Factors Influencing the Impact of ICT-use on Students' Learning

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Abstract

Education policy documents in many countries have placed emphases on promoting the use of ICT in teaching and learning, often in conjunction with curriculum reform initiatives that aim to enhance the development of 21st century skills such as collaborative inquiry and collaboration. Is there evidence that ICT-use actually contributes to the development of 21st century skills? Does the pedagogical approach adopted by the teacher matter? Do the teacher's technical and pedagogical competence in using ICT to support teaching and learning relate in any way to the impact of ICT-use on students' learning outcomes? These are the questions that will be explored in this paper through a secondary analysis of the SITES 2006 data. The teacher survey in SITES 2006 was designed to provide a variety of indicators related to pedagogy and ICT, including: (1) teachers' perceived impacts of ICT-use on their students, (2) teachers pedagogical orientations for their overall practices as well as for their ICT-using practices, and (3) teachers' self-reported technical and pedagogical competence in using ICT for teaching and learning. Multilevel analysis found that the general pedagogical orientation of the teacher has a much stronger relationship with the perceived impact of ICT-use on students' learning compared to the more specifically ICT-related pedagogical orientations. Further, the self-perceived pedagogical ICT-use competence of the teacher was an even stronger predictor for the perceived impact of ICT-use on students. The implications of these findings are discussed.

Keywords: *information technology, learning outcomes, pedagogical orientation, lifelong learning, inquiry skills*

Introduction

Education policy documents in many countries have placed emphases on promoting the use of ICT in teaching and learning, often in conjunction with curriculum reform initiatives that aim to enhance the development of 21st century skills such as collaborative inquiry and collaboration. While SITES is a series of comparative studies on ICT-use in education, all three modules maintained a strong focus on pedagogy and pedagogical innovation for two main reasons. All three completed SITES modules (Pelgrum & Anderson, 1999; Kozma, 2003; Law, Pelgrum & Plomp, 2008) are interested in identifying (1) whether there is evidence that the policy rhetoric about the need for pedagogical change to prepare students for the knowledge economy has made any impact on pedagogical practice in classrooms around the world, and (2) if yes, whether ICT-use is contributing to such changes.

Many of the case studies of ICT-using innovative practices collected in SITES-M2 shared two key pedagogical characteristics – collaborative inquiry in the form of project work is a most way of organizing learning to promote lifelong learning skills and many made use of ICT to connect learners and teachers with peers and experts outside of the school (Kozma & McGhee, 2003; Law, 2004). Based on these findings, core indicators for three pedagogical orientations were developed for the teacher survey in SITES 2006: traditionally important, lifelong learning and connectedness (Law et al., 2008). In addition, supplementary indicators were also developed to provide a better understanding about pedagogy and ICT-use by grade 8 mathematics and science teachers as well as to support the building of explanatory models that relate various teacher- and school- level factors to teachers' pedagogy and ICT-use (Law, Chow & Pelgrum, in press).

Law & Chow (2008a) reported that of all the personal characteristics of a teacher, self-reported pedagogical ICT-competence was the best positive predictor of the teacher's adoption of ICT in the classroom. It was also found that in most systems, teachers with a stronger traditionally important orientation were less likely to make use of ICT in their teaching while those with a stronger 21st century orientation (i.e. lifelong learning and connectedness orientations) were more likely to do so. However, adoption of ICT in teaching and learning activities may not necessarily bring about the kind of 21st century learning outcomes that are being targeted in many education policy documents. Is there evidence that can demonstrate such a link? Are there other factors at the teacher, school or system level that influences the impact of ICT-use on students' learning outcomes? It is of course most desirable if student achievement data related to 21st century skills were available to explore these important questions. Unfortunately, SITES 2006 did not collect any information from students. On the other hand, there is a question in the SITES 2006 teacher questionnaire that asked for the teachers' perceptions of the extent of different kinds of impacts ICT-use had made on their students. Assuming that the teachers' responses to this question reflects to some extent the actual impact of ICT-use on students, these responses can then be used in analyses to explore the questions raised above.

