METHODOLOGICAL APPROACHES TO COMPARING PEDAGOGICAL INNOVATIONS USING TECHNOLOGY

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Abstract

The study of educational innovations has become increasingly important in education research as many countries around the world have embarked on education reforms that aim to change both the goals and practices in education. There is also a general expectation that such innovations can be leveraged or supported by the use of information and communication technology (ICT) in the learning and teaching process. However, comparative studies of innovations are relatively rare. SITES M2, as an international comparative study of innovative pedagogical practices involving 28 participating systems, thus faced important methodological challenges, the solution of which was no less an innovation in itself. This paper examines the methods of analysis used and the kind of research findings that resulted from the work of three research teams that had conducted comparisons of the case studies of innovation collected, including the SITES M2 International Coordinating Centre (ICC). Even though all three studies attempted to examine similarities and differences across the case studies, the analysis conducted by the ICC looked for characterizations of the innovations while the other two studies attempted to look for ways of analyzing the cases into "levels of innovation" across a number of dimensions. This paper discusses the methodological differences across these studies. In particular, it addresses the issue of whether and how one could compare different innovations in terms of their "levels of innovation" and the methodological implications for studying innovations involving the use of ICT.

INTRODUCTION

The study of educational innovations has attracted increasing attention in education research around the world as many countries have already embarked on education reforms that aim to change both the goals and practices in education. There is also a widespread expectation that such innovations can be leveraged or supported by the use of ICT in the learning and teaching process. However, comparative studies of innovations are relatively rare. SITES M2 (Second Information Technology in Education Study Module 2), as an international comparative study of innovative pedagogical practices using technology involving 28 participating education systems, was the first study conducted under the auspices of the IEA that focused on a comparison of pedagogical processes rather than students' learning outcomes, and employed an in-depth qualitative case study approach rather than using large scale surveys as have generally been done in other IEA studies. The SITES M2 study thus faced important methodological challenges, particularly in the data analysis stage of the study. In examining the methodological issues involved in comparing pedagogical innovations using technology, this paper contributes to a deeper discussion of the methodological issues within the IEA community as well as to pertinent methodological explorations in the wider education research community.

While there are many aspects of educational innovations that can be compared, one can broadly categorize them into two levels: pedagogical and institutional. The focus of this paper is to examine comparisons at the pedagogical level and builds on the work of three research teams that had conducted independent analysis on the SITES M2 case reports: the SITES M2 International Coordinating Centre (ICC) (Kozma, 2003), the Israel research team led by Mioduser & Nachimias (Mioduser et al., 2003; Tubin et al., 2003) and the Hong Kong research team led by Law[1] (Law et.al., 2003; Law 2003, 2004). Both the ICC team and the Hong Kong team analyzed cases from the 174 case studies collected internationally while the Israeli research team confined their work to the 10 case studies collected in Israel.

This study explores the different methodological approaches that can be used to compare pedagogical innovations using technology through a comparison of different research orientations and methods that have been used by three research teams in the analysis of the SITES M2 data. In particular, this paper wishes to address four research questions: (1) What are the different approaches that have been used to compare innovations? (2) In what ways can the concept of "levels of innovation" be operationalized? (3) What contribution can a comparison of "innovativeness" make to education and education research? (4) Would there be methodological differences, if any, between comparisons of pedagogical innovations using Information and Communication Technology (ICT) and comparisons of pedagogical innovations in general?

DIFFERING RESEARCH PERSPECTIVES FOR STUDY ICT AND PEDAGOGICAL INNOVATIONS: A COMPARISON

While SITES M2 was a study of innovative pedagogical innovations, the ICC team did not attempt to make any comparison of the case studies in terms of the levels of innovativeness. While it is reasonable to expect that there would be similarities and differences across the different case studies reported, Kozma & McGhee (2003) focused on providing descriptive accounts of the key features of the pedagogical practices through categorizing the practices and looking at the resulting profiles of features across the clusters. They focused on four main dimensions in building up a characterization of the ICT-based innovations: teacher practices (including methods, roles and collaborations), student practices (including activities and roles), ICT practices (the roles and functions played by ICT in the case studies) and the kinds of ICT used in schools.

On the other hand, both the Israeli and Hong Kong national research teams were upfront in their desire to examine the cases in terms of their levels of innovativeness. Both teams took as their point of departure that the introduction of ICT in schools would not per se lead to change and innovation. Instead, the role and impact of ICT use in schools would be better analyzed and understood in the context of broader changes in school education.

