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The Effect of Principals' Technological Leadership on Teachers' Technological Literacy and Teaching Effectiveness in Taiwanese Elementary Schools

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ABSTRACT

The purpose of this study is to investigate the relationships among principals' technological leadership, teachers' technological literacy, and teaching effectiveness. The survey target population consists of 1,000 teachers randomly selected from Taiwanese elementary schools. The survey asked teachers to measure the effectiveness of principals' technological leadership, teachers' technological literacy, and teaching effectiveness. Additionally, the data were analyzed using structural equation modeling to test how well the model captured the relationships between these quantities. The results of the common fit indices clearly indicate that the model fits the data quite well. The findings show that principals' technological leadership improves teachers' technological literacy and directly encourages teachers to integrate technology into their teaching. Furthermore, teachers' technological literacy directly affects their effectiveness. Principals' technological leadership also makes teachers more effective. Principals' technological leadership, as mediated by teachers' technological literacy, can affect teaching effectiveness. The results suggest that principals, as technology leaders, must develop and implement a vision and technology plan for their schools.

Keywords

Elementary schools, Teaching effectiveness, Technological leadership, Technological literacy

Introduction

The role of the principal has evolved from being primarily that of a building manager (Sharp & Walter, 1994) to that of an instructional and curricular leader (Checkley, 2000; Cheng, 2004; Glatthorn, 2000; Huang, 2004; Wu, 2004) and, more recently, to that of a technological leader (Anderson & Dexter, 2005; Bailey & Lumley, 1994; Ford, 2000; Inkster, 1998; Kadela, 2002; Matthews, 2002; McLeod, 2008; Scott, 2005; Seay, 2004; Stegall, 1998). Technological leadership is emerging within the increasingly diversified educational leadership world. Schools striving to excel in the information age need leaders that are well versed in the potential and in the pitfalls of information and communication technology. Many researchers (i.e., Anderson & Dexter; Byrom & Bingham; Gibson; Martin, Gersick, Nudell, & Culp) and educational organizations (i.e., the National School Boards Foundation; the United States Department of Education) note that strong leadership is essential to successful technology-based school reform (cited in Hughes, McLeod, Dikkers, Brahier, & Whiteside, 2005). Moreover, principals' technological leadership strongly correlates with teachers' integration of educational technology into their curriculums (Rogers, 2000). Technological leadership is vital for effective use of technology (Anderson & Dexter, 2005), and therefore, efforts to change and prepare schools and students for the information age demand effective technological leadership from principals (Ross & Bailey, 1996). As described above, in this era of digital technology, technological leadership is gaining importance. Thus, in pursuit of the ultimate goal of improving students' abilities, principals aiming to facilitate school reform should have technological leadership abilities.

Technological leadership differs from traditional leadership theory in that it does not focus on the characteristics or actions of leaders but instead emphasizes that leaders should develop, guide, manage, and apply technology to different organizational operations so as to improve operational performance. Technological leadership is thus a type of functionally oriented leadership practice (Chin, 2010). The advancement and application of technology has infused new energy into educational reform. Examination of new educational reform plans in many countries shows that technological leadership has already become an important strategy for improving academic quality and student achievement. Taking the U.S. as an example, the education departments of many states have established technological leadership academies that use instructional programs to advance the technological professionalism of educators. The purpose of this is to enhance the instructional efficiency of teachers and the learning effectiveness of students (Chang & Tseng, 2005; ECS, 2001). The National Educational Technology Standards for Administrators

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(NETS-A) developed by the International Society for Technology in Education (ISTE) serves as a guide for the implementation of technological leadership in each state. Since 2004, Hong Kong has integrated the application of information technology for teaching and learning to leadership training courses (Chang, 2010). Likewise, the U.K. emphasizes the understanding and recognition of technology by school administrators, and encourages teachers to share their views on the use of information technology through cooperative methods (Robinson, 1994). Flanagan and Jacobsen (2003) suggested that inappropriate integration of technology results in negative by-products. This is because the importance of technological leadership lies not only in the use of technology but also in the development and change of school culture. Anderson and Dexter (2005) also indicated that the technological leadership of the school principal has a key influence on the effectiveness of technology utilization by teachers in educational instruction. Combining the above perspectives, this study used the viewpoint of technological leadership to examine problems with domestic education practices. Practically speaking, educators must realize that one-sided technology use cannot effectively enhance learning quality. Rather, only through the practical leadership in the school can an appropriate environment be built to change the mindsets of staff and create new instructional models. Internationally, the concept of technological leadership has received considerable emphasis, as indicated by studies (i.e., Anderson & Dexter, 2005; Bridges, 2003; Yee, 2000) and much research effort has been invested in investigating the practice and effectiveness of technological leadership.

