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USING LEARNING ENVIRONMENT ATTRIBUTES TO EVALUATE THE IMPACT OF ICT ON LEARNING IN SCHOOLS

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Research on Information and Communications Technologies (ICT) use in schools is increasingly finding that the impact on learning outcomes is not directly causal but depends on how the technologies are used within learning environments. This paper presents one key dimension, the 'Learning Environment Attributes' dimension, of a complete literature-based framework — the 'New ICT Supporting Schooling' (NISS) framework — designed to provide systematic rich guidance for teachers and school leaders in deciding how to facilitate ICT use. A substantial trial showed that this theory-building stage has produced an effective rubric-based tool to facilitate the measurement of this dimension. Indications are that it is particularly useful for whole-school analysis.

Keywords: Information and communications technologies; educational technology; learning environments; theoretical models.

1. Introduction

Information and Communications Technologies (ICT) are increasingly used in schools to support teaching and learning based on the belief that this will improve learning outcomes (Becta, 2006). However, research suggests that this is unjustified (e.g. Fitzer *et al.*, 2007; National Center for Education Evaluation and Regional Assistance, 2007) and that it depends on how the technology is used rather than that it is used (Lei & Zhao, 2007). Therefore, the decisions that teachers and school leaders make about the use of ICT and the basis for those decisions are critical to the investment in the technology providing a return.

Personal computers have been in most Australian schools for up to three decades with educators finding it difficult to keep up with the rapidly changing nature of the technology, let alone critically considering applications to teaching and learning (Hayes, 2007). Given the constraints of budgets, curriculum and time it is difficult for educators to know on what to base decisions about the use of ever-improving ICT to enhance student learning. Rather than decisions made on an *ad hoc* basis, teachers and school leaders need a framework to support a systematic approach to such decision-making giving confidence that this will be based on appropriate research. The *New ICT Supporting Schooling (NISS)* framework, developed and implemented by a research team in Australia, is such a framework. This paper sets out to introduce one dimension of the five contained in this framework, the *Learning Environment Attributes* (LEA) dimension.

A research process was undertaken to develop and validate the dimension that began with a comprehensive review of the research literature and concluded with a longitudinal trial involving a sample of Australian schools. The complete framework comprises five interdependent dimensions that are briefly described later in the paper in order to indicate the scope of the framework within which the LEA dimension resides. The original aims for the LEA dimension were: to describe the impact of ICT on activities within learning environments; to assist teachers in planning to integrate ICT into learning environments; and to document progress in improving learning environments.

This paper uses empirical data to support a proof of concept as it represents a theory-building process rather than a reporting of a full empirical study. Nevertheless, the LEA is gradually confirming its value over the longitudinal evaluation study of which it is part, and further publications are planned on completion of this research. To operationalize the LEA dimension, a simple descriptive rubric was developed based on attributes drawn from the literature that are discussed in the next section (summarized in Table 1). The rubric formed the basis for a set of measures that generated quantitative values referred to as LOPA (Learning Outcomes and Pedagogy Attributes) scores or ratings.

To warrant the theory building process this paper will first present a wide-ranging literature review and second propose a rich model incorporating how ICT can contribute in learning settings; finally a brief review of some of the methodology of and data being captured by the current longitudinal research will flesh out how the LOPA can both measure performance and guide improvements to the design and implementation of learning settings.

2. Building a Framework from a Review of the Literature

There is no causal relationship between the use of ICT and how or what people learn; however, complex links can be identified (Bransford, Brown, & Cocking, 2000). Research over the past 30 years has yielded a considerable and compelling knowledge base to assist in understanding this connection. But to be of value to educators this needs to be synthesized and interpreted into useable measures and tools. Therefore, a comprehensive conceptual framework based on this research literature is needed to describe and evaluate the impact of ICT on learning, and to provide schools with tools to support decision-making. Such a framework begins with a consideration of the rationales for ICT in schools and the beliefs that gird these.

2.1. *Solving problems in the environments that mediate learning*

Throughout the history of humanity, technologies have been developed to solve particular problems, and therefore it follows that educational technology should be conceived to address particular educational problems. Many educators (e.g. National Centre for Vocational Education Research, 2002) believe that there is no shortage of problems (e.g. learner misconceptions, content management) and that enough is known about learning to effectively employ computer-based technologies as part of a range of solutions (e.g. Schank & Cleary, 1995). The challenge may be to ensure teachers use it and are not distracted by it — not falling into the trap of what Papert (1987) calls ‘technocentric thinking’. Instead the use of such technology in learning settings should be driven by accepted understandings of learning, much going back for a century or more (e.g. Fullan, 1995; Means & Olson, 1994; Papert, 1987).