The analysis scheme devised by Mioduser et al. (2003) aimed to study systematically transformational processes in schools that extensively embrace the use of ICT. A core assumption underlying the work of this team is that the change that occurs will develop from being preliminary alternations of the school's routine due to the initial assimilation of ICT, through a transitional level to being far-reaching transformations in pedagogical practices and learning processes. They have defined four domains of innovation for their analysis, each being one *important area of impact that ICT has created on various aspects of the school milieu.*

The Hong Kong SITES research team has a broader range of concerns in their approach to the study of innovative pedagogical practices at the classroom level, which encompass both a desire to capture the characteristics of ICT-using innovative pedagogical practices as well as a comparison of the case studies on some scales of levels of innovation. This team used a variety of methods to build up characterizations of the pedagogical innovations studied, which will be of use to teachers wanting to learn and improve their own practices based on the case studies, released. The characterization comprised three main aspects, the pedagogical arrangements and learning activities involved, the teachers' roles and the students' roles. The details on the methods used will be described and discussed in a later section. The Hong Kong SITES team considered the case studies collected as examples of *curriculum innovation that has incorporated the use of ICT.* Based on their framework for conceptualizing ICT-supported pedagogical practices in school settings (Law et. al., 2000), they developed a six-dimensional scheme for assessing the levels of innovation for the cases studied: curriculum goals, teachers' roles, students' roles, multiple types of learning outcomes exhibited, connectedness of the classroom with the outside world and the pedagogical sophistication of the technology used.

It is thus clear from the above description that the three research teams differ not only in the research questions they asked, but also in the perspectives they took in studying ICT-supported pedagogical innovations. In Mioduser et al. (2003)'s analysis, the focus was clearly on the impact of ICT on various aspects of learning and teaching in schools. In the work reported by Law et. al. (2003), the focus was on curriculum change and ICT was only one of the various dimensions in their curriculum model. The perspective taken by Kozma & McGhee (2003) was again different in that out of the four dimensions in their analysis, only two were explicitly linked to the use of technology: ICT practices and ICT used. The other two dimensions, teacher practices and student practices, characterized aspects of the case studies that are important for any pedagogical setting in general.

COMPARING INNOVATIVENESS

Comparing extent of change brought about by the adoption of ICT

Mioduser et al. (2003) developed a scheme for assessing the levels of innovation for the 10 case studies of ICT-supported innovative pedagogical practices collected in Israel. The scheme comprised nine aspects grouped within four different ***domains of innovation*** in a school's milieu: time/space configuration (including the physical space involved, digital space used as well as the constraints posed or otherwise of the time dimension of the curriculum), students (roles), teachers' roles (in relation to students, other teachers and the subject matter content of the study) and the impact of ICT on various aspects of the school curriculum (content, pedagogical organization and assessment), respectively. Mioduser et al., (2003) further defined three levels of innovation to reflect the extent to which the use of ICT triggered a gradual departure from previous patterns of work in each of the nine aspects of the school milieu within the four identified domains of innovation. It was assumed that the process of change brought about by technology adoption would start with a process of *assimilation* that would involve only minimal changes to existing practices. *Transition* and *transformation* were labels used to indicate progression towards higher levels of innovation in the use or impact of ICT on each of the nine aspects under study.

Arguably, the most important aspects of pedagogical innovations are those that are expected to contribute directly to education in the information society, that is, the change towards more collaborative and self-directed inquiry-based learning for students, the more facilitative roles for teachers as well as greater connectedness of the classrooms (Pelgrum & Anderson, 1999, p. 6-7). Therefore, the levels of innovation in the four domains of innovation as defined in Mioduser et al., 's (2003) framework may not contribute equally to levels of "emergence" as described in the SITES study framework. For example, changes occurring in terms of time and spatial configuration may have arisen because of the tyranny of space across learners and the teachers, and the extent of transformation possible may also be constrained by the age and level of the students concerned, or simply by the level of technology access available. Also, the students' role, as defined in Mioduser et al.'s (2003) framework, focused on the levels of innovation in terms of students' roles in using ICT only and may not reflect the students' main roles in the pedagogical practice overall. Therefore, cases with high scores and are thus more "transformative" according to this analysis scheme may not necessarily be pedagogically more exciting or "emergent" than cases with a low score in this domain. Furthermore, there is no necessary correlation between the levels of change for the different domains.

Using the framework that Mioduser et al., (2003) developed, Tubin et al., (2003) reported on their analysis of the 10 Israel cases of innovative case studies collected in SITES M2. They found that in most schools, the extent of change was not the same for the different aspects of change analyzed. A mean overall "level of innovation" was also computed for each school across all the 9 aspects and the analysis found large variations in score from 2.0 to 4.7. While this mean overall "level of innovation" may not be easily interpretable since it is an aggregate score from rather different domains, the findings also indicated that a high level of transformation may not be found in all domains even for cases selected as examples of innovative practice. Another noteworthy finding was that the levels of innovation in the various domains were highly correlated, with the exception of teacher's role with other teachers, indicating that changes in teachers' communication and work patterns in the 10 Israeli innovative case studies had little effect on changes in the other aspects. The analysis also showed that didactic solutions was the domain with the highest correlation with nearly all other domains, indicating that this was the central domain of innovation for these 10 cases.

