



Available online at www.sciencedirect.com



Computers & Education 51 (2008) 1523–1537

**COMPUTERS &
EDUCATION**

www.elsevier.com/locate/compedu

Identifying discriminating variables between teachers who fully integrate computers and teachers with limited integration

Julie Mueller^{a,*}, Eileen Wood^a, Teena Willoughby^b, Craig Ross^c, Jacqueline Specht^d

^a Wilfrid Laurier University, Faculty of Education, Department of Psychology, 75 University Avenue, Ontario, Canada N2L 3C5

^b Brock University, Department of Child & Youth Services, 500 Glenridge Avenue, St. Catherines, Ontario, Canada L2S 3A1

^c University of Windsor, Department of Psychology, 173 Chrysler Hall South, 401 Sunset Avenue, Windsor, Ontario, Canada N9B 3P4

^d The University of Western Ontario, Faculty of Education, 1137 Western Road, London, Ontario, Canada N6G 1G7

Received 6 October 2007; received in revised form 31 January 2008; accepted 4 February 2008

Abstract

Given the prevalence of computers in education today, it is critical to understand teachers' perspectives regarding computer integration in their classrooms. The current study surveyed a random sample of a heterogeneous group of 185 elementary and 204 secondary teachers in order to provide a comprehensive summary of teacher characteristics and variables that best discriminate between teachers who integrate computers and those who do not. Discriminant Function Analysis indicated seven variables for elementary teachers and six for secondary teachers (accounting for 74% and 68% of the variance, respectively) that discriminated between high and low integrators. Variables included positive teaching experiences with computers; teacher's comfort with computers; beliefs supporting the use of computers as an instructional tool; training; motivation; support; and teaching efficacy. Implications for support of computer integration in the classroom are discussed.

© 2008 Elsevier Ltd. All rights reserved.

Keywords: Computer integration; Elementary and secondary teachers; Computers in classrooms; Teacher Characteristics; Computer technology; Teachers; Computers

1. Introduction

Computer technology continues to advance at an unprecedented rate in all aspects of our society. The ever increasing availability of computers and Internet access has made computer technology a fixture in elementary and secondary schools throughout North America. Systematic reviews of computer-assisted instruction suggest that there are small but positive effects beyond those found in traditional instruction (Blok, Oostdam, Otter, & Overmaat, 2002; Torgerson & Elbourne, 2002). However, despite increasing access and potential

* Corresponding author.

E-mail address: jmueller@wlu.ca (J. Mueller).

learning advantages, North American research suggests that computers are under-used in many schools and the potential of computer technology is not being realized (Abrami, 2001; Ertl & Plante, 2004; Muir-Herzig, 2004; Sutherland et al., 2004). International research paints a similar picture of computer integration. Work conducted in the United Kingdom, Thailand, Greece, Australia and The Netherlands suggests that computers are still under-used in terms of quantity and quality of use (Conlon & Simpson, 2003; Demetriadis et al., 2003; Hayes, 2007; Pelgrum, 2001; Wilson, Notar, & Yunker, 2003; Wooley, 1998). The impetus for researchers then is to understand why computers are not being used to their full potential in the classroom.

Previous research has identified both environmental variables and individual characteristics of teachers as potential barriers to the successful integration of computer technology (e.g., Becker & Ravitz, 2001; Cuban, Kirkpatrick, & Peck, 2001; Hayes, 2007; Mueller, Wood, & Willoughby, 2007; Rosen & Weil, 1995; Sandholtz, Ringstaff, & Dwyer, 1997; Windschitl & Sahl, 2002). The majority of existing research, however, has focused on environmental barriers (e.g., equipment based issues such as limited access, technical problems and malfunctions); most likely because these issues were immediate concerns facing teachers and administrators when computers were first being introduced in schools. Ongoing advances with computer technology make it important to continue to consider the role of environmental barriers in the integration of computers in the classroom.

The relative impact of environmental barriers is challenging to evaluate over time. Continual and rapid advances in computer technology, compounded with institutional changes within schools (e.g., regarding the presence of technology) constantly change the kinds of environmental barriers that teachers encounter when integrating computers. Recent research (Wood, Mueller, Willoughby, Specht, & DeYoung, 2005), however, suggests that some of the barriers identified early on may no longer be perceived as the insurmountable barriers that they once were. For example, the majority of teachers now have access to and use computers on a regular basis making technical difficulties and lack of access less problematic. Although increased access and familiarity with computers may reduce some of the original concerns addressed in the research, environmental barriers associated with new technologies may still present substantial obstacles to the seamless integration of technology within the classroom (Wood et al., 2005).

Although environmental barriers remain important considerations, it is the individual differences in beliefs, attitudes, and skills among teachers that is the key area of interest for researchers today (Dexter, Anderson, & Becker, 1999; Mercer & Fischer, 1992; Mishra & Koehler, 2006; Sanders & Horn, 1994; Schofield, 1995; Zhao, Pugh, Sheldon, & Byers, 2002). Educators are the focus of interest because it is educators that have the primary contact with students and it is educators that experience the barriers and supports to integration of technology first-hand.

Given the critical role of educators, it is important to understand the contributions that teachers make in supporting or inhibiting the integration of computer technology in the classroom. Although today's teachers may be more familiar with technology in general, they still may not be fully prepared or able to integrate computer technology in their classrooms. Abrami (2001) suggested that teachers may not be using computers to their potential as a cognitive tool due to teachers' lack of experience in the "craft" of computer integration. Others have suggested that developing the skills required to integrate technology can be a lengthy process. For example, Hadley and Sheingold (1993) suggest that it takes 5 or 6 years for a teacher to gain mastery in integrating technology, and that is when teachers are given support and time to learn and plan for integration. Sandholtz et al. (1997) described a multi-stage process that teachers need to navigate before being fully able to integrate technology in the classroom. Transitions across these stages may not be static. For example, transitions could be compromised as a function of the rapid pace of change in computer technology.

Continual changes in technology may result in teachers being "perpetual novices" in the process of technology integration, or at least teachers may find themselves repeating stages or stalling as advances in technology continually present new opportunities and potential uses. Teachers' experience with technology may reflect a recursive spiral (Huberman, 1992) rather than a linear change, with lower levels of computer use simply reflecting that not enough time has passed for higher level uses to emerge in classrooms (Ertmer, 2005).