In a wide-ranging review of the literature on learning, the Committee on Developments in the Science of Learning (Bransford, Brown, & Cocking, 2000, p. 10) argued that, increasingly, commonly accepted understandings about learning are those bearing the label of constructivism. They argued that, “the contemporary view of learning is that people construct new knowledge and understandings based on what they already know and believe.” Further, if it is commonly accepted that learning occurs within a physical and psycho-social learning environment that determines the roles of the teacher and students and comprises a complex of relationships between entities such as learners, instructors, curriculum, and resources (Fraser, 1994), then we must be wary of taking too narrow a view. Interactive technologies involved in the delivery of the curriculum have a place within the psycho-social, not just the physical structures of a learning environment (e.g. Lynch, 1990).

Learning environments are constructed by the participants and are thus dependent on their beliefs and actions, particularly the underlying pedagogical philosophy of the teacher. Therefore there is considerable variation in the ways ICT may be effectively incorporated within a learning environment, and there is no suggestion that a particular option is preferable (i.e. there is no one optimal way of using ICT to teach calculus to 16 year olds). However, there has now been sufficient reported research to identify principles that may be applied to guide the inclusion of ICT support for effective learning environments. Many researchers, including educational bodies (e.g. Bransford, Brown, & Cocking, 2000), have elaborated the base principles critically built on theories of constructivism, including the concept of proximal learning, based on the work of Vygotsky (1978), that has led to the use of the term *computer supported learning* being where ICT is used to either maintain a learning environment or to support the learner (DeCorte, 1990; Mevarech & Light, 1992). The hope is that with the support of ICT a wider range of effective learning environments will be employed than has traditionally been the case (Glickman, 1991).

Studies that have tried to isolate the impact of computers on learning have typically been inconclusive, since learning is mediated through the learning environment and thus the interaction between factors is complex (DeCorte, 1990). A report from the ImpaCT2 study (Becta, 2002, p. 3) conducted in the UK did not find a "consistent relationship" between the amount of ICT use and "effectiveness in raising standards" but instead concluded that the type of use was critical. Research evidence supporting an indirect positive impact of appropriate uses of ICT on a range of learning outcomes has been mounting, particularly over the past decade (Lei & Zhao, 2007; Mann, Shakeshaft, Becker, & Kottkamp, 1999; Schacter, 1999). To add to the plethora of smaller studies, there have been a number of recent major studies that have provided substantial supporting evidence (Becta, 2002; Laferrière, Breuleux, & Bracewell, 1999).

Clearly the relationship between using ICT and learning gains is probabilistic rather than causal. It is possible to suggest likely impacts on learning by connecting ICT use with teaching and learning strategies or activities that are based on well-researched theories of learning. The Bransford, Brown, and Cocking (2000) report identified five major purposes for using ICT that educators should consider: to access and analyze information on real world problems; to provide scaffolding; to provide feedback, reflection and guidance; to communicate with local and global communities; and to access information and tools to extend teacher learning. Jonassen's (2000) website ("Designing a Constructivist Learning Environment") shows similar intent with a sub-section of five tool categories, each of which outlines different ways to design constructivist learning environments. From these and other reviews of recent research findings were distilled the eleven non-mutually exclusive attributes of high quality learning environments that may be enhanced through the use of ICT. These attributes were used to operationalize the LEA dimension as the LOPA and are described in Table 1 along with illustrative supporting references (for a more detailed discussion refer to Newhouse, 2002).

2.2. *The framework concerning the impact of ICT in schools*

The LEA dimension, which is the focus of this paper, was one of five developed for the NISS framework from a review of the literature. The dimensions were: *Student Characteristics*, *Learning Environment Attributes*, *Teacher Professional ICT Attributes*, *School ICT Capacity*, and *School Environment.* The diagram in Figure 1 connects these dimensions and illustrates their contribution to an impact on learning through the learning environment. Although this paper only considers the LEA dimension of the framework, it is important to keep in mind its connection with the other four enabling dimensions.