Other than computing the mean overall "level of innovation" for each school as was done by Tubin et al., (2003), it would in fact be interesting to compare the mean extent of change across the 9 aspects based on the mean score for each aspect for the 10 cases studied. A calculation based on the scores provided by Tubin et al., (2003) revealed that the least change was recorded in the area of physical space (2.6) and the highest in curriculum content (3.8), while the overall mean across all domains and cases was 3.3.

The findings from this study reveal some important patterns emerging from a cross-case comparison of levels of innovation. However, it is not clear whether the patterns so detected would be replicated in the other 164 cases collected in SITES M2, and whether there would be national/regional differences in these patterns. This would be a worthwhile follow-up study to conduct.

Comparing extent of emergence, with ICT as one of the dimensions for comparison

The Hong Kong SITES National Research Team also developed a framework for differentiating the case studies in terms of levels of innovation along several dimensions (Law et. al., 2003). However, as described in the earlier section, this team considered the case studies collected as examples of curriculum innovation that has incorporated the use of ICT. For this team, the concept of emergent pedagogical practices was grounded on the belief that innovation needs to build on existing practices for it to be viable and yet needs to have the courage to break new ground in order to be fruitful. Each case study was examined for indicators of change (as in breaking new ground) on a continuum along a traditional versus emergent dichotomy for key dimensions of analysis. The following excerpt from their online research report[2] provides a clear encapsulation of their standpoint:

> **ICT and Educational Innovations**
>
> The introduction of ICT into the school curriculum began around the early 1980s. With the short timespan of a quarter century, not only has the presence of ICT in schools increased exponentially in many countries, the key justification for their presence (Why should ICT be

> introduced into the curriculum?) has also changed. The technological changes brought about by ICT have led to deep changes in the workplace. Towards the end of the 20th century, many countries have identified the development of 21st century competencies through educational reforms that encompass fundamental changes in pedagogy that integrate the use of ICT to be their top educational priority. The Second International Information Technology in Education Study (SITES M2) has thus identified innovative pedagogical practices the focus of this comparative study in order that we can learn from the most innovative cases of ICT use in schools around the world how ICT can transform our classrooms to better prepare our students for the future. The Hong Kong SITES research team has analyzed the SITES cases collected from around the world based on an analysis model that conceptualizes ICT use as an integral part of curriculum interactions within the context of school, regional and national policies and strategies.

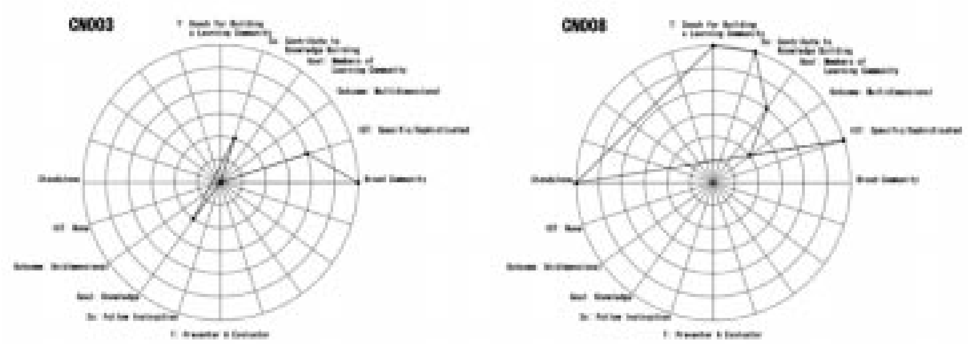
Six dimensions were identified by the team to be the most important aspects of any curriculum implementation using ICT that warrants detailed examination (Law, 2003; Law et. al., 2003):

- Intended curriculum goals of the innovative practices
- Pedagogical role(s) of the teachers
- Role(s) of the students
- Nature and sophistication of the ICT used
- Multiple types of learning outcomes exhibited (to be referred to as "manifestation of learning outcomes" in subsequent discussions)
- Connectedness of the classroom

Law et. al., (2003) reported large diversities along each of these 6 dimensions when the case studies were examined. While some of the features observed were very similar to traditional practices, others may have quite innovative features that are rarely found in current classrooms. To compare the innovations, a "scale of innovativeness" was developed on the basis of the "magnitude of change" along each of the 6 dimensions of analysis, taking the "traditional" classroom to be typically one that is isolated, knowledge-focused, teacher-centered, does not use ICT and only assesses students on cognitive learning outcomes. Details of the scoring rubric used can be found at *http://sitesdatabase.cite.hku.hk/i_classroom/P_3_1.htm.*

The research team did not see it appropriate to compute an aggregate innovation score, but developed a graphical representation for the extent of innovativeness along the 6 dimensions based on the case report descriptions so as to provide a bird's eye view of the team's perception of the profile in the extent of innovation for case analyzed (see Figure 1). They also claimed that such analyses delineating the innovativeness of each case along the six dimensions would contribute to a better understanding of the patterns of development of pedagogical innovations and consequently to research on effective ways of undertaking and promoting innovations at the classroom level.