Some researchers suggest that more professional training in how to integrate technology into classroom practice is needed in order to move teachers through the stages toward integration (Foon Hew & Brush, 2007; McGrail, 2005). Traditionally, professional development has taken a "training" approach, with a short term focus. For example, training might be arranged around a particular software, or on what Maddux and

Johnson (2005) refer to as Type I applications – using technology to do the same thing only faster or easier. More recent professional development approaches suggest that both the context of teaching and the opportunity for reflection are key components for professional development (Lawless & Pellegrino, 2007). Professional development involving Instructional Technology may require a design that is more durable. Specifically, the content needs to address broader issues related to the reforms required to successfully integrate computers (Wells, 2007). It may be necessary, therefore, to explicitly address the impact of technology on beliefs, attitudes, and philosophy. For example, in a study of middle and high school English teachers' attitudes toward technology, McGrail (2005) describes the teachers' perceptions of technological change in their instructional practice. Teachers pointed out disadvantages of computer use; pedagogical concerns about students; concerns about instruction and language; administrative challenges; and ethical concerns. It was not obvious to these teachers how computer technology fit into their instructional style or how it could be integrated into current curriculum. A teacher's pedagogical beliefs about how technology fits, or does not fit with those beliefs, may be a determining factor in computer integration.

An educator's knowledge, skill and philosophy determine his or her instructional methods in general (Bain & McNaught, 2006; Staub & Stern, 2002), and have significant effects on the students that they teach (Abbott-Shim, Lambert, & McCarty, 2000; Ross, 1994). Teachers' beliefs about their own computer efficacy, and the values and costs of technology, have been shown to predict computer integration in the classroom (Wozney, Venkatesh, & Abrami, 2006).

The impact of the pedagogical beliefs of teachers on classroom practice has been well-documented (Buchman, 1987; Lumpe, Haney, & Czerniak, 2000; Mishra & Koehler, 2006; Nespor, 1987; van Driel, Beijaard, & Verloop, 2001) but the direct influence of pedagogical beliefs for the integration of computers is not as clear (Wozney et al., 2006). Teachers are likely to use their past experiences, beliefs, and attitudes about learning and teaching to develop their beliefs about technology as a teaching method or instructional tool (Ertmer, 2005; McGrail, 2005; Niederhauser & Stoddart, 2001; Windschitl & Sahl, 2002). To use computers as a cognitive tool in knowledge construction, educators must acknowledge the computer as a learning tool and to be able to incorporate it into the classroom (Hokanson & Hooper, 2000).

Teaching philosophy, in particular a constructivist approach, has been suggested as a prerequisite for successful computer integration. According to Richardson (2003), constructivist pedagogy involves the following characteristics: it is student-centred; group dialogue leads to shared understanding; formal domain knowledge is introduced, both planned and unplanned; there are opportunities for students to challenge existing beliefs through engagement in structured tasks; and, there is development of meta-awareness of the student's own learning processes. The computer has enormous potential to be used as a cognitive tool to support all of these characteristics (LaJoie, 2000). The questions are whether teachers acknowledge this potential and whether they can harness it.

Niederhauser and Stoddart's (2001) survey of over 2170 elementary and secondary teachers, identified two discrete categories of beliefs about the effective use of computer technology: transmission-oriented, in which computers are used as teaching machines to present information, give reinforcement and track student progress; and constructivist-view, in which computers are used to collect, analyze and present information. It follows that teaching philosophy will be related to whether and how a teacher integrates computer technology. Although Becker's extensive survey of 516 teachers from grades three to twelve (1994) did not find a significant difference between the teaching philosophy of "exemplary computer-using teachers" and other teachers, there were differences in how teachers used computers. The activities in the classrooms of the exemplary teachers provided opportunities for students to expand knowledge and grow intellectually rather than merely develop isolated skills-in line with a more constructivist approach. It may take several years of use to integrate computer technology according to a constructivist philosophy – that is, using the computer as a cognitive tool for knowledge construction rather than to replicate traditional tasks such as word processing, drill and practice, and information searching (Ertmer, 2005; Marcinkiewicz, 1993; Sandholtz et al., 1997).

Intervention studies have suggested that an inverse relationship between computer integration and beliefs may be true – that is, a teacher's pedagogical philosophy may be altered following the integration of computers. The changing role of the teacher was identified by Schofield (1997) as a significant social impact of computer integration, along with increased student motivation and increased peer instruction. Following a

computer integration intervention, teachers saw themselves as facilitators, interacted with students more, and conducted fewer whole group lessons.

In addition, pre-service teachers and higher education faculty in a Goals 2000 Pre-service Technology Infusion Project ([Vannatta & Beyerbach, 2000](#)) demonstrated significant increases in constructivist-related beliefs about technology following an intervention that included demonstration of technology integration, videoconferencing with technology-using teachers, and individual technology plans and support. Changes in beliefs happen through personal experience, vicarious experiences and social-cultural influences ([Ertmer, 2005](#)). It may be that teachers need to experience positive outcomes of computer integration personally or vicariously through other teachers, in order to alter their beliefs and encourage more widespread computer integration. Measurement of teachers' beliefs following computer integration is necessary to identify lasting changes within the classroom.

Even if a teacher's pedagogical beliefs and attitudes toward technology suggest that computer integration would be a meaningful teaching approach, the teacher must believe that he or she is capable of implementing technology successfully in order to act on those beliefs. A teacher's judgment about his or her ability to perform actions which lead to student learning is based on past experience. It follows that a teacher's positive personal or vicarious experiences with computer technology will lead to greater integration. However, [Ross \(1996\)](#) concluded that teacher self-efficacy is a specific construct that varies within educators across contexts. A teacher with high teaching efficacy, therefore, may not necessarily hold an equally positive view of their ability to effect change using computer technology.

[Wozney et al. \(2006\)](#) used cost-expectancy theory to explain how individual teacher characteristics and environmental variables influence computer integration. This theory proposes that teachers consider value (beliefs about the good technology does) and expectancy (efficacy beliefs, access, and support available), and then weigh that against cost (including time, energy, anxiety, teacher numbers) in their decision to implement computer technology in their classrooms. The results of their survey of 764 elementary and secondary teachers indicated that the important predictors of implementation were expectancy of success and perceived value – teachers' attitudes toward technology and the likelihood that they could accomplish instructional goals using the technology. The diminished emphasis on costs lends support for the idea that barriers to computer integration are lessening and research should focus on a teacher's attitudes and perceptions as important influences. Indeed, [Vannatta and Fordham \(2004\)](#) identified the need for additional study of the complexity of the "development of a skilled, reflective technology-using teacher" (p. 262) that includes random sampling of a large, heterogeneous sample and the inclusion of a variety of teacher attributes, both technology and non-technology specific. It is necessary to investigate the variables that are responsible for successful integration beyond the experience of teachers and the supports provided. What is it that makes a teacher successful in the integration of computer technology?

1.1. The current study

The purpose of the current study was to survey in-service teachers who did, and did not integrate computers in their classrooms, in order to identify the variables that best discriminated between these two groups at both the elementary and secondary school levels. The study drew high and low integrators from a random sample of both elementary and secondary teachers from across a large school district to measure their computer use, attitudes, and beliefs. Teachers completed an extensive questionnaire in an effort to identify the individual characteristics of teachers who successfully integrate computer technology. This study provided an opportunity to examine variables impacting successful integration beyond identification of barriers and reasons for under-use ([Conlon & Simpson, 2003](#)), and included both computer-related and general constructs.