Indicators for eight kinds of impacts were constructed based on answers to this question (Law, Chow & Pelgrum, in press): traditional outcomes, inquiry skills, collaboration, ICT skills, self-paced learning, affective impact, achievement gap and socioeconomic divide. Of these, the last two are negative impacts. For the purpose of the present research, we are mainly interested in learning outcomes related to 21st century skills. We have thus selected the indicator, impact of ICT-use on students' inquiry skills, to be the focal learning outcome to be explored. In fact, Law & Chow (2008b) conducted, at the system level, an exploration of the possible relationships between the pedagogical orientations of the teachers' ICT-using practices and their perceptions of the impact of ICT-use on their students. The findings they report were very thought-provoking. They found that only the lifelong learning pedagogical orientation in ICT-using practices were positively and significantly correlated with seven out of the eight kinds of perceived impacts while the traditionally important orientation was not significantly correlated with any kind of outcomes (Law & Chow, 2008b, p. 176). Since these reported findings are based on the correlation coefficients calculated on the system level means for the indicators involved, one can only draw the conclusion that a country whose teachers report a higher mean lifelong learning pedagogical orientation for their teaching practices tend to report also a higher mean perceived impact of ICT-use on students' lifelong learning outcome. They do not provide information about the possible relationship between the teachers' reports of pedagogical orientation and the perceived impact on students at an individual level. Also, we do not know whether the relationship, if any, holds similarly for all countries. To answer these questions and to find out the relationship between the perceived impact on students' learning and school level factors, a better and stronger methodological approach, multilevel analysis, is employed and the findings are reported in this paper.

Hierarchical Nature of Factors influencing Impact of ICT-use on Students

The data collected in SITES 2006 was hierarchically structured. The sampling was conducted through a two-step process such that schools were firstly random sampled from each participating system. Then the two samples of mathematics teachers and science teachers were then randomly selected from the teachers teaching these two subjects at grade 8 in the sampled schools to complete the teacher questionnaire. Principals and technology coordinators from the sampled schools were also invited to complete the respective survey questionnaires, the results of which were then analyzed to provide statistics at the school level. Hence the data collected from SITES 2006 is hierarchically structured, with teacher data (level-1) nested within schools (level-2) and school data nested within educational systems (level-3). As such, multilevel analysis is a more appropriate and stronger method for exploring the questions described in the earlier section. This section describes the key factors at the three levels that are explored using multilevel analysis and reported in the remainder of this paper.

At the individual teacher level, there are two groups of characteristics that are most likely to have influence on the perceived impact of ICT-use on students' inquiry skills (ImpS_IN) based on findings reported in the first international report. The first group is the [self-reported] ICT competence of the teacher, both pedagogical (PEDA_IT) and general (GEN_IT) ICT competence (Law & Chow, 2008a). The other group is the lifelong learning pedagogical orientation of the teacher as that was found to correlate significantly with perceived student learning outcomes at the system level (Law & Chow, 2008b). There are two sets of ICT-related lifelong learning pedagogical orientation indicators from this study, one for ICT-using teacher practice (ICT_TPL) and the other for ICT-using student practice (ICT_SPL). These four factors are hence selected to be included in the level-1 model.

The findings from SITES-M2 indicate that vision of the school leadership, technical and pedagogical support from the school are important factors contributing to the sustainability and scalability of pedagogical innovations (Owston, 2003). A number of indicators related to these school level factors are included in the level-2 models explored.

There are many socioeconomic and contextual differences across countries and it is not evident which Level-3 factors may have the greatest contribution towards explaining the differences across systems in terms of ImpS_IN. In this study, three potentially important system level factors related to historical and policy contexts are explored. One important context is the history of ICT adoption across the curriculum within an education system. Technical coordinators were asked how long the school had introduced the use of ICT into the school curriculum (ICT_EXP). While this data was collected at the school level, it is argued here that much of the variance in ICT_EXP pertains to system level differences due to different policy priorities and socioeconomic contexts. Hence the system mean for ICT_EXP (ICT_EXPm) can be taken as a level-3 variable reflecting the historical context in ICT-use in a system.

A second potential predictor at the system level is whether the system has explicit polic(ies) to promote the development of 21st century skills. The National Research Coordinator questionnaire returned by the participating systems has this information (Anderson & Plomp, 2008).