Figure 1: A diagrammatic representation of the extent of innovativeness for two of the case studies collected in Hong Kong.



This team used their analysis framework to analyze not only the case studies collected in Hong Kong, but also those collected internationally. In analyzing the case reports, they found great variation in the level of details available about the practices in the collection of reports. In particular, some of the case reports contain very general descriptions of teachers' and students' activities that did not make reference to specific curriculum or learning contexts. This may be related to the fact that some countries participated in both the SITES M2 and the OECD (Organization for Economic Co-Operation and Development) studies and used the same set of case studies for both studies. The case selection criteria for these two studies were different and the OECD case studies focused on school-wide innovations. In the end, the team considered 83 reports to have sufficient details for the purpose of scoring the levels of innovation for the classroom level analysis. The team found from their analysis that there were large diversities across cases. Classroom practices that were highly innovative along all 6 dimensions were rare. On the other hand, many of the case studies were highly innovative along one or a few of the 6 dimensions. Based on the innovation scores assigned to the 83 cases, some interesting observations can be found from a study of the mean and standard deviation of the innovation scores along the 6 dimensions.

Table 1: The mean innovation score and related descriptive statistics along each of the six dimensions of innovation for the 83 cases analyzed by Law et. al., (2003).

Dimension of innovation	*Mean innovation score*	*Min. score*	*Max. score*	*Std. Deviation*
Curriculum goals	4.18	1	6	1.30
Teacher's roles	4.34	2	7	1.35
Students' roles	4.31	2	7	1.61
ICT sophistication	5.71	5	7	0.74
Manifestation of learning outcomes	4.13	1	7	1.66
Connectedness of the classroom	4.16	1	7	2.06

It is interesting to note from Table 1 that of all six dimensions, ICT sophistication is the dimension that has the highest mean innovation score as well as the smallest standard deviation. This indicates that while the overall ICT availability differs greatly in different countries around the world (Pelgrum & Anderson, 1999), the cases selected as innovative by countries are much more similar in terms of the technology used than any of the other dimensions. Furthermore, the connectedness of the classroom has the greatest standard deviation, indicating that connectedness is possibly more dependent on other factors such as the prevalent classroom culture than hardware connectivity.

A breakdown of the innovation scores for the cases found in different geographic regions (see table 2) reveals sizeable regional differences in terms of the profile of innovation. In particular, it is noteworthy that of all the 6 dimensions, the manifestation of learning outcomes has the lowest mean score for nearly all the regions and has a score below "4" for all regions except Western Europe, indicating that change along this dimension has not reached the "emergent" level, or the mid-point of the innovation scale. Furthermore, the regional statistic reveals that Western Europe has the highest mean innovation score for all dimensions, except for the dimension ICT sophistication. On the other hand, with the exception of the ICT sophistication dimension, the mean innovation scores for Asia were below 4 for all the other 5 dimensions. One interpretation of these findings is that the predominant pedagogical practice found in Asia has the greatest difference with the most innovative end of the pedagogical dimensions examined.

Table 2: The mean innovation score and related descriptive statistics along each of the six dimensions of innovation for the 81[3] cases analyzed by Law et. al., (2003) as distributed across geographical regions[1].

Dimension of innovation	*Western Europe (45) **	*America (8)*	*East Europe (6)*	*Asia (25)*
Curriculum goals	4.60	4.25	3.67	3.48
Teacher's roles	4.74	4.13	4.00	3.64
Students' roles	4.57	4.13	4.50	3.76
ICT sophistication	5.79	6.00	5.50	5.52
Manifestation of learning outcomes	4.45	3.88	3.33	3.76
Connectedness of the classroom	4.67	4.50	4.00	3.16

* The figures in brackets are the number of case studies from countries within the respective regions that were included in this analysis.

Table 3: Correlation matrix of the dimension scores of cases across all regions (N=83)

	G_SCORE	*T_SCORE*	*S_SCORE*	*IT_SCORE*	*M_SCORE*	*C_SCORE*
G_SCORE	1					
T_SCORE	.74**	1				
S_SCORE	.67**	.77**	1			
IT_SCORE	0.14	.22*	0.06	1		
M_SCORE	.56**	.59**	.72**	0.07	1	
C_SCORE	0.21	.31**	.26*	.31**	.28**	1

*p< 0.05, **p<0.01

Table 4: Correlation matrix of the dimension scores of cases within Western Europe (N=42)

	G_SCORE	*T_SCORE*	*S_SCORE*	*IT_SCORE*	*M_SCORE*	*C_SCORE*
G_SCORE	1.00					
T_SCORE	0.64**	1.00				
S_SCORE	0.56**	0.67**	1.00			
IT_SCORE	-0.08	-0.01	-0.02	1.00		
M_SCORE	0.50**	0.57**	0.81**	0.17	1.00	
C_SCORE	0.04	0.15	0.17	0.42**	0.20	1.00