The NISS framework centers on the learning environment and connects this with the characteristics of comprising entities that are related to ICT use, represented by

Table 1. Descriptions of the attributes of the LEA dimension with sample references to research findings that indicate amenability to enhancement through student use of ICT.

Attribute	Description	Sample References
Investigate reality	Students investigate the real world using current information and tools to analyze, interpret and present this information.	(Bransford, Brown, & Cocking, 2000; Huppert, Lomask, & Lazarowitz, 2002)
Knowledge building	Students use tools and information to build a broader and deeper knowledge base.	(Bereiter, 2002; Berge & Collins, 1998; Laferrière, Breuleux, & Bracewell, 1999)
Active learning	Students are active participants in their own learning and learn by doing.	(McFarlane, 2000; Réginald Grégoire inc., Bracewell, & Laferriére, 1996)
Authentic assessment	Student assessment emanates directly from learning activities.	(Brown, 1994; Kimbell, Wheeler, Miller, & Pollitt, 2007)
Engagement	Students are engaged with their own learning through being motivated and challenged by learning experiences.	(Cradler & Bridgforth, 2002; Reid, Burn, & Parker, 2002; Smith, 2002)
Productivity	Students are supported for maximum productivity, particularly with repetitive, low-level tasks involving writing, drawing and computation.	(Becker & Riel, 2000; Passey, 2000; Van Daal & Reitsma, 2000)
High level thinking	Students are scaffolded in the development of higher level thinking skills such as application, analysis and synthesis.	(Laferrière, Breuleux, & Bracewell, 1999; The National Foundation for the Improvement of Education, 2001)
Learner independence	Students are provided with learning experiences and resources that permit them to progress at their own pace.	(Alagic, Gibson, & Doyle, 2003; Hennessy, Deaney, & Ruthven, 2003)
Collaboration and cooperation	Students are supported to work cooperatively within and beyond the learning environment and to participate in rich learning communities.	(Réginald Grégoire inc., Bracewell, & Laferriére, 1996; The National Foundation for the Improvement of Education, 2001)
Learning styles	Students are provided with learning experiences that are tailored to their needs and are suited to their own learning styles.	(Betts, 2003; Cradler & Bridgforth, 2002; Eadie, 2000)
Physical disabilities equity	Students with a physical disability are provided the opportunity to be involved in similar learning activities to other students.	(Abbot & Cribb, 2001; Harris, 2004)

four enabling dimensions (School ICT Capacity, School Environment, Teacher Professional ICT Attributes, and Student Characteristics). This is considerably more useful than just considering what technology is used and how often, as is typically the case in relevant studies. Finally, these enabling dimensions and their operationalized measures, such as the LOPA, suggest strategies that individuals, school

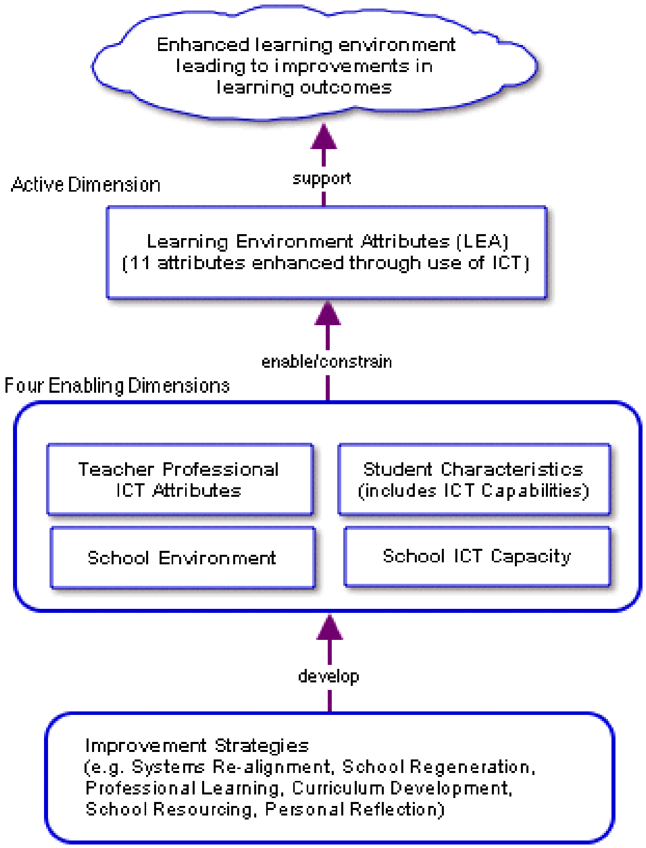

Figure 1. A conceptual schematic showing the dimensions of the NISS framework and highlighting the impact of the use of ICT on learning outcomes.

communities, or system leaders should consider to increase the likely positive impact of ICT use appropriate to the context; for example an area of the curriculum or phase of schooling.