In terms of policy, in 1980 the government of Taiwan began to place emphasis on investment in the application of information technology in education. "The Nine-Year Integrated Curriculum Policy" also emphasizes the development of basic technological skills. Ability to use information technology has become one of the new objectives of the school curriculum (Ministry of Education, 2003). "The 2008–2011 White Paper on Information Education in Junior High and Elementary Schools" from the Ministry of Education proposes eight main objectives and 20 strategies for the promotion of these objectives. One strategy is to encourage school principals and teachers to apply information technology in their teaching. Education departments in each city and county have made enhancement of information-technology literacy and usage an important focus in the professional growth of school principals. Taking "The Technology Leadership Training Workshop for Elementary School and Junior High School Principals" held by Department of Education, Taipei City Government in Taiwan in 2011 for example, such an activity is to strengthen school principals' technological leadership, establish future vision, and improve school members' technological competence through technological leadership, in order to effectively guide the establishment and management of technology facilities, encourage and support teachers to put technology into teaching practice, and cultivate the legal and ethical literacy for technology application. In addition, elementary school and junior high school principals can implement the promotion of information education policies and integrate the planning of school information technology with development, operation, and management-related issues. It is hoped that the training workshop can be used to provide the directions for understanding school information environment and integrating information technology with teaching and teachers' professional development. Therefore, we can see that the concept of technological leadership has already taken root and has begun to grow in the field of education in Taiwan. The development of methods to effectively put technological leadership into practice to improve teaching and learning in schools is a critical issue to be highlighted by the principal.

The purpose of the study

The purpose of this study is to investigate the relationships among technological leadership of principals and the technological literacy and teaching effectiveness of elementary school teachers. The study also explores the notion that principals' technological leadership, as mediated by teachers' technological literacy, can affect teaching effectiveness.

Theoretical framework

The dimensions of technological leadership

Research on technological leadership began in the U.S. in the 1990s and has since gained significance. To be an experienced and capable technological leader, the principal must be trained in the following five areas:

(1) Vision, planning and management: As the most important foundation of technological leadership, a technological leader must develop a vision of how school reform will be affected by technology (Cory, 1990). The development of this vision requires that the principal understand the direction and trends of technology development, as this understanding will strongly influence the principal's effectiveness. The principal must maintain a very clear technological vision, as well as understand the potential uses of technology in the classroom (Bailey, 1997; Bridges, 2003; Cory, 1990; Inkster, 1998; Jewell, 1998; Ray, 1992).

(2) Staff development and training: Ford (2000) showed that planning and establishing resources for staff development are the most important responsibilities of a technological leader. In staff development, the leader must prepare the newest models and material (Anderson & Dexter, 2000; Aten, 1996; Bailey, 1997; Bailey & Lumley, 1994; Ford, 2000; Inkster, 1998).

(3) Technological and infrastructure support: When instructors and staff require assistance, technological leaders must supply skilled support to preserve equal access to technological resources and appropriate technology-use environments. This must be a technological leadership skill of the principal (Anderson & Dexter, 2000; Aten, 1996; Bailey, 1997; Ford, 2000; Inkster, 1998; Kearsley & Lynch, 1994; Kline, 1993).

(4) Evaluation and research: Effective principals must administer procedures for measuring the growth of each individual teacher by rating instructors. They also must set technological targets and introduce professional development plans. An effective principal will gauge instructors' performance by the results of studies on technological effectiveness. Simultaneously, principals should study students' grades and encourage instructors to implement technology to improve academic performance (Aten, 1996; Cory, 1990; Ford, 2000; Inkster, 1998; ISTE, 1998, 2001; Kline, 1993; Moursund, 1992).

(5) Interpersonal and communication skills: Interpersonal skills are important in technological leadership, and these skills actually override technological skills. When new technology is implemented in a school, the leader must be able to provide support; thus, proper communication is the first skill that academic technology leaders must have. A complementary relationship is required between a principal's communication skills and his or her closely correlated individual technological leadership skills (Aten, 1996; Bailey, 1997; Jewell, 1998; Moursund, 1992).