2. Method

2.1. Participants

The final sample included 185 elementary teachers and 204 secondary teachers representing 94 elementary and 16 secondary schools from one school board in a midsized Canadian city. The majority of participants

were female (262 female and 127 male). The mean age of the sample was 41.8 years ($SD = 8.43$) with average teaching experience of 14.8 years ($SD = 8.75$). The majority of teachers had an undergraduate degree (87.2% elementary, 78.3% secondary) and an additional 10% of elementary teachers and 15.3% of secondary teachers held Masters or Ph.D. degrees.

Teachers were sampled from the school board's complete list of teachers. A first wave of surveys was sent to 325 elementary and 325 secondary teachers. If no response to the initial mailing was received after two months, a second mailing was sent to the participant. A follow-up two months after the second mailing indicated that 17 of the sampled elementary teachers were unavailable for participation (1 deceased, 6 on maternity leave, and 10 had changed schools and did not receive the survey) and 15 of the secondary teachers were unavailable (5 on maternity leave and 10 had changed schools). In total, the return rates for the elementary and secondary samples were 45% and 53%, respectively, with an overall return rate of 49%.

In order to increase the sample size, an additional mailing was sent to a different sample of 139 elementary teachers and 88 secondary teachers from the same school board. This mailing was made only once near the end of the school year, and yielded lower response rates (27% for elementary and 39% for secondary). A multivariate analysis of variance examining demographic and other survey variables indicated that the first and second mailing samples did not differ, Pillai's Trace = .995, Wilk's Lambda = .005, $F(22, 366) = 1.30$, $p = .16$. As a result, participants from both mailings were included in the present study. The demographics of the final sample described above represent participants from the two mailings.

2.2. Materials and procedure

Each participant was asked to complete one survey. Two versions of the survey were developed (one elementary and one secondary). The versions were identical in content except for questions relating to current teaching assignments. The survey was developed based on the responses from educators in an earlier focus group study with elementary and secondary teachers (Wood et al., 2005). Face validity of computer-related measures was ensured through the use of participants' actual language for specific items describing computer technology issues. The survey included a comprehensive set of measures addressing both computer-related and general constructs. Computer-related constructs included computer integration, comfort with computers, type of computer use, computer training, attitudes towards computers, and experiences with computer technology. General constructs included demographics, teacher-efficacy, teaching philosophy, and attitudes toward work. Brief descriptions of questions used to measure each construct are included below.

Single-item questions were used to assess demographic variables including participant gender and years of teaching experience.

2.2.1. Computer integration

Computer integration was a composite of eight items ($\alpha = .82$). Three questions asked teachers to rate the extent to which they integrate computer technology in the classroom, how often they assume that computer use by students will be part of their instructional plan, and how often they use a computer as a presentation tool, using a 5-point, Likert-type scale (0 – *never*, to 4 – *a great deal*). Participants also were asked to report the frequency of student computer use in the classroom for five different activities (on-line research, tool-based software use, subject-specific software use, communication, and assessment purposes), using the same scale. The integration measure attempted to address a multiplicity of behaviours in order to capture the complexity of computer integration and to follow a definition of integration that assumes use of technology by the teacher and students. This scale served as the mechanism for separating low from high integrating teachers.

2.2.2. Comfort with computers

Comfort with computers was a composite of two questions using a 5-point Likert-type scale (1–*very ill at ease/unenthusiastic*, to 5–*very at ease/enthusiastic*) measuring ease and enthusiasm with computers (Mueller & Wood, 2006; Wood et al., 2005). The two variables were significantly correlated, $r = .73$, $p < .001$.

2.2.3. Computer use

Type of computer use was an aggregate of 19 questions measuring teachers' use of computers at home and at school (Cronbach's alpha = .83). For example, home computer use was assessed by asking how frequently participants used a home computer for specific tasks in seven different areas: communication, entertainment, office tools, multimedia, personal financing, work-related tasks, and study. Participants reported the frequency of use for each task on a 5-point scale (0 – *never*, to 4 – *everyday*).

2.2.4. Computer training

Computer training was measured using a single item question that asked participants to report the number of computer-related workshops they had attended in the past three years.

2.2.5. Attitudes toward computers

Attitudes toward computers measured whether teachers saw computers as an *instructional tool* (7 items; e.g., "I see computers as tools that can complement my teaching"; Cronbach's alpha = .77) and as a *motivational tool* (3 items; e.g., "I use computers to motivate my students"; Cronbach's alpha = .66). All items used a 5-point Likert-type scale anchored by "strongly disagree" and "strongly agree".

2.2.6. Experiences with computer technology

Reported frequencies of specific experiences with computer technology were gathered using a nine-item computer experience questionnaire (CEQ) that was also developed through statements made by teachers in Wood et al. (2005) focus group study. Teachers were asked to indicate how frequently they experienced 9 specific events (e.g., "A colleague comes to you for help in using computers at school"), employing a 5-point Likert-type scale (0–*never*, to 4–*a great deal*). A factor analysis of the 9 items resulted in 3 specific types of experiences: *technical problems* (2 items; e.g., "Equipment failure when using computers in the classroom or lab" $r = .57$); *assistance from others* (3 items; e.g., "You ask a colleague for help in using computers at school" Cronbach's alpha = .70); and, *positive outcomes* (4 items; e.g., "Students finish their computer activities during class time" Cronbach's alpha = .75). The three subscales were analyzed separately.

2.2.7. Teacher efficacy

Teacher efficacy was assessed using a shortened version of the Teacher Efficacy Scale (TES) (Hoy & Woolfolk, 1993). Teachers were asked to report the degree to which they agreed or disagreed with nine statements that measured the extent to which they believed that their behaviour could impact their students (e.g., "When a student does better than usual, many times it is because I exerted a little extra effort), using a 6-point scale anchored with "strongly disagree" and "strongly agree". The Cronbach's alpha for the TES was .77.

2.2.8. Teaching philosophy

Teaching philosophy was assessed using the "constructivist teaching" subscale of the teacher beliefs survey (TBS) (Benjamin, 2003). Teachers indicated their level of agreement with 14 statements (Cronbach's alpha = .80), using a 6-point scale anchored by "disagree strongly" and "agree strongly" (e.g., "I involve students in evaluating their own work and setting their own goals").

2.2.9. Attitudes toward work

Attitudes toward work were assessed through three subscales of the work preference inventory (WPI) (Amabile, Hill, Hennessey, & Tighe, 1994). Two subscales assessed intrinsic orientation, *challenge* (5 items; e.g., "I enjoy tackling problems that are completely new to me") and *enjoyment* (10 items; e.g., I enjoy work that is so absorbing that I forget about everything else"); and one assessed extrinsic orientation, *outward* (10 items; e.g., "I am strongly motivated by the recognition I can earn from other people"). Participants rated the items on a 4-point scale ranging from 1 (*never or almost never true of me*) to 4 (*always or almost always true of me*). Cronbach's alphas for the 3 subscales were .78, .70, and .66, respectively.