**p<0.01

Table 5: Correlation matrix of the dimension scores of cases within America (N=8)

	G_SCORE	*T_SCORE*	*S_SCORE*	*IT_SCORE*	*M_SCORE*	*C_SCORE*
G_SCORE	1.00					
T_SCORE	0.12	1.00				
S_SCORE	0.60	0.79*	1.00			
IT_SCORE	-0.52	0.00	-0.43	1.00		
M_SCORE	0.14	0.21	0.49	-0.21	1.00	
C_SCORE	-0.31	0.17	-0.13	0.52	-0.36	1.00

*p< 0.05

Table 6: Correlation matrix of the dimension scores of cases within Asia (N=25)

	G_SCORE	*T_SCORE*	*S_SCORE*	*IT_SCORE*	*M_SCORE*	*C_SCORE*
G_SCORE	1.00					
S_SCORE	0.76**	0.85**	1.00			
IT_SCORE	0.35	0.45*	0.28	1.00		
M_SCORE	0.58**	0.64**	0.69**	-0.10	1.00	
C_SCORE	0.17	0.30	0.28	-0.03	0.35	1.00

*p< 0.05, **p<0.01

Table 7: Correlation matrix of the dimension scores of cases within Eastern Europe (N=6)

	G_SCORE	*T_SCORE*	*S_SCORE*	*IT_SCORE*	*M_SCORE*	*C_SCORE*
G_SCORE	1.00					
T_SCORE	0.93**	1.00				
S_SCORE	0.84*	0.72	1.00			
IT_SCORE	0.30	0.52	0.40	1.00		
M_SCORE	0.72	0.48	0.66	-0.21	1.00	
C_SCORE	0.39	0.27	0.62	0.17	0.71	1.00

*p< 0.05, **p<0.01

An examination of the correlation of scores between the different dimensions revealed important observations. The data in Table 3 shows that the ICT sophistication score has the lowest correlation with the other innovation scores and the ICT sophistication score correlation was significant only for the teacher's roles and classroom connectedness scores. On the other hand, the teachers' role scores showed the highest correlations with the other dimensions, indicating that this dimension played a key role in influencing the overall level of innovation for the cases analyzed. Tables 4-7 further revealed that the pattern of correlation was rather different for the cases collected from the different geographical regions. Specifically, the IT sophistication score correlated much more strongly (and positively) with the other dimensions for cases collected in Asia and Eastern Europe. On the other hand, the IT sophistication score correlated positively and significantly only with the connectedness dimension. It is in fact intriguing to note that the IT sophistication score correlated negatively with the innovation score on all other dimensions except for the connectedness dimension. Venezky & Davies (2002) concluded from their study of ICT-supported education innovation collected in the OECD countries that ICT is only a lever for change, and not a catalyst, meaning that the presence of ICT per se would not lead to the emergence of innovation. Instead, ICT could be used to leverage educational innovations to bring about more effective transformation. The regional correlation statistics listed in Tables 4-7 indicate that the impact of ICT on education innovation is possibly much more complex and is likely to differ for systems where schools have different levels of general access to ICT.

CATEGORIZING INNOVATIONS

As the case studies collected in SITES M2 were all considered to be among the most innovative examples of ICT-supported pedagogical practices in their own countries, some means of describing the characteristics of these cases in more specific terms would be very helpful not only for research purposes but would also contribute to the more effective dissemination of what can be learnt from these case studies as models. One advantage of conducting in-depth qualitative case studies is the richness of the data collected. In the SITES M2 study, the national research coordinators were required to submit a 5000 word case report according to a specified report structure for each of the cases accepted by the International Coordinating Centre (ICC). Both Kozma & McGhee

(2003) and Law et. al. (2003) tried to develop ways to characterize and categorize the case studies collected internationally based on the submitted case reports. While the ICC team (reported in Kozma & McGhee (2003)) analyzed the entire collection of 174 cases, the Hong Kong team (reported in Law et. al., 2003) only analyzed 83 selected case reports as they found the others to lack sufficient details at the classroom level for them to be coded without access to information beyond the reports.