The dimensions of technological leadership have been drawn from the empirical literature on principals' leadership in general and their effectiveness as technology leaders specifically. The aforementioned five dimensions have been examined and verified by early research (e.g., Chang, Chin, & Hsu, 2008; Chang, Hsiao, & Hsu, 2007; Chang & Hsu, 2009; Chang & Wu, 2008; Chin & Chang, 2006), and have been applied to relevant studies (i.e., Chang, 2006; Chang, 2009; Chen, 2006; Fu, 2009; Hsu, 2010; Lin, 2009; Lo, 2009; Sun, 2007; Tsai, 2008; Tsai, 2009; Tsai, 2010; Wu, 2006; Wu, 2008; Wu, 2009; Yen, 2010). The aforementioned five dimensions were chosen because they are the principals' core tasks in dealing with teaching, learning, and administrative operations that involve technology in their schools.

Technological leadership influences technological literacy

Recently, regional departments of education have continued to provide instructors and administrators with information technology training or technological literacy training. Such training aims to increase instructors' ability to fuse technology with academics and thereby increase students' academic performance. In Chang and Hsu's (2009) study, they explored the current state of elementary school principals' technological leadership and teachers' information-technology literacy in six urban areas of Taiwan. The results showed that principals' technological leadership has a significant and positive influence on teachers' information technology literacy (.42). Wu's (2009) study explored the relationship between principals' technological leadership and teachers' technological literacy, as well as the differences in these factors in terms of background variables of individual teachers and in terms of school environmental variables. Next, the study analyzed the predictive power of principals' technological leadership on teachers' technological literacy. The study found a significant positive correlation overall. Principals' technological leadership has predictive power for various aspects of teachers' technological literacy.

The professional information technology knowledge, development, and training of administrators are important leadership factors. Important responsibilities in technological leadership lie in planning instructor training and

obtaining financial resources (Ford, 2000). In other words, classroom instruction is strongly correlated with planning and training designs stemming from effective technological leadership (ISTE, 1998). Rogers' (2000) study showed that the Fort Wayne Community School instructors' individual self-ratings for technology use in the classroom correlated with the knowledge and support for technology integration from the principal's technological leadership. Chang's (2004) study indicated that the principal's information technological literacy was correlated strongly with instructor implementation of information technology. Thus, these researchers believe that the technological leadership of principals directly influences teachers' technological literacy as well as their integration of information technology into the curriculum.

Technological literacy influences teaching effectiveness

The concept of teacher effectiveness comes from Bandura's concept of self-efficacy, which focuses on an individual's assessment of his or her own organizational and planning abilities before taking action to achieve a certain goal. Bandura believes that self-efficacy is a theory about changing actions; it is a medium for action recognition and a concept that includes elements such as outcome expectancy and efficacy expectancy. Using this theory in conjunction with the concept of teacher effectiveness, the outcome expectancy is the degree to which the teacher believes that a situation is controllable. The efficacy expectancy is the teacher's assessment of his or her own ability to guide students to change positively. The phrase "teaching effectiveness" has several different definitions. Looking at its substance, we can analyze and discuss its main meaning based on the composition and level of the teacher's reaction to students' performance, students' learning, and the teaching process. Teacher effectiveness is the degree to which teachers believe that they have the power to influence a student's performance (Ashton, 1984). Teacher effectiveness is also the degree to which teachers believe that they themselves can influence a student's learning (Gibson & Denbo, 1984); it is the belief that with the anticipation of special circumstances, teachers can help students learn (Ashton & Webb, 1986). Overall, teaching effectiveness can be seen as a teacher's belief in his or her own teaching ability including teaching-material preparation, applications of teaching skills, classroom management, teaching assessment, and self-efficacy and belief.