3. Results

Analyses examined differences between teachers who do and do not integrate technology. First, group profiles were constructed for the two groups of teachers, high versus low integrators. Second, differences between the groups on the survey measures were examined. Third, to assess which measures best discriminate between the two groups, a multivariate discriminant function analysis was conducted. Separate analyses were conducted for the elementary and secondary samples based on differences in terms of teaching assignment and significant differences in past research (Wood et al., 2005). Correlations among study measures are listed in Table 1.

3.1. Group profiles

The purpose of the current study was to identify the variables that discriminate between in-service elementary and secondary teachers who do, and those who do not, integrate computers in their classrooms. “Low” and “high” integrator groups were created using the mean overall integration scores. Groups were based on the lowest 25% of scores and the highest 25% of scores within the sample for each level. “Low integrators” scored between 0 and .80 on the integration score for elementary teachers ($n = 54$) and between 0 and .95 for secondary teachers ($n = 51$). “High integrators” scored between 1.85 and 4.00 for elementary ($n = 52$) and between 2.15 and 4.00 for secondary teachers ($n = 53$). See Table 2 for means for the two groups on each of the integration questions. These two groups formed the sub-sample of teachers at each level (elementary and secondary) that were included in all further analysis.

3.2. Univariate analysis

Univariate group comparisons were conducted using one-way ANOVA's on each construct of interest for both elementary and secondary samples. A significance level of $p < .004$ was used to correct for multiple comparisons. ANOVA's were conducted on 14 variables: teaching experience, comfort, use, training, attitudes toward computer technology as an instructional tool, attitudes towards computer technology as a motivational tool, CEQ technical problems, CEQ assistance from others, CEQ positive outcomes, teacher efficacy, constructivist teaching, and work beliefs including challenge, enjoyment, and outward subscales. Means

Table 1
Correlation matrix for computer related and individual characteristic variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. Years of teaching	—														
2. Integration	.05	—													
3. Comfort with computers	-.09	.61*	—												
4. Computer use	-.06	.57*	.57*	—											
5. Training	.10	.25*	.25*	.23*	—										
6. FGTQ instructional tool	.04	.58*	.42*	.37*	.25*	—									
7. FGTQ motivational tool	-.05	.09	.07	.03	-.01	.39*	—								
8. CEQ Tech. problems	-.15	.04	.04	.07	.01	.00	.02	—							
9. CEQ assistance from others	.09	.09	-.15*	-.06	.05	.10	.03	.23*	—						
10. CEQ positive outcomes	.06	.73*	.60*	.51*	.33*	.51*	.08	.10	.09	—					
11. Teacher efficacy scale	.13	-.01	.02	.01	-.03	.13	.18*	.01	.08	-.01	—				
12. TBS constructivist	-.04	.12	.06	.16*	.09	.24*	.26	.07	.21*	.07	.33*	—			
13. WPI challenge	-.07	.33*	.36*	.45*	.18*	.19*	-.07	.09	.02	.33*	.12	.31*	—		
14. WPI enjoyment	-.04	.14	.20*	.23*	.13	.14	-.03	.12	.11	.15	.13	.31*	.47*	—	
15. WPI outward	-.03	-.02	-.05	-.08	.03	.00	.07	-.04	.02	-.06	.01	-.04	-.20*	-.02	—

Note: *Significant at $p < .002$ (corrected for multiple comparisons). FGTQ = Focus Group Theme Questionnaire, CEQ = Computer Experience Questionnaire, TBS = Teacher Belief Survey, WPI = Work Preference Inventory.

Table 2

Means and standard deviations for overall and specific integration measures for low and high integration groups by teaching level

Measure	Max	Elementary		Secondary	
		Low integration <i>M</i> (<i>SD</i>)	High integration <i>M</i> (<i>SD</i>)	Low integration <i>M</i> (<i>SD</i>)	High integration <i>M</i> (<i>SD</i>)
Overall integration	4	.50 (.26)	2.39 (.46)	.65 (.25)	2.89 (.50)
Self-report	4	.74 (.48)	2.87 (.79)	.98 (.37)	3.59 (.57)
Planning	4	.52 (.50)	2.87 (.74)	.78 (.49)	3.36 (.79)
Presentation	4	.19 (.40)	2.12 (.96)	.24 (.43)	2.61(1.15)
On-line research	4	.74 (.77)	2.34(1.14)	1.22 (.97)	2.93(1.05)
Tool-based software	4	.85 (.92)	2.83 (.92)	.96(1.06)	3.47 (.82)
Subject software	4	.87 (.90)	2.12(1.08)	.47 (.76)	1.44(1.16)
Communication tool	4	.02 (.06)	.14 (.44)	.07(.24)	.59 (1.14)
Assessment tasks	4	.21 (.62)	1.07(1.17)	.27 (.56)	1.70(1.25)

Table 3

Univariate and multivariate results for elementary level

Variables	ANOVA		Partial η^2	DFA	
	Low integrators <i>M</i> (<i>SD</i>)	High integrators <i>M</i> (<i>SD</i>)		SC	SCDFC
Years teaching exp.	12.35 (8.46)	15.99 (7.80)	.05	.13	.06
Comfort	3.27 (.86) _a	4.68 (.55) _b	.49	.59	.39
Use	17.65 (7.89) _a	31.12 (10.52) _b	.35	.44	.06
Training	1.11 (1.14) _a	5.00 (4.64) _b	.26	.35	.26
Attitudes					
Instructional tool	3.51 (.50) _a	4.31 (.43) _b	.42	.51	.30
Motivational tool	3.48 (.70)	3.63 (.73)	.01	.06	.01
Experiences					
Technical problems	2.75 (1.34)	2.63 (.82)	.01	.04	.09
Assist. from others	1.93 (.54)	2.02 (.87)	.01	.04	.11
Positive outcomes	1.83 (.54) _a	3.51 (.80) _b	.62	.75	.53
Teaching beliefs					
TES Teacher efficacy	4.64 (.63)	4.70 (.71)	.01	.03	.10
TBS Constructivist	4.11 (.60) _a	4.49 (.59) _b	.10	.19	.10
Work Beliefs					
WPI Challenge	2.56 (.54) _a	3.13 (.43) _b	.26	.36	.21
WPI Enjoyment	2.92 (.42)	3.12 (.39)	.06	.14	.09
WPI Outward	1.95 (.33)	1.88 (.36)	.01	.06	.09

Notes: Means in the same row with different subscripts are significantly different at $p < .004$. SC = structure coefficients. SDFC = standardized discriminant function coefficients. For the ANOVA results, standardized results are shown.

and standard deviations for the low and high integration groups at each level (elementary and secondary) are displayed in Tables 3 and 4.