To measure the LOPA, a simple descriptive rubric was developed based on the 11 attributes and the concept of progression from *No Use*, to *Developing Use*, to *Routine Use*, and finally to *Comprehensive Use*. Part of this rubric is shown in Table 2.[1] These statements of progression were illustrated with descriptions of examples from the research literature. Finally, to field test the dimension required the development of instruments (e.g. surveys and interviews) to collect data and the creation of tools (e.g. relational database) to facilitate the use of the rubric to make the judgments that provided the evidence. This allowed calculations such as the proportion of teachers at each level in a school.

[1]For a copy of the full rubric go to http://csalt.education.ecu.edu.au/reviews/

Table 2. Part of the rubric used by raters to make judgments on the Learning Environment Attributes dimension.

Attribute	Developing Use	Routine Use	Comprehensive Use
Investigate reality	Some learning activities incorporate aspects of real situations. Typically at the end of a learning sequence students apply knowledge and skills to an example situation. Examples may be used as an introduction.	Routinely the focus of learning activities is to investigate real situations. This will tend to involve problem-based learning with the connection to reality evident throughout.	All learning activities are organized around the investigation of real situations from which knowledge and skill development emanate.

3. Testing the LEA Dimension in an Evaluation Project

After its initial development, the NISS framework, including the LOPA measure, was used in an evaluation study involving samples of schools in Australia engaged in an ICT-related project. The project itself was intended to show that a specific set of ICT and related resources would positively affect student learning. These resources were broadly focussed and included additional hardware, a teacher-leader in each school to coordinate the integration of ICT, support for professional learning for teachers in the use and application of ICT, access to a range of software, a standard operating environment, and Internet access for every classroom.

3.1. *Evaluation methodology*

Instruments used in social science research lack the certainty of rulers and other physical measures of the physical sciences (Bond & Fox, 2001). Thus determining the validity and reliability of these instruments is both critical and complex. When theory-building, even more care is required, using principles such as triangulation. Therefore the evaluation study employed a methodology to provide thick data to allow both validation of the newly developed tools and an evaluation of the project in the schools involved. In this case the validity and reliability of the instruments to measure the LOPA (based on Table 1) was as important as the schools being evaluated. Indeed, the purpose of this paper is to present the results for the former and not the latter.

The evaluation, based on a quasi-ethnographic model of longitudinal evaluation, was chosen because of the need to collect rich data from a pre-specified group of schools where significant ICT investment was justified. Such methodologies require the development of strong working relationships with participants, particularly school coordinators, especially to maintain the quality of long-term data collection. Longitudinal repeated datasets traditionally provide significant triangulation as well as prospects for causation to be identified (Patton, 2002). Using the school as the unit of measure allows valid comparisons over time in real-world settings because the schools have a natural stability. The sample of schools used for illustrative purposes in this paper comprised groups of 12 to 16 public schools (primary and secondary), with typically about half in country areas, and varying in size from over 1000 students to less than 15 students. Sets of data were collected at least once each year over a three or four-year period with the first set of data termed the *Baseline* and subsequent sets of data termed *Compare1*, *Compare2* and *Compare3*. At the time of writing there was only the final set of data to collect for the last two sets of schools.

The unit of study was the school, not the teacher or student, and therefore the ultimate focus for analysis was on each school and then later a comparison between schools. Supported by the database system, a variety of measures were constructed (at least one per dimension), but this paper focuses on the LOPA measure for the LEA dimension.

3.2. *Method and analytic approach*

Both qualitative and quantitative techniques were relevant — they allowed collection of a rich dataset to consider regularity of ICT use, the range of software applications, connections between the applications, and the learning tasks to which they were applied, and intended learning outcomes for the students. Data were also collected concerning school organization and culture, curricular structures (like staffing, classes, priorities) and teacher attributes. These data were collected from system and school documents, school leaders, teachers, and students. A set of instruments was developed for data collection, including questionnaires, and pro forma for interviews, observations, work samples and document analyses. Table 3 lists the data collection requirements for each school.