Categorizing multi-dimensional features in one process

The building up of characterizations and categories of the cases collected need to be preceded by a process of coding of the aspects of the case studies that are considered to be pertinent to the innovations. The ICC used a 27-item "cover sheet" to code each of the 174 cases according to a broad range of characteristics such as grade level, subject area, type of curricular change involved, etc., using a common set of coding guidelines. To ensure reliability, the ICC shared their codes with the National Research Coordinators (NRCs) and changes were made to the codes if the NRCs could substantiate the rationale for change with existing data in the case reports or with additional information that had been collected for the cases in question. For the purpose of characterizing and categorizing ICT-supported classroom practices, Kozma & McGhee (2003) selected 38 codes from 4 of the "cover-sheet" items for their analysis. The four questions selected were on: (1) the type of activities that the innovation teachers carried out (9 examples listed, including lecture, advise, design materials, etc.), (2) the type of activities that the innovation students carried out (10 examples listed, including conduct research, search for information, solve problems, etc.), (3) which were the technologies used in the innovation (11 examples listed, including laptop computers, LAN, Email, etc.) and (4) what kinds of ICT practice (i.e. usage or function, including tutorial, product creation, information search, etc.) were involved in the innovation (8 examples listed). Each of the cases were coded for the presence or otherwise for each of the examples listed (resulting in a total of 38 codes). It is clear from the cover sheet items that the two questions on teachers' and students' roles were identifying pedagogical features in the cases reported, the question on technologies used was independent of the pedagogy used, while the question on ICT practice would provide indications about how the technology functioned pedagogically in the cases studied.

After confirming the validity of the codes with the NRCs, Kozma & McGhee (2003) conducted a K-means clustering (using the SAS FASTCLUS procedure) on the 38 codes associated with the 174 cases in order to explore how the cases might be "coalesced into distinguishable patterns that might form different models of ICT use in support of educational change" (ibid. p.47). Their goal was to understand "how certain teaching practices fit together with certain activities by students using technology, and how these practices might differ from one set of case to another".

K-means clustering is an exploratory multivariate procedure for identifying meaningful groupings in a dataset by clustering the cases into a pre-assigned number of groups (SPSS Inc., 1999). The researcher has to explore with different numbers of pre-assigned clusters in the analysis and the cluster-solution that provides the most meaningful interpretation of the different cluster characteristics as reflected in the weighting of the cluster centres corresponding to each variable is then taken as the optimal solution. After exploring the solutions for 4 to 8 clusters, Kozma & McGhee (2003) came to the conclusion that the 8 cluster solution was "most satisfying", while acknowledging that the choice was indeed subjective. They labeled seven of the clusters as Tool use, Student collaborative research, Information management, Teacher collaboration, Outside communication, Product creation and Tutorial according to what they perceive to be the identified features of those clusters, but had to label the 8th one as "undefined" as that cluster with 27 cases had no distinguishing features at all.

There are prima facie two features of their cluster solution that indicated potential problems with the analysis. One is the existence of a large cluster of 27 cases that were "Undefined" in their features. Another is the fact that they had to eliminate 4 cases as "outliers" from their analysis, two of which were considered as stellar cases, that is, the most interesting or exciting case study within the national selection by their respective National Research Coordinator. While the cluster analysis results should help to build distinction between cases in different clusters by highlighting the distinguishing common features (in other words the homogeneity) within the same cluster members and the heterogeneity between cases in different clusters, it was very difficult to identify the distinction between clusters. In fact, the report broke away from common practice in cluster analysis reporting and built four "models of innovative pedagogical practices" based on features that were shared by many of the clusters: the student collaboration, student research, product and outside collaboration models. It is not evident that the descriptions of the features of the clusters or the models were particularly helpful in categorizing or characterizing the 174 innovative pedagogical practices that could not have been gleaned through an inspection of the frequency of occurrence of the 38 variables used in the cluster analysis.

Methodological issues in using cluster analysis

Cluster analysis is a heuristic technique generally used to discover structure in data (i.e. structure-seeking), although the operation for this method is structure-imposing (Aldenderfer & Blashfield, 1984). The K-means cluster procedure is an iterative partitioning method that is used to produce a pre-set number of single-rank clusters that do not overlap in membership of data points. The choice of variables to be used with cluster analysis is one of the most critical and least understood steps in the research process. The key concern here is to choose the set of variables that best represents the concept of similarity for the study in question, and ideally the choice should be theory-driven. Otherwise the process may easily fall prey to "naïve empiricism" by the collection and subsequent analysis of as many variables as possible in the hope that the "structure" will emerge (ibid. p.20). A related issue is that the uncritical use of highly correlated variables to compute a measure of similarity in the clustering process may lead to rather dubious results. In Kozma & McGhee's (2003) analysis, no theoretical justification was provided for the particular choice of variables selected for the cluster analysis. Further, it is quite evident that some of the variables would be more highly correlated than others, sometimes for answers to items within the same question while others were answers to items in different questions. This will lead to problematic results when the cluster analysis is done on multi-dimensional data as is the case for their analysis. The variations in correlation for the innovation scores listed in Tables 3-7 provide another indication of the difficulty in clustering multi-dimensional data whose structure is not clearly understood.

Another very important methodological concern in using cluster analysis is that adequate evidence of the cluster analysis solution should be presented (ibid. p.81) since different clustering methods can and do provide different results when applied to the same data. Evidence of the validity of the results of the analysis that are independent of the method should be provided. No such evidence was provided in Kozma & McGhee's (2003) analysis.