Group differences in the elementary panel were significant for the computer related measures of comfort, use, training, attitudes towards computer technology as an instructional tool, and positive outcomes, smallest $F(1, 104) = 35.75$, $p < .001$ for the measure of training. General construct variables that showed significance differences included the work beliefs challenge subscale, $F(1, 104) = 37.30$, $p < .001$, and the teacher belief constructivist subscale, $F(1, 104) = 10.87$, $p = .001$. The partial eta squared results indicated that the magnitude of the significant group differences were all large (smallest partial eta squared of .10 for TBS Constructivist to largest of .62 for CEQ positive outcomes) (see Table 3).

The secondary results reported a similar list of significant variables with the exception of the training measure and the teacher belief constructivist subscale. Significant differences between low integrators and high

Table 4
Univariate and multivariate results for secondary level

Variables	ANOVA		Partial η^2	DFA	
	Low integrators <i>M</i> (<i>SD</i>)	High integrators <i>M</i> (<i>SD</i>)		SC	SCDFC
Years teaching exp.	15.53 (7.49)	14.09 (8.13)	.01	.06	.09
Comfort	3.38 (.88) _a	4.77 (.42) _b	.51	.70	.37
Use	21.58 (10.11) _a	36.49 (9.51) _b	.37	.53	.30
Training	1.45 (1.70)	2.79 (3.43)	.06	.17	.09
Attitudes					
Instructional tool	3.58 (.55) _a	4.33 (.40) _b	.39	.54	.30
Motivational tool	2.85 (.88)	3.27 (.85)	.06	.17	.03
Experiences					
Technical problems	2.66 (1.21)	2.91 (1.07)	.01	.08	.20
Assist. from others	2.20 (.82)	2.23 (.80)	.00	.02	.06
Positive outcomes	2.14 (.64) _a	3.73 (.77) _b	.56	.78	.54
Teaching beliefs					
TES Teacher efficacy	4.44 (.63)	4.53 (.53)	.01	.05	.03
TBS constructivist	3.90 (.63)	4.14 (.70)	.03	.12	.04
Work beliefs					
WPI challenge	2.82 (.59) _a	3.12 (.44) _b	.08	.20	.07
WPI enjoyment	3.05 (.39)	3.15 (.41)	.02	.09	.00
WPI outward	1.93 (.36)	1.95 (.48)	.00	.02	.15

Notes: Means in the same row with different subscripts are significantly different at $p < .004$. SC = structure coefficients. SDFC = standardized discriminant function coefficients. For the ANOVA results, standardized results are shown.

integrators were found on the computer-related measures of comfort, use, positive outcomes, and attitudes towards computer technology as an instructional tool. The smallest F was for computer use, $F(1, 102) = 60.03, p < .001$. The only general construct to demonstrate a significant difference between groups was the work belief challenge subscale, $F(1, 102) = 8.98, p = .003$. Parallel to the elementary groups, the magnitude of the differences for the secondary groups were large (smallest partial eta squared of .08 for WPI: challenge subscale to largest of .56 for CEQ positive outcomes) (see Table 4).

3.3. Multivariate analysis

To examine which individual characteristics best discriminate between teachers who integrate computer technology and those who do not, all study variables were simultaneously entered into a discriminant function analysis (DFA) for both the elementary and secondary school levels. DFA can be thought of as the opposite of MANOVA (Sprinthall, 2000). Rather than comparing scores on dependent variables for significant differences, scores on study variables are used to predict group membership. Unlike the univariate analysis, DFA provides an estimate of the relative importance of each of the study measures to the separation between the two teacher groups when examined simultaneously (Meyers, Gamst, & Guarino, 2003). Again, separate analyses were conducted for the elementary and the secondary groups.

3.3.1. Elementary

The Wilks' Lambda for the discriminant function analysis conducted for the elementary panel was significant, $\Lambda = .260, \chi^2(15) = 129.86, p < .001$, indicating that, overall, the variables in the study differentiated between the low integrators and high integrators. The discriminant function explained 74% of the separation between groups and 95.3% of the 106 teachers in the sub-sample were correctly classified by the resulting function.

As shown in Table 3, the measures having the strongest correlations with the discriminant function (i.e., structure coefficients of .30 or greater) for the elementary groups included, in descending order of importance: positive experiences with computers; teacher's comfort with computers; specific beliefs related to the use of

computers as an instructional tool; teacher's own use of computers at home and school; the challenge subscale of the WPI; and training (the number of technology workshops attended).

The standardized canonical discriminant function coefficients represent partial contributions of each variable to the discriminant function, controlling for other measures entered into the analysis (Garson, n.d.). As shown in Table 3, variables making notable, unique contributions to the discriminant function (i.e., standardized discriminant function coefficients of .10 or greater) included the following seven variables in order from largest coefficient to smallest: positive experiences with computers; teacher's comfort with computers; specific beliefs related to the use of computers as an instructional tool; number of workshops attended; the challenge subscale of the WPI; assistance from others; and teaching efficacy.

3.3.2. Secondary

The same variables used in the elementary analysis were entered into a simultaneous discriminant function analysis for the secondary panel. The analysis resulted in a significant Wilks' Lambda $\Lambda = .319$, $X^2(15) = 108.025$, $p < .001$, and explained 68.1% of the separation between groups. Ninety percent of the 104 teachers in the secondary sub-sample were correctly classified by the resulting function.

Examination of the structure coefficients indicated that only four variables had coefficients greater than .30. These key variables were similar to the elementary analysis, except for the exclusion of the number of technology workshops and the WPI challenge subscale. The rest of the most important indicator variables were the same, with the same rank order: positive outcomes with computers; teacher's comfort with computers; specific beliefs related to the use of computers as an instructional tool, and, the teacher's own use of computers at home and at school (see Table 4).

The standardized coefficients indicated that six variables made notable unique contributions to the discriminant function (see Table 4): positive experiences with computers; teacher's comfort with computers; specific beliefs related to the use of computers as an instructional tool; teacher's use of computer at home and at school; technical problems; and the work beliefs outward subscale.

4. Discussion

Our results clearly implicate both experience with computer technology and attitudes toward technology in the classroom as important variables that predict differences between teachers who successfully integrated computer technology from those who did not. Of the six variables that predicted integration among elementary school teachers, four were related to computer-related experience. Similarly, of the four variables that predicted integration among the secondary school teachers, three involved computer-related experience. These outcomes support opinions, expectations and previous research findings presented in the literature (Becker, 1994; Foon Hew & Brush, 2007; Hadley & Sheingold, 1993; Rosen & Maguire, 1990; Wood et al., 2005). Specifically, consistent with previous research, computer experience variables such as comfort with technology and higher frequency of use of computers were significant contributors to the function that separated successful elementary and secondary integrating teachers from their non-integrating peers. In addition, training with computers was important at the elementary level. Our results, however, suggest that "general" exposure and use is less critical than very specific, task-relevant, and classroom-applicable experience. Specifically, the positive outcomes measure contributed the most to the discriminating function for both elementary and secondary teachers.