Chang and Wu (2008) explored the current state of principals' technological leadership and teachers' teaching effectiveness in elementary schools in seven counties and cities in Taiwan. The results showed that principals' technological leadership has a significant and positive effect on teachers' teaching effectiveness (.77). Yen's (2010) study explored the current state of principals' technological leadership and teachers' teaching effectiveness. The study found a positive correlation between the principals' technological leadership as perceived by the teachers and the teachers' teaching effectiveness; there was a significant predictive power of principals' technological leadership for teachers' teaching effectiveness and the factor of "staff development and training" was the most predictive. Fu's (2009) study explored the current state and relationship between principals' technological leadership and teachers' teaching effectiveness and found a significant positive correlation. The factors "vision, planning, and management" and "evaluation and research" were the most predictive for overall teachers' teaching effectiveness. Lo (2009) discussed the current state, differences, and correlations of principals' technological leadership and teachers' teaching effectiveness and also found a significant positive correlation; principals' technological leadership can effectively predict teachers' teaching effectiveness.

Eaton-Kawecki (2003) pointed out that the use of technology in school by both students and teachers can be used to accurately predict academic achievement. Clearly, a student's academic achievements are often used to evaluate teaching effectiveness and are influenced by the use of technology in school. In other words, a student's use of technology represents the teacher's integration of technology into teaching and curricula and also affects the teacher's effectiveness (for example, with regard to results of a statewide achievement performance assessment). Reed's (2003) study showed that students' academic achievements are noticeably influenced by the teacher's use of technology. A teacher's technological literacy directly affects whether students can incorporate technology into the curriculum to improve students' academic achievements. Therefore, I propose that teachers' technological literacy can improve teaching effectiveness. Actual evidence from studies (Jean, 2003; Pai, 2004) supports the perspective that teachers' technological literacy affects teaching effectiveness. Is there a significant correlation between teachers' technological literacy and teaching effectiveness? Does a principal's technological leadership affect teaching effectiveness? In this paper, these questions will be discussed and explained.

Based on an examination of the literature on principals' technological leadership and teachers' technological literacy and teaching effectiveness, I hypothesize the model (see Figure 1) that principals' technological leadership directly influences teachers' technological literacy and improves teaching effectiveness. Furthermore, teachers' technological literacy directly influences their teaching effectiveness. More important, the notion that principals' technological leadership, as mediated by teachers' technological literacy, can affect teaching effectiveness will be tested.

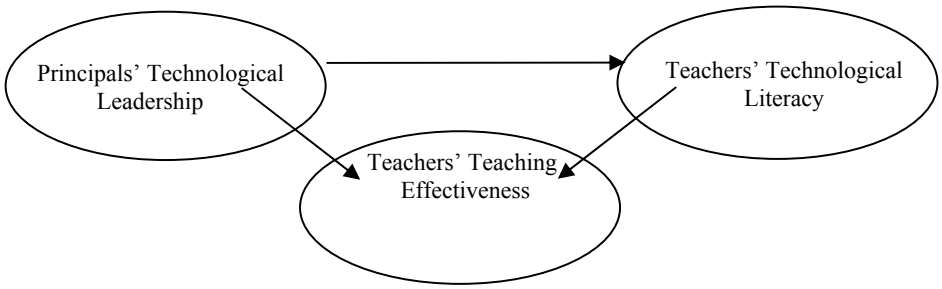

Figure 1. Hypothesized conceptual model

Research method

Data collection

The target population consisted of 1,000 teachers randomly selected from 100 elementary schools within the following six metropolitan cities in Taiwan: Keelung City, Taipei City, Hsinchu City, Taichung City, Tainan City, and Kaohsiung City. These cities are located in the northern, central, and southern parts of the island respectively, and this sample is indicative of the broader teaching population of Taiwan. The survey was randomly sent to the Director of Academic Affairs Division of each elementary school. Then, the Director randomly selected the teachers based on the cover letter sent to the school. The survey asked teachers to evaluate the principal's role in leading and facilitating technology use, teachers' technological literacy and teaching effectiveness in their schools. The respondents in this study were teachers (i.e., tenured teachers, mentor teachers, teachers serving as administrators and directors) reporting to their principals. To encourage the return rate, follow up thank you postcards and personal contacts were made until a satisfactory percentage of participants completed the questionnaire. Of the 1,000 questionnaires distributed, 60.5% were returned. Table 1 displays the demographic characteristics of the respondents. Demographic variables provide a descriptive profile of those individuals who responded to the survey.