Table 3. The data sources/instruments used in the evaluation study and an explanation of their use and scope.

Data Source/Instrument	Explanation and Scope
Teacher questionnaire	Completed by all teachers in each sample school.
Teacher interviews	Two to four teachers selected in consultation with the coordinator on the basis that they were likely to be using ICT with students.
Student questionnaire	Completed by students from one class for each teacher to be interviewed and by students from some randomly selected classes.
Principal and Coordinator questionnaires and interviews	The principal and coordinator in each sample school.
Student interview forums	Five students selected from a class of each interviewed teacher.
Work samples	A representative set selected by each interviewed teacher.
Lesson planning documents	Examples from interviewed teachers were copied or photographed.
Learning activity materials	Samples of activity support materials from interviewed teachers.
Observations	Brief observation of spaces used by interviewed teachers.

The administration of the surveys was facilitated by a teacher-leader, known as the project coordinator, at the school usually prior to a researcher's visit. A researcher then visited for a day or sometimes slightly more to collect documents, observe the school environment, and conduct interviews. Documents included school planning/policy documents, teachers' planning documents and samples of student work. Observations included viewing and photographing facilities such as libraries, classrooms and laboratories with computers. Interviewees included selected teachers, groups of up to five students associated with the selected teacher, school Principal and project coordinator, and sometimes other key school personnel. The teachers who were interviewed were nominated by the school's project coordinator as being exemplary in the use of ICT and therefore represented the leading edge for the school. Most interviews were digitally recorded and documents were collected in paper, electronic or photographic form. There was also electronic communication with teachers and key personnel to collect sample documents or clarify issues raised during the visit.

Quantitative data were analysed largely using descriptive and frequency procedures within spreadsheets or the SPSS statistical software package. While the qualitative data were initially either transcribed or summarized into descriptions and entered into a relational database system specifically constructed for the evaluation. Graphs, summary statistics and results from statistical tests from the quantitative data were also entered into the database system. This then allowed the researchers to make judgements according to rubrics associated with the dimensions of the NISS framework using the large array of data, summaries and results. Further, conclusions could then be drawn based on the analyses of all these data and summaries could be exported allowing the reliability of the measures to be tested and comparisons to be made between sets of data using ANOVA, t-tests, chi squared tests and graphical representations.

3.3. *Results from testing the LOPA measures*

It was evident that various LOPA measures had relevance, including teacher LOPAs for each teacher, based on judgments on questionnaire responses; leading edge teacher LOPAs primarily based on responses to the interview; school LOPAs based on summaries of the teacher LOPAs of all teachers in the school; and sample LOPAs based on summaries of all school LOPAs in the sample. The ease with which this data could be assembled was important and reflected on its validity and reliability in various ways.

In both the teacher questionnaire and interview, the focus of most items related to learning outcomes, pedagogy and ICT use to enhance pedagogy. There were items related to the prevalence of the learning environment attributes (Table 1), such as the degree to which group work occurred, or students analyzed information or investigated real world situations, and items related to the degree to which ICT supported these attributes. These data were analyzed in holistic terms of the

LOPA using the rubric with descriptors for the levels of use from *None*, to *Developing*, *Routine*, and *Comprehensive* (refer to Table 2). There were separate database screen layouts to support making judgements for each of the LOPA measures, one layout collating relevant data from the questionnaire for each teacher, and two layouts associated with the leading edge interviews, one focussed on general pedagogy and the other on pedagogy involving ICT use. Layouts included the LOPA rubric with buttons to indicate judgements, representations of the relevant responses or summaries of responses from questionnaires and interviews (leading edge teachers and their students) and, in some cases, relevant photographs and/or summaries of other data and/or observations. Researchers used the layouts in the database system to review all the relevant data and make judgements for each teacher. These judgements were recorded in the database along with annotations to justify each judgement and checked by other research team members.

It was more difficult to make LOPA judgments based on the teacher questionnaire than the interviews. Typically, from the relevant questionnaire items it was not difficult to determine whether a teacher *Routinely* used ICT to enhance learning in terms of a particular attribute, but for many teachers it was difficult to determine whether they were developing this or not doing so at all. This required the researcher to make informed 'guesses' as to the likely reasons for the use of particular software applications. Therefore, in making judgments from the questionnaire data the *Developing* use level was split into two categories, *Possibly Using* and *Definitely Using*. Further, field-testing showed it was typically not possible to make judgments of the *Comprehensive* level. Few teachers, even when interviewed, could be judged to be at this level for any attribute.

