4	5	6	7	comfortable	(46)

Part 8

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	I like to talk to others about computers. (98)	1	2	3	4	5
2.	It is fun to figure out how computers work. (193)	1	2	3	4	5
3.	If a problem is left unsolved in a computer class, I continue to think about it afterward. (85)	1	2	3	4	5
4.	I like reading about computers. (100)	1	2	3	4	5
5.	The challenge of solving problems with computers does not appeal to me. (57)	1	2	3	4	5
6.	When there is a problem with a computer that I can't immediately solve, I stick with it until I have the answer. (69)	1	2	3	4	5

Part 9

Instructions: Select one level of agreement for each statement to indicate how you feel.

SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree

		SD	D	U	A	SA
1.	It is important for students to learn about computers in order to be informed citizens. (96)	1	2	3	4	5
2.	All students should have an opportunity to learn about computers at school. (95)	1	2	3	4	5
3.	Students should understand the role computers play in society. (172)	1	2	3	4	5
4.	Having computer skills helps one get better jobs. (97)	1	2	3	4	5
5.	Computers could stimulate creativity in students. (199)	1	2	3	4	5

Thank you for your time.

AC v 6.1 5/2001