Table 1. Number and percent of respondents by demographics * N=605

Demographics	Frequency	Percentage
Gender		
Male	210	34.7%
Female	394	65.1%
Age		
30 (or below) years old	118	19.5%
31-40 years old	268	44.3%
41-50 years old	186	30.7%
51 (or above) years old	33	5.5%
School Size (N of class)		
17 (or below) classes	104	17.2%
18-35 classes	172	28.4%
36-53 classes	178	29.4%
54 (or above) classes	150	24.8%
Teaching Year		
5 (or blew) years	120	19.8%
6-15 years	235	38.8%
16-30 years	224	37.0%
31 (or above) years	26	4.3%

Educational Level		
BA or BS	97	16.0%
BA or BS (from teachers college or normal university)	338	55.9%
M.A. or M.Ed.	165	27.3%
Ph.D. or Ed.D.	1	0.2 %
Position		
Mentor Teacher	256	42.3%
Specialist Teacher	69	11.4%
Administrative Head	190	31.4%
Director	88	14.5%

* Numbers and percentages in the categories may not total 100 due to some missing data.

Instrumentation and variables

The Principals' Technological leadership Instrument was conceptualized as five interrelated dimensions: (1) vision, planning and management (e.g., clearly articulates a shared vision for technology use in the school); (2) staff development and training (e.g., encourages technology in-service training); (3) technological and infrastructure support (e.g., ensures appropriate technology facilities); (4) evaluation and research (e.g., considers effective technology use as one performance assessment component of instructional staff); and (5) interpersonal and communication skills (e.g., demonstrates an understanding of technology needs and concerns of faculty). *The Teachers' Technological Literacy Instrument* comprised four dimensions: (1) hardware and software operation (e.g., understands the functions of basic components of computer hardware); (2) law and ethics (e.g., understands the meaning of ownership and publication, and show respect to intellectual property rights); (3) technological integration (e.g., understands the benefits and scope for applying computer to teaching); and (4) management and assessment (e.g., possesses the ability in using teaching software and evaluating online teaching materials). *The Teachers' Teaching Effectiveness Instrument* included five dimensions: (1) teaching-material preparation (e.g., be comprehensively familiar with the content of the unit to be taught before teaching); (2) applications of teaching skills (e.g., continuously attracts students' attention by changing activities during class); (3) classroom management (e.g., continually compliments and encourages students for their progress); (4) teaching assessment (e.g., effectively implements various evaluation methods according to teaching needs); and (5) self-efficacy and belief (e.g., has a positive influence on students' learning achievements). These three instruments comprised 101 Likert-type items on 5-point scales. A response of "1" indicated that the teacher strongly disagreed with the statement on the scale, and a response of "5" indicated that the teacher strongly agreed with the statement on the scale. A pilot study was conducted with approximately 204 teachers and school administrators to improve the instruments' reliability and validity. The Cronbach's alpha coefficients (shown in parentheses and see also table 2) were calculated for each scale: vision, planning and management (.96); staff development and training (.90); technological and infrastructure support (.92); evaluation and research (.96); interpersonal and communication skills (.93); hardware and software operation (.94); law and ethics (.90); technological integration (.91); management and assessment (.90); teaching-material preparation (.92); applications of teaching skills (.88); classroom management (.93); teaching assessment (.89); and self-efficacy and belief (.95).

In addition to reliability analysis, construct validity tests of the aforementioned three instruments were performed. Five factors were extracted using Varimax rotation from *The Principals' Technology Leadership Instrument*. The variance factors were as follows: 21.148% (vision, planning and management), 15.858% (evaluation and research), 15.430% (technological and infrastructure support), 14.573% (interpersonal and communication skills), and 11.958% (staff development and training). The total explained variance of these five factors was 78.966%. Four factors were extracted using Varimax rotation from *The Teachers' Technology Literacy Instrument*. The variance factors were as follows: 24.474% (hardware and software operation), 22.055% (technological integration), 13.304% (law and ethics), and 10.375% (management and assessment). The total explained variance of these four factors was 70.208%. Five factors were extracted using Varimax rotation from *The Teachers' Teaching Effectiveness Instrument.* The variance factors were as follows: 22.082% (applications of teaching skills), 19.060% (self-efficacy and belief), 12.726% (teaching-material preparation), 11.314% (teaching assessment), and 10.029% (classroom management). The total explained variance of these five factors was 75.211% (see table 2).