Countries differ also in terms of their education policy priorities given to the promotion of lifelong learning oriented pedagogical practices. It is expected that such policy differences will influence the principals' vision in the promotion of lifelong learning pedagogy in their schools. A question that can provide an indicator for principal's pedagogical vision for lifelong learning (VIS_L) was included in both SITES-M1 and SITES 2006. Here again, the system mean for this indicator can be taken as a system level indicator for the policy priority for lifelong learning in a system. As it takes time for system level policies to have impact on practice at the school level, the system mean of the principals' vision measured in SITES-M1 in 1998 (VIS_L98) may be a better level-3 predictor for ImpS_IN than the mean value measured in SITES 2006 (VIS_L06). Both indicators are hence used in the initial exploration in the current study as level 3 predictors. There were 15 systems that participated in both SITES-M1 and SITES 2006. All of these have near 100% access to computers for use in the teaching and learning of grade 8 students, except South Africa where the access was only 38% (Pelgrum, 2008). Possibly because of this, many of the survey response statistics from South Africa were outliers. Hence, in this study, data from South Africa has not been included in the analyses. The 14 systems included in the analyses and reported in this paper are Chinese Taipei, Denmark, Finland, France, Hong Kong SAR, Israel, Italy, Japan, Lithuania, Norway, Russian Federation, Singapore, Slovenia, and Thailand. The multilevel analyses reported in this paper were done using HLM6 (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2004). As the models explored in this study involve predictors pertaining to different levels, they are constructed and reported progressively starting with lower level predictors, as is the general practice in multilevel modeling.

Model 1: The Null Model

Before embarking on building an explanatory model for the perceived impact of ICT-use on students' inquiry skills (ImpS_IN), a 3-level null model (i.e. a 3-level model with no predictors) was computed to find out the distribution of variance over the three levels. A simplified general form of the model is presented as follows:

ImpS_IN = B00 + R0 + E --- (1)

where

B00 is the intercept,

R0 is the random error at the school level, and

E is the random error at the teacher level.

As shown in equation (1), this simple model does not include any predictor variable. However, it might be interesting to study B00 because it can help explore the impact of school level factors to ImpS_IN. As mentioned earlier, the SITES 2006 data are hierarchically organized such that schools are nested within education systems. Given the likelihood of such a relationship, B00 was further expanded into a level-3 model:

B00 = G000 + U00 --- (2)

where

G000 is the fixed component of the level-3 intercept, and

U00 is the random error at the system level.

The null model found that the proportion of the variance at the teacher, school and system levels were respectively 41.58%, 44.14% and 14.27%. This shows that the proportion of variance in ImpS_IN is largest at the school level (level-2), which is slightly higher than that at the individual teacher level (level-1). Details of the computational results are presented in Table 1.

[Insert Table 1 about here]

Model 2: A Model Involving only Teacher Level Predictors

In the second model, four level-1 predictors are introduced: PEDA_IT, GEN_IT, ICT_TPL and ICT_SPL, representing the following four teacher characteristics respectively: pedagogical ICT competence, general ICT competence, ICT-using teacher practice orientation, and ICT-using student practice orientation. These four variables were linearly scaled to have the same minimum and maximum values in order to compare the relative effects of these predictors. The simplified general form of the model is shown as follow:

ImpS_IN = B00 + B10*GEN_IT + B20*PEDA_IT + B30*ICT_TPL +

B40*ICT_SPL + R0 + R1*GEN_IT + R2*PEDA_IT +

R3*ICT_TPL + R4*ICT_SPL + E --- (3)

where

B10, B20, B30, and B40 are the coefficients for the teacher-level predictors, which are GEN_IT, PEDA_IT, ICT_TPL, and ICT_SPL respectively,

R1, R2, R3, and R4 are the random errors for the teacher-level predictors, which are GEN_IT, PEDA_IT, ICT_TPL, and ICT_SPL respectively.

This model is similar to that as shown in equation (1), except that four level-1 predictors were introduced into the model at the same time. Further, with an addition of equation (2), the following four level-3 equations were also included in the model at the system level:

B00 = G000 + U00 --- (4)

B10 = G100 + U10 --- (5)

B20 = G200 + U20 --- (6)

B30 = G300 + U30 --- (7)

B40 = G400 + U40 --- (8)

Equation (4) concerns the intercept B00 for the model in equation (3). Each of the other four equations gives the model for the respective coefficient of the relevant teacher factor. For example, equation (5) provides a breakdown of the parameters modeled for the teacher-level factor GEN_IT. The fixed effect on GEN_IT for systems is G100, whereas the random effect across systems is U10. The key results of this model are presented in Table 2.