The positive outcomes variable measured how frequently teachers had experienced "positive" outcomes using computer technology in the classroom. These highly specific, positive experiences may add to teachers' confidence with using computers as an instructional tool above and beyond preparing them to use computers for personal use or for other general uses. The need for specific positive experiences with technology in the classroom indicates that teachers need to see that an innovation has the potential to improve learning or instruction before they are willing to endorse it (Evers, Brouwers, & Tomic, 2002; Fuchs, Fuchs, & Bishop, 1992). In fact, it may be the case that actual classroom success with computer technology is a prerequisite or catalyst for the integration of computers as an instructional tool (Kiridis, Drossos, & Tsakiridou, 2006).

Hands-on, direct practice with computer technology in a teacher's own classroom or teaching context may build the confidence that is necessary for a teacher to take the risk of including computers as an additional tool in their teaching repertoire. Success may come in the form of personal hands-on experience and it may also include vicarious modeling by other teachers having successful experiences in their classrooms. For example, having access to a "key" teacher on staff that is skilled in the instructional use of computer technology has been identified as an important support for encouraging less experienced teachers to adopt and integrate technology within the classroom (Wood et al., 2005). Although computer-related variables in general continue to impact on teachers' ability to integrate technology, it is positive experiences with computers in the classroom context that build a teacher's belief in computer technology and their confidence in its potential as an instructional tool.

It is interesting to note that there was no significant impact of number of years of teaching experience in our analyses. This outcome suggests that teachers at all stages of their career were equally able to integrate computer technology. Currently, one might anticipate that younger teachers would have more experience with technology and be better equipped to introduce it in their classrooms (Hadley & Sheingold, 1993). However, those same teachers are at the early "survival" stage of their career (Bitan-Friedlander, Dreyfus, & Milgrom, 2004; Criswell, 1996), focussed on issues of classroom management and course development, and may have few resources left to surmount the barriers to computer integration that are still apparent in many classrooms. Even though their experiences with computer technology may be limited, more experienced teachers may have the time and resources to explore an innovation such as computer technology and apply it to their developed curriculum.

Attitudes towards computer technology also proved to be a critical contributor that distinguished successful and less successful integrators at both teaching levels. At both levels of teaching, attitudes towards computers as an instructional tool was the third variable identified through the discriminant function analysis. Overall, both elementary and secondary high integration groups had higher, more positive, scores on this scale. This scale measures the degree to which a teacher sees computer technology as a viable, productive, cognitive tool that is appropriate for use within their teaching context.

The predictive strength of attitudes toward computer technology as an instructional tool is consistent with recent research based on value-expectancy theory (Wozney et al., 2006) and past research identifying the importance of perceived usefulness in microcomputer usage in the business world (Igbaria & Iivari, 1995). For example, Wozney et al. used regression analysis to identify important predictors of computer implementation. Their findings report that a teacher's attitude toward technology, specifically the value of the innovation, along with expected success, was one of the chief indicators of implementation. In the field of management, similar to the teachers in the current survey, business workers needed to see the computer as a useful tool before they would consider its implementation (Igbaria & Iivari, 1995). Perceived usefulness was an important component of their motivation to use computers, while organizational support and computer anxiety had only indirect effects on usage, through perceived usefulness.

It was expected that teaching efficacy would impact on integration. Teaching efficacy, however, was not an important part of the function. This sample of teachers, regardless of their level of computer integration, reported a relatively strong teaching efficacy. However, the teacher self-efficacy scale did not include items directed specifically at computer self-efficacy. It may be that teachers need a feeling of efficacy related directly to computer usage and not teaching in general.

The high and low integration groups did not differ in terms of gender, years of experience, technical problems they had experienced, or the enjoyment and outward motivation for their work. It may be that technology has been a part of education for a long enough period of time that teaching experience is no longer influential on computer experience, and that technical glitches have been smoothed out to some extent (e.g., Wood et al., 2005). The non-significant difference in extrinsic motivation is not surprising, considering that there are unlikely to be external rewards for teachers who integrate technology above those offered to teachers who teach with little computer integration.

The computer is seen in the literature as a cognitive tool that has great potential to support a constructivist form of teaching and learning (Brown, Hedberg, & Harper, 1994). Although the univariate results for the elementary groups reported a significant difference between low integrators and high integrators, the constructivist subscale of the Teacher Belief Survey was not identified as a significant contributor to the function

discriminating high integrators from low integrators in this study. Although underlying teaching philosophy has been suggested as a determining characteristic for computer integration, findings have been inconsistent. Schofield (1995) suggests that a change in teacher's role, and ultimately philosophy, may be a result of computer integration rather than a prerequisite. Vannatta and Fordham (2004) included teacher philosophy as a possible predictor of computer usage but reported no differences between those who integrated computers and those who did not. In the present study, however, there was little variation in teacher belief scores across the sample and teachers generally scored close to neutral, suggesting that the reported teaching philosophy of participants was not extreme.

There is some question as to how closely reported-philosophy matches actual behaviour (Keys, 2005). Judson (2006) suggests that there may be little correlation between stated beliefs and actual practice. Although the computer has the potential to support a constructivist style of teaching and learning, it may be that teachers are using the computer to enhance current practice and whatever philosophy they currently teach under is being supported by the technology.

One significant difference between elementary and secondary teaching levels in the present study was that elementary teachers who were integrating computer technology to a greater degree reported higher scores on the WPI intrinsic motivation: challenge subscale than low integration teachers, suggesting that these teachers may be more intrinsically motivated than their low integration counterparts to do their job because of the challenge it presents. It may be that integrating computers into the elementary classroom requires a great deal of effort and risk that provides few rewards outside the intrinsic satisfaction of meeting the challenge. Becker (1994) also found support for this hypothesis, with exemplary computer teachers more willing to take initiative and challenge themselves beyond the regular requirements of their position than non-exemplary computer teachers. For teachers who are not "risk takers", professional development aimed at improving technological skill, may still not have a great impact unless integration is seen as less of a challenge. Some teachers will need to see positive outcomes and begin to view technology as an instructional tool that does not include insurmountable challenges.

Professional development and the process of integration must address the attitudes of teachers and present them with opportunities for positive computer experiences within the context of their instruction (e.g., Foon Hew and Brush, 2007). Although the sample size for particular subject areas in the current study was too small to analyze the data as a function of the subject taught, teachers are likely to need experiences specific to their topic of instruction (Jones, 1999). Personal experience with technology success could be necessary for any change in attitudes and increase in computer efficacy (Ross, 1996). Administration may need to identify teachers who are successfully integrating technology and develop mentor programs or workshop training to expose teachers to successful integration in a practical way. Opportunities to observe classroom practice, and the introduction of technology in more gradual ways to support current classroom practice (Ertmer, 2005), may be of more benefit than attempts to alter teaching philosophy. Teachers need to see the potential of computer technology as a cognitive tool.