Table 2. Analysis of reliability and validity

Dimension	Cronbach's alpha coefficient	Variance explained
Vision, planning and management	.96	21.148%
Staff development and training	.90	11.958%
Technological and infrastructure support	.92	15.430%
Evaluation and research	.96	15.858%
Interpersonal and communication skills	.93	14.573%
Hardware and software operation	.94	24.474%
Law and ethics	.90	13.304%
Technological integration	.91	22.055%
Management and assessment	.90	10.375%
Teaching-material preparation	.92	12.726%
Applications of teaching skills	.88	22.082%
Classroom management	.93	10.029%
Teaching assessment	.89	11.314%
Self-efficacy and belief	.95	19.060%

Data analysis

This research empirically investigated the relationships among principals' technological leadership, teachers' technological literacy, and teaching effectiveness and tested the structural equation model (SEM). SPSS was used to calculate scale reliabilities (the Cronbach's alpha) and to perform factor analyses. The final SEM model was done with LISREL.

Results

SEM lets researchers simultaneously define and measure multidimensional constructs (e.g., principals' technological leadership). The fit of the model to the data was assessed with SEM fit indices. The Chi-Square value was 271.97 with 74 degrees of freedom and significance (p=.00). The NFI, NNFI, PNFI, CFI, SRMR, GFI, AGFI and PGFI values were .98, .99, .80, .99, .043, .93, .90 and .66, respectively. The Critical N was 204.42. The results of these common fit indices (see table 3) clearly indicated that the model fit these observed data quite well.

Table 3. Assessment of overall model fit

Fit Indices	Ideal fit index	Results
Degrees of Freedom=74		
Absolute fit indices		
Chi-Square	Not significant	271.97 (p＝.00)
GFI	＞.90	.93
AGFI	＞.90	.90
SRMR	≦.05	.043
Comparative fit indices		
NNFI	＞.90	.99
CFI	＞.90	.99
NFI	＞.90	.98
Parsimonious fit indices		
PNFI	＞.50	.80
PGFI	＞.50	.66
Critical N	＞200	204.42

After ensuring that the model fit the data, the standardized parameter estimates were considered in the model. As shown in Figure 2, the parameter estimates for the five constructs (i.e., *vision*, planning and management; *staff* development and training; technological and infrastructure *support*; *research* and evaluation; *interpersonal* and

communication skills) that comprised principals' technological leadership were significant (.91, .82, .89, .90, and .87). The parameter estimates for the four constructs (i.e., *hardware and software* operation; *law* and ethics; technological *integration*; *management* and assessment) that comprised teachers' technological literacy were significant (.83, .65, .88, and .92). The parameter estimates for the five constructs (i.e., teaching-material *preparation*; applications of teaching *skills; classroom* management; teaching *assessment*; and self-efficacy and *belief)* that comprised teaching effectiveness were significant (.83, .92, .90, .88, .90). As presented in Figure 2, principals' technological leadership (*TECHLEAD*) had a significant positive effect on teachers' technological literacy (*LITERACY*) (*.58*).