[Insert Table 2 about here]

As can be seen from the column of fixed effects in Table 2, the multilevel analysis results show that the largest coefficient across the four level-1 predictors is PEDA_IT. This finding indicates that among the four selected indicators, teachers' pedagogical ICT-competence was the strongest predictor for the students' inquiry skills. It may be surprising to readers that the coefficient of GEN_IT is negative, indicating that the general ICT-competence was a negative predictor of ImpS_IN ($p < 0.05$, T-ratio = -9.397, d.f. = 13). It should be mentioned here that if GEN_IT were the only level-1 predictor in this model, the coefficient for GEN_IT would still be significant but positive (G100 = 0.124, $p < 0.05$, the other results from this model is not presented here in the interest of space.) One possible explanation for this finding is that GEN_IT and PEDA_IT were highly inter-correlated (Pearson Correlation $\gamma = 0.751$, $p < 0.01$). As such, the coefficient for GEN_IT would be greatly influenced by the presence of PEDA_IT in the model. Nonetheless, it was found that, together, the four level-1 predictors can explain 83.2% of the total variance at the individual level. Hence, no further modeling with other level-1 factors was pursued.

Model 3: Adding School Level Predictors

Law (2008) identified a number of school level indicators computed from responses to the principal questionnaire to have a strong influence on teachers' ICT_TPL: student:computer ratio, technical support available in minutes per week per student, the principal's vision for ICT-use to support lifelong learning pedagogy, pedagogical support available, technical support available and the principal's priority for leadership development. Each of these six indicators was added to Model 1 as a level-2 predictor to find out if any of these were statistically significant predictors. However, none of these six level-2 predictors was found to be significant when added as a single level-2 predictor to Model 1. This indicates that although these six school level factors were significant predictors for one of the level-1 predictors, ICT_TPL, they did not have direct influence on ImpS_IN. In the interest of space, the details of this set of multilevel explorations are not presented.

The principal questionnaire was further examined to look for possible indicators for use as a suitable predictor at the school level. In particular, one of the questions asked the principal about the priority given to resource allocation in a number of areas in order to enhance the use of ICT in teaching and learning for grade 8 students in the school. Two scale indicators can be computed from the responses. One indicator is the priority for improving infrastructure (PR_INFR) based on responses to 5 items (to decrease the number of students per computer, to increase the number of computers connected to the internet, to increase the bandwidth for internet access of the computers connected to the internet, to increase the range of digital learning resources related to the school curriculum, and to establish/enhance an online learning support platform and its management so that teaching and learning can take place anytime/anywhere). The other indicator is the priority for promoting teachers' use of ICT (PR_TEACH) based on responses to another set of 5 items (to improve the technical skills of teachers, to improve the ability of teachers to make good pedagogical use of ICT, to broaden teachers' pedagogical repertoire and to widen their pedagogical competence to engage in new methods of teaching and learning, to provide teachers with incentives to integrate ICT-use in their teaching, and to increase the number of teachers using ICT for teaching/learning purposes). Each of these two level-2 predictors were added to Model 2 to become Model 3 and Model 3a respectively as follows and the key results are presented in Table 3:

<u>Model 3:</u>

ImpS_IN = B00 + B01*PR_INFR + B10*GEN_IT + B20*PEDA_IT +

B30*ICT_TPL + B40*ICT_SPL + R0 + R1*GEN_IT +

R2*PEDA_IT + R3*ICT_TPL + R4*ICT_SPL + E --- (9)

<u>Model 3a:</u>

ImpS_IN = B00 + B01*PR_TEACH + B10*GEN_IT + B20*PEDA_IT +

B30*ICT_TPL + B40*ICT_SPL + R0 + R1*GEN_IT +

R2*PEDA_IT + R3*ICT_TPL + R4*ICT_SPL + E --- (10)

The level-3 models for Model 3 and Model 3a are very similar to equations (4, 5, 6, 7, 8), despite that an additional equation is introduced into the model:

B01 = G010 + U01 --- (11)

where

G010 is the correlation coefficient (slope) for the level-2 predictor: PR_INFR for model 3 and PR_TEACH for model 3a, and

U01 is the component of the slope that varies across systems.