Alternative methods of categorizing pedagogical practices

The Hong Kong SITES team also saw the need to categorize IPPUTS at a descriptive level (categorization of pedagogical practices) and delved into the innovations by exploring the categorizations of the cases. The major difference with the analysis undertook by Kozma & McGhee was that instead of clustering the cases with a set of mixed data attributing different dimensions, Law made several different categorizations, each specifically addressing one dimension: organizational arrangement of learning activities, curriculum goals, teacher's role and students' roles. Two categorization approaches were adopted. First, expert judgment was adopted to identify the pedagogical approach for the practices (that is, the configuration and organizational arrangement of learning activities in the classroom). Secondly, a K-means analysis was conducted on detail coding for each of the three dimensions - curriculum goals, teachers' roles and students' roles - in order to arrive at a better understanding of the features of the innovative practices along these dimensions.

Characterizing pedagogical features holistically by expert judgement

The categorization of the 83 SITES M2 pedagogical practices was conducted by the Hong Kong SITES research team, which according to their activity organization was done by expert judge. The pedagogical approach of a practice, which is its organizational and activity aspects, form the key concern of many teachers in their planning and implementation of teaching and is very valuable for purposes of understanding and disseminating findings on innovative practices. On the other hand, Law and her team considered such features to be general and superficial aspects which would be more appropriately categorized through careful reading rather than statistical calculation. The team identified 6 types of pedagogical practices across the 83 cases, including project work (34 cases), scientific investigations (7 cases), media production (18 cases), task-based activities (10 cases), virtual schools or online courses (11 cases) and expository lessons (3 cases)[4].

Building up separate categorizations for identified dimensions

Besides categorizing the pedagogical approach used in the innovative case studies, the team was also interested in exploring and building deeper levels of understanding of the innovations through cluster analysis. However, contrary to the approach adopted by Kozma & McGhee (2003), they focused on discovering structures within each of the six dimensions. In order to achieve this, they developed a rather detailed coding rubric for each of the six dimensions (details of the coding guide are available as pop-up windows from their online research report) and coded each of the 83 case reports using the rubric so as to build up a detailed database of features for these cases to be further analyzed.

Based on the results of the exploratory cluster analysis of the 83 cases in all the 6 dimensions, the team was only able to find satisfying cluster results for three of the six dimensions: curriculum goals, teachers' roles and students' roles. The coding rubrics for these three dimensions are listed in Table 8.

Table 8: Coding rubric used by the Hong Kong SITES research team in 3 of the 6 dimensions that the SITES M2 case reports were coded on by the team.

Curriculum goals		*Teachers' roles*		*Students' roles*	
G1	Conceptual learning	T1	Explain or present information	S1	Listen and understand presentation
G2	Motivate students	T2	Give task instruction	S2	Follow task instructions
G3	Problem solving skills	T3	Monitor students' task progression	S3	Search for information
G4	Critical thinking skills	T4	Assess students	S4	Presentation of own learning
G5	Catering for individual differences	T5	Provide learning support to students	S5	Design and create products
G6	Active learning	T6	Develop teaching materials	S6	Data gathering and processing
G7	Equity	T7	Design curriculum and learning activities	S7	Analyzing and drawing conclusion from data
G8	Collaborative & organizational Skills	T8	Select ICT tools	S8	Peer Evaluation
G9	Information skills	T9	Support students' inquiry process	S9	Reflect on own learning
G10	Communication skills	T10	Co-teaching	S10	Electronic presentation of own learning
G11	Inquiry skills	T11	Support team building of students	S11	Engage in collaborative task with other students
G12	Empower students' learning with ICT skills	T12	Mediate between students and experts	S12	Engage in enquiry
G13	Students can evaluate their own learning	T13	Liaise with parties outside school	S13	Collaborate with remote peers
G14	Self-access learning			S14	Peer tutoring
G15	All-round development			S15	Provide technical support to teachers/other students
G16	Personal development			S16	Provide Computer Courses for Teachers
G17	Improve learning attitude			S17	Determine own learning schedules and strategies
G18	Developing Values				
G19	Provide authentic learning contexts to students				

To give an indication of the kind of insight this team was able to draw from the cluster analysis procedure, the cluster labels for these three dimensions are listed here. Law et al., (2003) identified 5 curriculum goal clusters:

- To develop lifelong learning capabilities through learning activities that are related to real-life, complex authentic learning contexts which will foster the development of collaborative and organizational skills as well as attitudes and values that are considered to be important socially or nationally;
- To promote the effective learning of subject-related knowledge or concepts;
- To develop skills in accessing and evaluating information;
- To empower students through use of ICT by enhancing their productivity; and
- To increase students' motivation to learn.

As for the teacher's roles, Law et al., (2003) found the 5 cluster solution to be most meaningful, and they gave these clusters the following labels:

- Facilitating exploratory learning,
- Guiding collaborative enquiry,
- Administer learning tasks,
- Provide learning resources, and
- Present, instruct and assess.