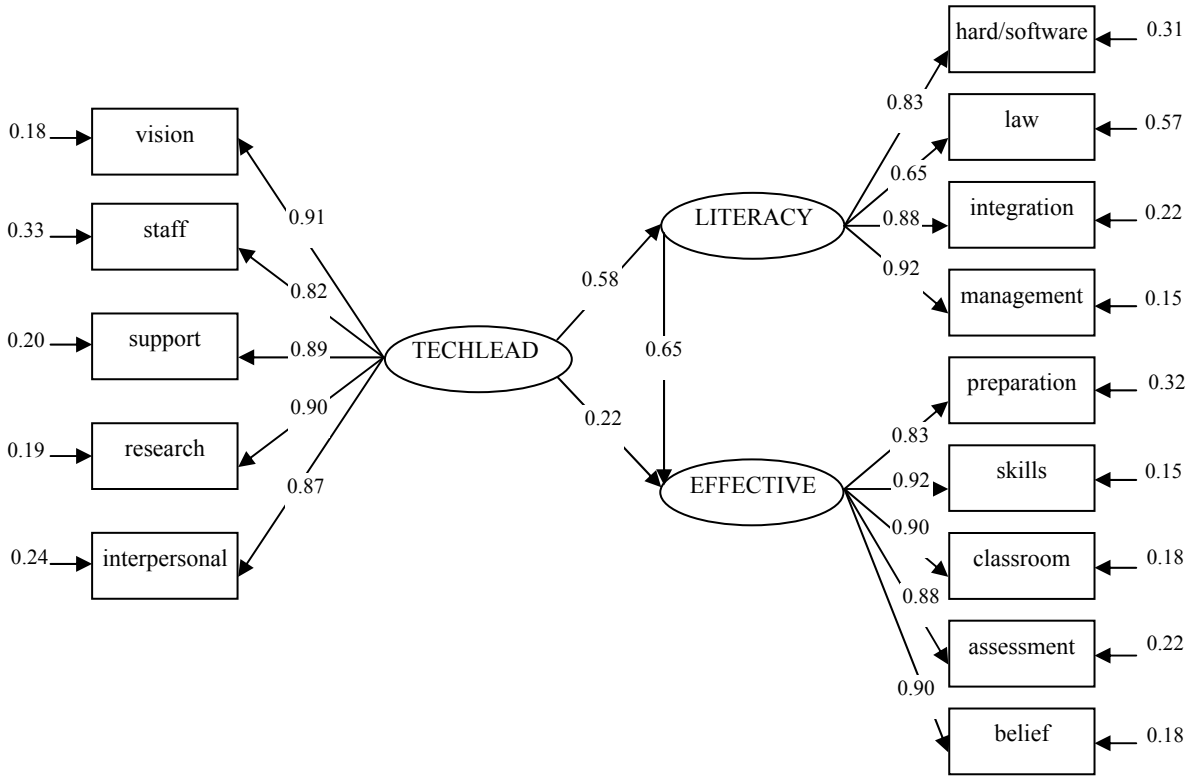

Figure 2. Final structural equation model

These findings confirmed previous research that principals' technological leadership improves teachers' technological literacy development and directly influenced teachers' integration of technology into their teaching practices. Furthermore, teachers' technological literacy (*LITERACY*) directly affected teaching effectiveness (*EFFECTIVE*) (.65). Principals' technological leadership also improved teachers' teaching effectiveness (.22). The findings also supported previous research mentioned earlier in this study. Table 4 displays the summary of parameter estimation for the mediated-effects model.

Table 4. Summary of parameter estimation for the mediated-effects model

Parameter	*t*	R^2	Standardized solution	*Parameter*	*t*	R^2	Standardized solution
λ_1	-	0.83	0.91	δ_1	12.05*	-	0.18
λ_2	26.07*	0.67	0.82	δ_2	14.34*	-	0.33
λ_3	31.54*	0.79	0.89	δ_3	12.66*	-	0.20
λ_4	32.30*	0.81	0.90	δ_4	12.30*	-	0.19
λ_5	29.88*	0.76	0.87	δ_5	13.31*	-	0.24
λ_6	-	0.69	0.83	ε_1	13.41*	-	0.31
λ_7	16.39*	0.42	0.65	ε_2	15.25*	-	0.57
λ_8	25.20*	0.77	0.88	ε_3	11.65*	-	0.22
λ_9	26.91*	0.85	0.92	ε_4	8.97*	-	0.15

λ_{10}	-	0.69	0.83	ε_5	14.50*	-	0.32
λ_{11}	27.55*	0.85	0.92	ε_6	11.94*	-	0.15
λ_{12}	26.76*	0.81	0.90	ε_7	12.71*	-	0.18
λ_{13}	25.67*	0.77	0.88	ε_8	13.46*	-	0.22
λ_{14}	26.73*	0.81	0.90	ε_9	12.73*	-	0.18
γ_{11}	13.17*	0.34	0.58				
γ_{21}	5.74*	0.05	0.22				
$\beta 21$	13.98*	0.42	0.65				

Note: the symbol ' – ' in the *t* value column indicates the *constraints parameter;* $^*p < .05$

Discussion

Technological leadership's effects on technological literacy and teaching effectiveness