[Insert Table 3 about here]

Findings presented in Table 3 show that both PR_INFR and PR_TEACH are statistically significant predictors with very similar coefficients and standard errors. Hence a further exploration was conducted to add these two indicators simultaneously as level-2 predictors into Model 2 to become Model 3b (see equation (12) below):

ImpS_IN = B00 + B01*PR_INFR + B02*PR_TEACH + B10*GEN_IT +

B20*PEDA_IT + B30*ICT_TPL + B40*ICT_SPL + R0 +

R1*GEN_IT + R2*PEDA_IT + R3*ICT_TPL +

R4*ICT_SPL + E --- (12)

The level-3 of Model 3b in the same as that of Model 3, with an additional equation

B02 = G020 + U02 --- (13)

The key HLM results for Model 3b are presented in Table 4. It can be seen that in this model, only PR_INFR is a significant predictor. One possible explanation of this finding is that there is a strong correlation between PR_TEACH and PR_INFR ($\gamma = 0.606$, $p < 0.01$) and that PR_TEACH may not be as strong a predictor for ImpS_IN as PR_INFR.

[Insert Table 4 about here]

Since PR_TEACH is not a significant level-2 predictor for ImpS_IN when combined with PR_INFR, model 3 is taken as the final model that includes both level-1 and level-2 predictors. Regarding the effect of PR_INFR on ImpS_IN, Table 3 results for Model 3, which shows that the coefficient for PR_INFR is 0.051, indicating that in schools where the principal gave higher resourcing priority to the improvement of ICT infrastructure, their teachers perceived a stronger impact of ICT-use on students' inquiry skills.

Further, it was found that the variance across the intercept at the teacher level was substantially reduced by 94.67% after introducing the four level-1 predictors. It is also observed that, additionally, 3.69% variance was reduced after introducing the level-2 indicator, PR_INFR, into Model 2. This finding indicates that much of the difference across schools, with respect to the perceived student impact of ICT-use on students' inquiry skills, is in fact due to the variation in level-1 factors, i.e., the teacher characteristics across schools.

Adding System Level Predictors

As mentioned earlier, four potentially useful predictors at the system level were identified, which were ICT_EXPm, P21, VIS_L98 and VIS_L06. Each of these level-3 predictors was added to Model 3 individually as an initial exploration. The general form of the level-1 and level-2 models is provided in Equation (9), whereas the level-3 models are provided in equations (11, 5, 6, 7, 8), with an addition of the following equation:

B00 = G000 + G001*system_factor + U01 --- (14)

where

> the system_factor may be ICT_EXPm, P21, VIS_L98 or VIS_L06, depending on which indicator is used for the purposes of modeling

Table 5 presents the key results from these 4 analyses.

[Insert Table 5 about here]

As shown in Table 5, it can be seen that both P21 and VIS_L06 are not significant indicators for predicting ImpS_IN. It should also be noted that the coefficient found for ICT_EXPm as listed in Table 5 is negative, indicating that in schools with all other factors held equal, teachers in schools with less experience of ICT-use perceived a stronger positive impact of ICT-use on their students' inquiry skills. For VIS_L98, the coefficient as shown in Table 5 is positive, indicating that there is a delayed positive effect between the principals' vision and the perceived impact of ICT-use on students' inquiry skills. Such a finding can be interpreted as demonstrating that the impact of system level education policy takes time to have observable impact on classroom practice.

Model 4: A final 3-level model

Based on the analytical results from Models 1, 2 and 3, a final 3-level model was developed (Model 4). In this model, there are four level-1 factors: PEDA_IT, GEN_IT, ICT_TPL and ICT_SPL; one level-2 predictor, PR_INFR; and two level-3 predictors, ICT_EXPm and VIS_L98. The general form of the level-1 and level-2 models is provided in Equation (9), whereas the level-3 model is provided in equations (5-8, 11), with an addition of the following equation:

B00 = G000 + G001*ICT_EXPm + G002*VIS_L98 + U00 --- (15)

Table 6 presents the key findings from this final model.

[Insert Table 6 about here]

In accordance with the findings shown in Table 6, the level-3 indicator, VIS_L98, was found to be statistically insignificant ($p > 0.05$, T-ratio = -1.047, d.f. = 11). This is probably because the average length of ICT-use experience for a country's schools was actually correlated with their principals' vision for ICT-use to promote lifelong learning in 1998 (correlation between ICT-EXPm and VIS_L98, $\gamma = -0.679$, $p < 0.01$). However, why is there such a negative correlation between these two system level indicators needs further exploration.