In a recent evaluation of an extended technology integration program, Wells (2007) concluded that the professional development process was greatly impacted by two design factors. Effective program designs should be learner-centred and offer high engagement to participants. Learner-centred approaches focus on individual teachers and the exploration of theory and pedagogy involved in technology integration. Engagement allows teachers to actively experience the IT innovation. For example, "teachers could study their lesson plans to identify potential applications". These factors were supported in the present research and may be important predictors of successful integration following professional development.

A recent review of professional development in technology integration presents a 3 phase approach to evaluation of professional development (see Lawless & Pellegrino, 2007). Specifically, the authors suggest that phase one needs to examine the methodology of professional development programs, for example, method delivery, length of time, etc. The second phase should measure outcomes in terms of teacher attitudes and behaviours. The third phase, long-term student outcomes, requires future research to measure integration within the classroom and the impact on student learning. The present study addresses the second phase outlined in this approach. Using, teacher attitudes, beliefs and behaviours is one step toward developing effective professional development. Research now needs to move to the final stage, but this will require more complete integration of technology in classrooms at both elementary and secondary levels.

In summary, the comprehensive set of variables and the random sampling of a heterogenous group of elementary and secondary teachers from across a school board made it possible to examine the complex issue of computer integration. The large amount of variance accounted for by the variables included in the discriminating function suggests that these individual characteristics of teachers are of significance. Influential variables went beyond comfort with computers and workshop training. Clearly, professional development cannot be a one-for-all solution – setting out the challenge of computer integration may be of benefit for some teachers and not for others. Teachers need to see positive outcomes and successful practice – they need to actually experience positive events. Barriers to integration appear to be breaking down and it is now time to build on supports.

Acknowledgments

Funding for this research was provided by the Canadian Language and Literacy Research Network and the Social Sciences and Humanities Research Council. We would like to thank the Computers across the Curriculum Committee and the teachers of the Waterloo Region District School Board for their participation and contributions.

References

- Abbott-Shim, M., Lambert, R., & McCarty, F. (2000). Structural model of head start classroom quality. *Early Childhood Research Quarterly*, 15, 115–134.
- Abrami, P. C. (2001). Understanding and promoting complex learning using technology. *Educational Research and Evaluation*, 7, 113–136.
- Amabile, T., Hill, K. G., Hennessey, B. A., & Tighe, E. M. (1994). The work preference inventory: Assessing intrinsic and extrinsic motivational orientation. *Journal of Personality and Social Psychology*, 66, 950–967.
- Bain, J. D., & McNaught, C. (2006). How academics use technology in teaching and learning: Understanding the relationship between beliefs and practice. *Journal of Computer Assisted Learning*, 22, 99–113.
- Becker, H. J. (1994). How exemplary computer-using teachers differ from other teachers: Implications for realizing the potential of computers in schools. *Journal of Research on Computing in Education*, 31(4), 356–385.
- Becker, H. J., & Ravitz, J. L. (2001). Computer use by teachers: Are Cuban's predictions correct? *Paper presented at the annual meeting of the American educational research association*, Seattle, Washington, March, 2001.
- Benjamin, J. (2003). Revision & validation of the revised teacher beliefs survey. *Paper presented at the American educational research association annual conference*, Chicago, IL.
- Bitan-Friedlander, N., Dreyfus, A., & Milgrom, Z. (2004). Types of “teachers in training”: The reaction of primary school science teachers when confronted with the task of implementing an innovation. *Teaching and Teacher Education*, 20, 607–619.
- Blok, H., Oostdam, R., Otter, M. E., & Overmaat, M. (2002). Computer-assisted instruction in support of beginning reading instruction: A review. *Review of Educational Research*, 72, 101–130.
- Brown, C., Hedberg, J., & Harper, B. (1994). Metacognition as a basis for learning support software. *Performance Improvement Quarterly*, 7, 3–29.
- Buchman, M. (1987). Teaching knowledge: The lights that teachers live by. *Oxford Review of Education*, 13, 151–164.
- Conlon, T., & Simpson, M. (2003). Silicon valley versus silicon glen: The impact of computers upon teaching and learning: A comparative study. *British Journal of Educational Technology*, 34, 137–150.
- Criswell, J. R. (1996). Becoming a teacher: Reflections of a teacher educator mid-career. *Journal of Instructional Psychology*, 23, 9–13.
- Cuban, L., Kirkpatrick, H., & Peck, C. (2001). High access and low use of technologies in high school classrooms: Explaining an apparent paradox. *American Educational Research Journal*, 38, 813–834.
- Demetriadis, S., Barbas, A., Molohides, A., Palaiogeorgiou, G., Psillos, D., Vlahavas, I., et al. (2003). ‘Cultures in negotiation’: Teachers’ acceptance/resistance attitudes considering the infusion of technology into schools. *Computers and Education*, 41, 19–37.
- Dexter, S. L., Anderson, R. E., & Becker, H. J. (1999). Teachers’ views of computers as catalysts for changes in their teaching practice. *Journal of Research on Computing in Education*, 31, 221–238.
- Ertl, H., & Plante, J. (2004). *Connectivity and learning in Canada’s schools*. Research Paper No. 56F0004MIE – No. 011, Science, Innovation and Electronic Information Division. Ottawa, ON: Statistics Canada.
- Ertmer, P. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration?. *Educational Technology Research and Development* 53, 25–39.
- Evers, W. J. G., Brouwers, A., & Tomic, W. (2002). Burnout and self-efficacy: A study on teachers’ beliefs when implementing an innovative educational system in The Netherlands. *British Journal of Educational Psychology*, 72, 227–243.
- Foon Hew, K., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research Development*, 55, 223–252.
- Fuchs, L. S., Fuchs, D., & Bishop, N. (1992). Instructional adaptation for students at risk. *Journal of Educational Research*, 86, 70–84.