The team also decided on a 5 cluster solution for the students' roles and the labels used were:

- Enquiry-based Learning,
- Online Enquiry-based Learning,
- Productive Learning,
- Low Level Project Work, and
- Follow Instructions.

With the finer grain coding and cluster analyses, the team was then able to undertake further analysis to build up a better understanding of ICT-supported pedagogical innovations. For example, in an examination of the kinds of teachers' roles found in the diverse range of case studies, Law (2003) found greater role differentiation in the cases involving virtual schools and online classes (which the paper referred to as cyber institutions), such that the roles of the teacher in conventional school settings were then taken up by a number of different individuals who contributed to different aspects of the teaching process. These roles included study coaches, curriculum material developers, and expert tutors. Even though the innovation score for the cases of cyber institutions were generally relatively low along the dimension of teachers' roles and relatively high along the ICT sophistication dimension, Law (2003) argued that this process of differentiation brings about the emergence of new education professionals. The process of differentiation was also expected to be a process of evolution which, while starting primarily as an innovation in the adoption of new technologies to broaden the education opportunities of learners in remote areas, will become an evolutionary process that will bring about a new professional ecology in education as it now becomes imperative that the differentiated education professionals communicate and collaborate effectively. Thus Law (2003) further argued that cyber institutions will contribute to "the generat[ion] of innovations in learning technologies, pedagogy as well as new types of educational professionals leading to new ecologies and cultures in education communities".

Building on the categorization of the innovation case studies into different pedagogical practices and pedagogical roles, Law (2004) observed that while some of the pedagogical approaches such as scientific investigations, project work and media production possess features that one would expect to be associated with teachers who play more emergent/innovative roles, a cross-tabulation of the teachers' roles with the various kinds of pedagogical practices analyzed revealed such expectations did not necessarily hold true. Many teachers still played rather traditional roles in presenting, instructing and assessing students, providing learning resources, or administering learning tasks even though the pedagogical practices they engaged in were prima facie ones that require students to conduct open investigative work. Such inconsistency indicates teacher professional development needs to go much further than introducing teachers to new technologies and new approaches to pedagogical organization in order to bring about and sustain innovations. This finding also sheds light on possible reasons for the lack of structural clarity in Kozma & McGhee's (2003) cluster analysis results, as that analysis confounded surface, organizational and technological features with the roles played by teachers and students in the innovations.

Based on their categorization and characterization of the innovations, Law, Yuen & Chow (2003) found that the ICT tools used in the innovations were mostly general-purpose tools that were not specifically designed for education or for use in specific disciplinary domains. The most education- specific digital resources used belonged to two categories: those that support investigative work, such as simulations, modeling tools, datalogging equipment and data-analysis tools, and those that support traditional instruction such as drill-and-practice tutorials and reference resources. This indicates that the use of ICT for pedagogical purposes per se does not prioritize particular pedagogical approaches or roles. Rather, it is the latter which determines the selection of digital resources to be used.

The cluster analysis results on teachers' roles also revealed geographic regional differences in the profile of roles taken up by teachers in the innovations found in the different regions (Law, 2004). The regional differences found were consistent with the regional differences reported in an earlier section based on the expert judgment of levels of innovation along the dimension of teachers' roles. This incidentally provides independent evidence on the validity of the cluster analysis results reported by Law et al., (2003).

CONCLUSION

The SITES M2 study posed serious methodological challenges for researchers in the field of international comparative studies of education. The challenges involved are two-fold. First of all, comparative studies involving complex multiple case studies of the scale found in the SITES M2 study are very rare. Another major challenge relates to the lack of established methodologies for the international comparative study of educational innovations. Studies of educational innovations were generally done at individual institutional levels, or on several institutions that share similar contexts. SITES M2 thus posed serious challenges in terms of both the scale and complexity involved. The published findings for SITES M2 is still very limited compared to the richness and massiveness of the data that have been collected. Nevertheless, these publications provide important insight to our understanding of ICT-supported pedagogical innovations. This paper attempts to provide a discussion of some of the methodological issues revealed through the published findings related to this study. In particular, this paper presented two approaches to assessing the level of innovation, both of which contributed important insight to the understanding of the nature and complexity of changes found in ICT-supported pedagogical innovations selected around the world. The paper also presented several approaches to the categorization and characterization of pedagogical innovations using technology, including the associated methodological challenges involved. It is hoped that this discussion will stimulate further debates and developments in research methods on comparative case studies of educational innovations as well as more varied analysis of the SITES M2 data.

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NOTES

1. More details of the research findings can be found from their website, http://sitesdatabase.cite.hku.hk/online/index.asp
2. http://sitesdatabase.cite.hku.hk/ict_innovation/main.asp?in_page=3
3. The 4 Australian cases included in this analysis were categorized together with cases from West Europe. Further, 2 of the 83 cases from South Africa were eliminated from this regional analysis.