Discussion

It should be re-emphasized that the dependent variable modeled in the above analyses is not students' actual learning outcome as SITES 2006 did not collect any student data. On the other hand, if we assume that teachers' perceptions reflect to some extent their observation of how much their use of ICT in their teaching of the target subject (mathematics or science, as sampled) had impacted their students' learning, then there are important implications ensuing from the findings reported. First of all, teachers' pedagogical competence in the use of ICT, the lifelong learning orientations in their ICT-using teacher practices and ICT-using student practices were all positive predictors for impacts of ICT-use on students' inquiry skills, explaining 83.2% of the teacher level variance. Hence, professional development to prepare teachers for the effective use of ICT should address not only ICT specific issues but should also encompass the development of pedagogies that support collaborative inquiry and connectedness.

For the school level, the principal's priority for resource allocation to improve ICT infrastructure and to encourage teachers to use ICT (such as making provisions for ICT-related teacher professional development) were found to be positive predictors. However, it was found that principals who give high priority to improvement of infrastructure also gave high priority to ICT-related professional development such that these two indicators were highly correlated. When placed in the same model as level-2 predictors, the priority that principals give to infrastructure improvement was found to be the only significant level-2 predictor. It is also noteworthy that when these level-1 predictors were introduced, the variance at the school level was reduced by 94.67%, indicating that much of the variance between schools within the same system can be explained by the difference across schools in terms of these teacher characteristics as well. Hence these findings indicate that school leadership priorities, when translated into resource allocation for ICT infrastructure and ICT-related professional development, will correlate positively with students' improvements in inquiry skills (taken as an indicator of lifelong learning ability) when ICT is used in teaching and learning.

At the system level, the findings also indicate that education policies have influence on the impact of ICT-use on students' inquiry skills. However, such effects can only become evident when translated into principals' visions for ICT-use to improve lifelong learning, and that there is a delay for the effect to be observed. Also it was observed that teachers in systems with a longer history of ICT-use experience in their schools reported a lower level of impact compared with teachers in systems with shorter ICT-use history. Why this may be the case needs to be further explored. It might be just a difference in perception across systems, but it could also be a reflection of the policy changes in systems with longer histories of ICT-use in schools as these two were found to be correlated.

References

Anderson R., & Plomp, T. (2008). National Contexts. In N. Law, W. J. Pelgrum, & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: Findings from the SITES 2006 study* (pp. 38–66). Hong Kong: CERC and Springer.

Kozma, R. (Ed.). (2003). *Technology, Innovation, and Educational Change: A Global Perspective.* Eugene, OR: ISTE.

Kozma, R., & McGhee, R. (2003). ICT and Innovative Classroom Practices. In R. Kozma, J. Voogt, W. Pelgrum, R. Owston, R. McGhee, R. Jones, R. Anderson (Ed.), *Technology, Innovation, and Educational Change: A Global Perspective*. (pp. 43–80). Eugene, OR: ISTE.

Law, N. (2004). Teachers and Teaching Innovations in a Connected World. In A. Brown & N. Davis (Eds.), *Digital Technology, Communities and Education* (pp. 145-163). London: Routledge Falmer.

Law, N. (2008). In search of explanations. In N. Law, W. J. Pelgrum, & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: Findings from the SITES 2006 study* (pp. 251–262). Hong Kong: CERC and Springer.

Law, N., & Chow, A. (2008a). Teacher characteristics, contextual factors, and how these affect the pedagogical use of ICT. In N. Law, W. J. Pelgrum & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: findings from the SITES 2006 study* (pp. 182-219). Hong Kong: CERC and Springer.

Law, N., & Chow, A. (2008b). Pedagogical orientations in mathematics and science and the use of ICT. In N. Law, W. J. Pelgrum & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: findings from the SITES 2006 study* (pp. 121-179). Hong Kong: CERC and Springer.

Law, N., Chow, A., & Pelgrum, W. J. (in press). Scale and indicator construction. In R. Carstens & W.

J. Pelgrum (Eds.), *IEA SITES 2006 technical report*. Amsterdam: International Association for the Evaluation of Educational Achievement.

Law, N., Pelgrum, W. J., Monseur, C., Brese, F., Carstens, R., Voogt, J. M., et al. (2008). Study design and methodology. In N. Law, W. J. Pelgrum & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: findings from the SITES 2006 study* (pp. 13-36). Hong Kong: CERC and Springer.