- Garson, G. D. (n.d.). Statnotes: Topics in multivariate analysis. Retrieved December 4, 2006, from NC State University, College of Humanities and Social Sciences website: <<http://www2.chass.ncsu.edu/garson/pa765/statnote.htm>>.
- Hadley, M., & Sheingold, K. (1993). How exemplary computer-using teachers differ from other teachers: Implications for realizing the potential of computers in school. *Journal of Research on Computing in Education*, 26, 291–321.
- Hayes, D. (2007). ICT and learning: Lessons from Australian classrooms. *Computers and Education*, 49, 385–395.
- Hokanson & Hooper, S. (2000). Computers as cognitive media: Examining the potential of computers in education. *Computers in Human Behavior*, 16, 537–552.
- Hoy, W. K., & Woolfolk, A. E. (1993). Teachers' sense of efficacy and the organizational health of schools. *The Elementary School Journal*, 93(4), 355–372.
- Huberman, M. (1992). Linking the practitioner and researcher communities for school improvement. *Keynote Address at the International Congress for School Effectiveness and Improvement, Victoria, BC*. (January).
- Igbaria, M., & Iivari, J. (1995). Effects of self-efficacy on computer usage. *OMEGA-International Journal of Management Science*, 23, 587–605.
- Jones, A. (1999). Teachers' subject subcultures and curriculum innovation: The example of technology education. In John Loughran (Ed.), *Researching teaching: Methodologies and practices for understanding pedagogy*. London: Falmer Press.
- Judson, E. (2006). How teachers integrate technology and their beliefs about learning: Is there a connection? *Journal of Technology and Teacher Education*, 14, 581–597.
- Keys, P. M. (2005). Are teachers walking the walk or just talking the talk in science education? *Teachers and Teaching: Theory and Practice*, 11, 499–516.
- Kiridis, A., Drossos, V., & Tsakiridou, H. (2006). Teachers facing information and communication technology (ICT): The case of Greece. *Journal of Technology and Teacher Education*, 14, 75–96.
- Lajoie, S. P. (2000). *Computers as cognitive tools, volume two: No more walls.*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Lawless, K. A., & Pellegrino, J. W. (2007). Professional development in integrating technology into teaching and learning. *Review of Educational Research*, 77(4), 575–614.
- Lumpe, A. T., Haney, J. J., & Czerniak, C. M. (2000). Assessing teachers' beliefs about their science teaching context. *Journal of Research in Science Teaching*, 37, 275–292.
- Maddux, C. D., & Johnson, D. L. (2005). Information technology, type II classroom integration, and the limited infrastructure in schools. *Computers in the Schools*, 22(3/4), 1–5.
- Marcinkiewicz, H. R. (1993). Computers and teachers: Factors influencing computer use in the classroom. *Journal of Research on Computing in Education*, 26, 220–237.
- McGrail, E. (2005). Teachers, technology, and change: English teachers' perspectives. *Journal of Technology and Teacher Education*, 13, 5–24.
- Mercer, N., & Fischer, E. (1992). How do teachers help children to learn? An analysis of teachers' interventions in computer-based activities. *Learning and Instruction*, 2, 339–355.
- Meyers, L. S., Gamst, G., & Guarino, A. J. (2003). *Applied multivariate research. Design and interpretation*. Thousand Oaks, CA: Sage Publications, Inc.
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108, 1017–1054.
- Mueller, J., & Wood, E. (2006). *Predicting computer integration in elementary and secondary classrooms: Individual characteristics of teachers*. Poster session presented at the annual meeting of the Canadian Society for the Study of Education, Toronto, ON.
- Mueller, J., Wood, E., & Willoughby, T. (2007). The culture of computers among teachers. In E. Wood & T. Willoughby (Eds.), *Children learning in a digital world*. Oxford, UK: Blackwell Publishing.
- Muir-Herzig, R. G. (2004). Technology and its impact in the classroom. *Computers and Education*, 42, 111–131.
- Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies*, 19, 317–328.
- Niederhauser, D. S., & Stoddart, T. (2001). Teachers' instructional perspectives and use of educational software. *Teaching and Teacher Education*, 17, 15–31.
- Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: Results from a worldwide educational assessment. *Computers & Education*, 37, 163–178.
- Richardson, V. (2003). Constructivist pedagogy. *Teachers College Record*, 105, 1623–1640.
- Rosen, L. D., & Maguire, P. D. (1990). Myths and realities of computerphobia: A meta-analysis. *Anxiety Research*, 3, 175–191.
- Rosen, L. D., & Weil, M. M. (1995). Computer availability, computer experience and technophobia among public school teachers. *Computers in Human Behavior*, 11, 9–31.
- Ross, J. A. (1994). *Beliefs that make a difference: The origins and impacts of teacher efficacy*. Paper presented at the annual meeting of the Canadian Society for the Study of Education, Calgary.
- Ross, J. A. (1996). Within-teacher predictors of teacher efficacy. *Teaching & Teacher Education*, 12, 385–400.
- Sandholtz, J. H., Ringstaff, C., & Dwyer, D. C. (1997). *Teaching with technology. Creating student-centred classrooms*. NY: Teachers College Press.
- Sanders, W. L., & Horn, S. P. (1994). The Tennessee value-added assessment system (TVAAS): Mixed-model methodology in educational assessment. *Journal of Personnel Evaluation in Education*, 8, 299–311.
- Schofield, J. (1995). *Computers and classroom culture*. Cambridge: Cambridge University Press.
- Schofield, J. W. (1997). Computers and classroom social processes – A review of the literature. *Social Science Computer Review*, 15, 27–39.
- Sprinthall, R. C. (2000). *Basic statistical analysis* (6th ed.). Needham Heights, MA: Allyn and Bacon.

- Staub, F. C., & Stern, E. (2002). The nature of teachers' pedagogical content beliefs matter for students' achievement gains: Quasi-experimental evidence for elementary mathematics. *Journal of Educational Psychology, 94*, 344–355.
- Sutherland, R., Armstrong, V., Barnes, S., Brawn, R., Breeze, N., Gall, M., et al. (2004). Transforming teaching and learning: Embedding ICT into everyday classroom practices. *Journal of Computer Assisted Learning, 20*, 413–425.
- Torgerson, C. J., & Elbourne, D. (2002). A systematic review and meta-analysis of the effectiveness of information and communication technology (ICT) on the teaching of spelling. *Journal of Research in Reading, 25*, 129–143.
- van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*, 137–158.
- Vannatta, R. A., & Beyerbach, B. (2000). Facilitating a constructivist vision of technology integration among education faculty and preservice teachers. *Journal of Research on Computing in Education, 33*(2), 132–148.
- Vannatta, R. A., & Fordham, N. (2004). Teacher dispositions as predictors of classroom technology use. *Journal of Research on Technology in Education, 36*, 253–271.
- Wells, J. G. (2007). Key design factors in durable instructional technology professional development. *Journal of Technology and Teacher Education, 15*(1), 101–122.
- Wilson, J., Notar, C., & Yunker, B. (2003). Elementary in-service teachers' use of computers in the elementary classroom. *Journal of Instructional Psychology, 30*, 256–263.
- Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal, 39*, 165–205.
- Wood, E., Mueller, J., Willoughby, T., Specht, J., & DeYoung, T. (2005). Teachers' perceptions: Barriers and supports to using technology in the classroom. *Education, Communication, & Information, 5*, 183–206.
- Wooley, G. (1998). Connecting technology and learning. *Educational Leadership, 55*, 62–65.
- Wozney, L., Venkatesh, V., & Abrami, P. C. (2006). Implementing computer technologies: Teachers' perceptions and practices. *Journal of Technology and Teacher Education, 14*, 120–173.
- Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record, 104*, 482–515.