As presented in Figure 2, principals' technological leadership (*TECHLEAD*) improves teachers' technological literacy (*LITERACY*) significantly. These findings confirm previous research that principals' technological leadership improves teachers' technological literacy development (Chang & Hsu, 2009; Wu, 2009) and directly influences teachers to integrate technology into their teaching (Chang, 2004; Eaton-Kawecki, 2003; Reed, 2003; Rogers, 2000). Furthermore, teachers' technological literacy (*LITERACY*) directly improves their effectiveness (*EFFECTIVE*) as does principals' technological leadership (Chang & Wu, 2008; Fu, 2009; Jean, 2003; Lo, 2009; Pai, 2004; Yen, 2010). The findings also support previous research mentioned earlier in this study. Based on the aforementioned results, schools must develop a long-term technology plan with a vision and goals for the school's faculty and staff. In addition, development of technological skills is essential for the professional growth of faculty and staff. Regarding the provision of infrastructure, schools must provide full technological support and equal opportunities to obtain resources. Lastly, schools must be able to assess themselves; the leaders must be able to evaluate their own professional technological plans and give teachers performance evaluations. Principals' interpersonal and communication skills subtly affect the success of their leadership. Principals who can listen to teachers' advice and opinions while providing them with sufficient support will make their school's operational development more productive. Only a principal who can understand current knowledge of technology can ensure that the school will continue to develop. In addition, when a principal is competent at technological leadership and integration and also creates a technological learning environment, teaching effectiveness will increase and in turn will improve student performance.

Principals' technological leadership mediated by teachers' technological literacy can affect teaching effectiveness

Based on the results of the literature review indicating that teachers' technological literacy mediates the effects of principals' technological leadership on teaching effectiveness, the mediated-effects model was proposed (see Figure 1). As shown in Figure 2, principals' technological leadership (*TECHLEAD*) positively and significantly ($\gamma_{21} = .22$, $p < .05$) influences teachers' teaching effectiveness (*EFFECTIVE*). Principals' technological leadership (*TECHLEAD*) also positively and significantly ($\gamma_{11}=.58$, $p < .05$; $\beta_{21}=.65$, $p < .05$) influences teachers' teaching effectiveness (*EFFECTIVE*) via teachers' technological literacy (*LITERACY*). The indirect effects value is .38 ($\gamma_{11}*\beta_{21}$), and the R-Squared value is 0.64. The result shows that through the mediated-effects of teachers' technological literacy, the principals' technological leadership can explain 64% of the variance in teaching effectiveness. The result of the mediated-effects model indicates that teachers' technological literacy results in significant mediated effects of principals' technological leadership on teaching effectiveness.

Conclusions

As this study indicates, principals as technological leaders must develop and implement vision and technology plans for their schools, encourage the technological development and training of teachers, provide sufficient technological infrastructure support, and develop an effective school-evaluation plan. Principals who can embrace their ever-

changing roles and become technological leaders are those who can effectively lead and prepare their schools for the decades to come. More important, teachers, who practice their craft in the technological age, should look diligently to develop their own technological literacy; they should change the traditional unidirectional method of teaching, and learn how to incorporate technology into their teaching in order to encourage their students' academic achievement. It is an open question whether, in this age of information, principals (with their ever-evolving roles) can become competent technology leaders who nurture and increase the ability of teachers to integrate technology into their teaching. Such leaders not only make teachers more effective but also directly affect students' academic achievement.

Implications for practice

A school's internal administration is no longer a closed-circuit system but rather a dynamic educational ecology. Schools can no longer ignore the influence of technological development outside of the school. In particular, schools in the information age can no longer face the rapidly changing world with an attitude that hopes to preserve the past. Similarly, the role of the principal has also changed from solely a school administrator to the current, multi-faceted role of curricular and technological leader. Therefore, the most important task of a principal is to figure out how to become an appropriate technological leader. A principal can then guide teachers to improve their technological literacy (or technology-implementation abilities) and to improve teaching effectiveness and students' academic achievements through educational reforms. This study acts as a reference for school leaders regarding administrative management. One important thing for principals to remember is that while they are carrying out technological leadership, they should not focus only on hardware. There is a need to emphasize not only the involvement of technology but also the integration of technology.

Implications for theory

The study uses structural equation modeling to test the relationships among principals' technological leadership, teachers' technological literacy, and teaching effectiveness. In addition to technological leadership positively influencing teaching effectiveness, the results show that principals' technological leadership influences teaching effectiveness through the mediated-effects of teachers' technological literacy. When interpreting the relationships among the three variables, the function of the "mediated-effects" in the model should be emphasized. That is, technological leadership influences teaching effectiveness through technological literacy.

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