Law, N., Pelgrum, W. J., & Plomp, T. (Eds.). (2008). *Pedagogy and ICT in schools around the world: findings from the SITES 2006 study*. Hong Kong: CERC and Springer.

Owston, R. (2003). School Context, Sustainability and Transferability of Innovation. In R.B. Kozma (Ed.), *Technology, Innovation, and Educational Change: A Global Perspective.* (pp. 125-161). Eugene, OR: ISTE.

Pelgrum W. (2008). School Practices and Conditions for Pedagogy and ICT. In N. Law, W. J. Pelgrum, & T. Plomp (Eds.), *Pedagogy and ICT in schools around the world: Findings from the SITES 2006 study* (pp. 67-120). Hong Kong: CERC and Springer.

Pelgrum, W.J. & Anderson, R. (Ed.). (1999). *ICT and the Emerging Paradigm for Life-Long Learning*. Amsterdam: IEA.

Raudenbush, S., Bryk, A., Cheong, Y. F., Congdon, R., & du Toit, M. (2004). *HLM 6: Hierarchical Linear and Nonlinear Modeling.* Lincolnwood, USA: SSI Scientific Software International.

Table 1: Summary of key results for Model 1

Teacher Level	Fixed				Random (level 1 & 2)				Random (level-3)			
	Coefficient		Standard Error	*p*	Variance Component		Standard Deviation	*p*	Variance Component		Standard Deviation	*p*
INTERCEPT	G000	3.811	0.11	*	R0	0.220	0.47	*	U00	0.071	0.27	*

Note:
1. Variability of level-1 units in ImpS_SI (s^2) = 0.207
2. * p <0.05

Table 2: Summary of the key results with four level-1 predictors (Model 2)

Teacher Level	Fixed				Random (level 1 & 2)				Random (level-3)			
	Coefficient		Standard Error	*p*	Variance Component		Standard Deviation	*p*	Variance Component		Standard Deviation	*p*
INTERCEPT	G000	3.073	0.03	*	R0	2.297	1.52	*	U00	0.004	0.06	
GEN_IT	G100	-0.092	0.01	*	R1	0.328	0.57	*	U10	0.000	0.02	
PEDA_IT	G200	0.250	0.03	*	R2	0.351	0.59	*	U20	0.006	0.08	
ICT_TPL	G300	0.065	0.01	*	R3	0.086	0.29	*	U30	0.001	0.03	
ICT_SPL	G400	0.119	0.02	*	R4	0.074	0.27	*	U40	0.002	0.04	

Note:
1. Variability of level-1 units in ImpS_SI (s^2) = 0.035
2. * p <0.05

Table 3: Summary of the key results after adding PR_INFR (Model 3) and PR_TEACH (Model 3a) as level-2 indicators into Model 2

			PR_INFR (Model 3)			PR_TEACH (Model 3a)		
			Coefficient	Standard Error	*p*	Coefficient	Standard Error	*p*
Fixed	INTERCEPT	G000	2.959	0.03	*	2.929	0.07	*
	LEVEL 2 PREDICTORS	G010	0.051	0.02	*	0.056	0.02	*
	GEN_IT	G100	-0.101	0.01	*	-0.102	0.01	*
	PEDA_IT	G200	0.253	0.04	*	0.252	0.03	*
	ICT_TPL	G300	0.058	0.02	*	0.055	0.01	*
	ICT_SPL	G400	0.120	0.02	*	0.123	0.02	*
			Variance Component	Standard Deviation	*p*	Variance Component	Standard Deviation	*p*
Random (level 1 & 2)	INTERCEPT	R0	2.314	1.52	*	2.307	1.52	*
	GEN_IT	R1	0.343	0.59	*	0.331	0.58	*
	PEDA_IT	R2	0.355	0.60	*	0.357	0.60	*
	ICT_TPL	R3	0.090	0.30	*	0.089	0.30	*
	ICT_SPL	R4	0.069	0.26	*	0.079	0.28	*
			Variance Component	Standard Deviation	*p*	Variance Component	Standard Deviation	*p*
Random (level-3)	INTERCEPT	U00	0.004	0.06		0.02	0.14	
	LEVEL 2 PREDICTORS	U01	0.001	0.04		0.00	0.04	
	GEN_IT	U10	0.000	0.02		0.00	0.02	
	PEDA_IT	U20	0.008	0.09	*	0.01	0.08	
	ICT_TPL	U30	0.001	0.03		0.00	0.03	
	ICT_SPL	U40	0.001	0.04		0.00	0.05	

Note:
1. For Model 3, the variability of level-1 units in ImpS_SI (s^2) = 0.03432
2. For Model 3a, the variability of level-1 units in ImpS_SI (s^2) = 0.03378
3. * $p < 0.05$

Table 4: Summary of the key results for Model 3b

			Coefficient	Standard Error	*p*
Fixed	INTERCEPT	G000	2.934	0.05	*
	PR_INFR	G010	0.048	0.02	*
	PR_TEACH	G020	0.013	0.01	
	GEN_IT	G100	-0.107	0.01	*
	PEDA_IT	G200	0.257	0.04	*
	ICT_TPL	G300	0.059	0.02	*
	ICT_SPL	G400	0.121	0.02	*
			Standard Deviation	**Variance Component**	***p***
Random (level 1 & 2)	INTERCEPT	R0	1.522	2.32	*
	GEN_IT	R1	0.584	0.34	*
	PEDA_IT	R2	0.594	0.35	*
	ICT_TPL	R3	0.300	0.09	*
	ICT_SPL	R4	0.263	0.07	*
			Standard Deviation	**Variance Component**	***p***
Random (level-3)	INTERCEPT	U00	0.110	0.01	
	PR_INFR	U01	0.038	0.00	
	PR_TEACH	U02	0.028	0.00	
	GEN_IT	U10	0.016	0.00	
	PEDA_IT	U20	0.088	0.01	
	ICT_TPL	U30	0.032	0.00	
	ICT_SPL	U40	0.037	0.00	

Note:
1. Variability of level-1 units in ImpS_SI (s^2) = 0.03444
2. * p <0.05

Table 5: Summary of the key results after adding the level-3 predictors

FIXED		ICT-EXPm			P21			VISL98			VISL06	
		Coeff.	s.e	*p*	Coeff.	s.e	*p*	Coeff.	s.e	*p*	Coeff.	s.e
INTRCPT	G000	3.63	0.05	*	2.96	0.04	*	2.29	0.15	*	2.32	0.72
LV3	G001	-0.24	0.02	*	-0.05	0.07		0.25	0.05	*	0.19	0.22
LV2:PRIN06IN	G010	0.05	0.02	*	0.05	0.02	*	0.05	0.02	*	0.05	0.02
GEN_IT	G100	-0.09	0.01	*	-0.10	0.01	*	-0.09	0.01	*	-0.10	0.01
PEDA_IT	G200	0.25	0.04	*	0.25	0.04	*	0.25	0.04	*	0.25	0.04
ICT_TP_L	G300	0.06	0.02	*	0.06	0.02	*	0.06	0.02	*	0.06	0.02
ICT_SP_L	G400	0.11	0.01	*	0.12	0.02	*	0.12	0.01	*	0.12	0.01

Note:
1. * p<0.05

Table 6: of the key results after adding ICT-EXPm and VIS_L98 into model 3 (Model 4)

			Coefficient	Standard Error	*p*
Fixed	INTERCEPT	G000	3.947	0.27	*
	L3:ICT-EXPM	G001	-0.270	0.04	*
	L3:VIS_L98	G002	-0.086	0.08	
	L2:PR_INFR	G010	0.054	0.02	*
	GEN_IT	G100	-0.091	0.01	*
	PEDA_IT	G200	0.257	0.04	*
	ICT_TPL	G300	0.058	0.02	*
	ICT_SPL	G400	0.114	0.01	*
			Standard Deviation	Variance Component	*p*
Random (level 1 & 2)	INTERCEPT	R0	1.524	2.32	*
	GEN_IT	R1	0.585	0.34	*
	PEDA_IT	R2	0.596	0.36	*
	ICT_TPL	R3	0.300	0.09	*
	ICT_SPL	R4	0.263	0.07	*
			Standard Deviation	Variance Component	*p*
Random (level-3)	INTERCEPT	U00	0.144	0.02	
	L2:PR_INFR	U01	0.037	0.00	
	GEN_IT	U10	0.024	0.00	
	PEDA_IT	U20	0.088	0.01	*
	ICT_TPL	U30	0.033	0.00	
	ICT_SPL	U40	0.032	0.00	

Note:

1. Variability of level-1 units in ImpS_SI (s^2) =0.03432
2. * p <0.05