To investigate the reliability of judgments made from the questionnaire data, two researchers each made judgments independently. These were then statistically compared so that the researchers could jointly consider instances where their judgments differed significantly, with the aim of arriving at a consensus. For example, for one set of data after the initial judgments the inter-rater reliability between the researchers on the LOPA ratings was calculated to be 0.72 (Pearson's correlation coefficient) with about a 0.4 proportion of judgments with unacceptable differences. An unacceptable difference was defined to arise when, for more than one LOPA attribute, either rater selected *Definitely* or *Routinely* and the other did not. It was decided that because there was a high degree of speculation in the *Possibly* option, differences between raters were acceptable. After a consensus meeting, the inter-rater reliability was 0.86, significant at $p < 0.01$, and no unacceptable differences remained. Typically, inter-rater reliability correlations for LOPA ratings have been found to be around 0.8 and 0.9 although the inter-rater reliability on individual attributes were between 0.7 and 0.8 with a few lower than this, even down to about 0.2. In one case, a low reliability for the *Higher Level Thinking* attribute was due to most judgments being either *No Use* or *Possibly* (the difference between these two is often based on some 'on balance' speculative interpretation by the rater of very few words provided by the questionnaire respondent — e.g. "web searches" may

Table 4. A summary of LOPA ratings from teacher questionnaire data collected at a sample of schools.

Attribute	Mean % of Teachers/School Judgments on Current ICT Use		
	*P**	*D**	*R**
Reality	29	27	6
Knowledge	12	3	0
Active learning	34	11	1
Assessment	37	15	2
Engagement	38	15	3
Productivity	40	20	8
Thinking	12	1	0
Independence	14	4	0
Collaboration	9	5	3
Learning styles	44	14	0
Disabilities	1	7	0
Mean	24.5	11.2	2.0

**P* = possibly, *D* = developing, *R* = routine

lead to an on balance judgment that *Possibly* the teacher is facilitating ICT use with students to *Investigate Reality*). No such difficulties occurred for interviewed teachers with teachers able to explain their intentions explicitly.

The proportion of teachers at each level (*P-Possibly*, *D-Definitely*, *R-Routinely*) for each of the 11 LOPA attributes was calculated for each school and then an average proportion across the sample of schools. The results of this process for a sample of schools are shown in Table 4. A mean proportion was then calculated for each level across all the attributes and is shown at the bottom of the table.

For teachers who were interviewed, judgments were made not only for the use of ICT to support each LOPA attribute but also for the general contribution of the attribute, regardless of ICT use, to the learning environments typical for that teacher. Since only between 2 and 4 teachers were interviewed from each school, and these teachers were selected on the basis that they were the most likely to be using ICT in an exemplary fashion, there was no value in calculating proportions and averages across the schools using these teachers. Instead, the percentages were calculated of schools where the LOPA rating was the highest judged among the interviewed teachers for the school (refer to Table 5). This analysis provided a measure of the 'leading edge' for each school and across the schools in terms of targeting ICT use at the LOPA attributes. These judgements were made both in terms of the teacher's general focus on enhancing the attribute for their learning environments (termed *General* in Table 5) and towards using ICT to enhance this attribute (termed *ICT Use* in Table 5).

Typically, the results were more positive for the interviewed teachers with most schools having at least one teacher who routinely incorporated activities, not necessarily using ICT (refer to the *R* status in the *General* column in Table 5), or

Table 5. A summary of the LOPA ratings from data collected from teachers and students at a sample of schools using the interviews, teacher planning documents and student work samples.

Attribute	% Schools with Interviewed Teacher Judged at Highest Level					
	General			ICT Use		
	*D**	*R**	*C**	*D**	*R**	*C**
Reality	14	72	14	21	72	0
Knowledge	36	64	0	29	58	0
Active learning	21	72	7	21	78	0
Assessment	21	72	7	36	58	7
Engagement	14	78	7	14	78	7
Productivity	21	64	7	21	64	7
Thinking	43	50	0	36	50	0
Independence	43	58	0	43	58	0
Collaboration	36	50	14	36	50	7
Learning styles	50	50	0	43	43	0
Disabilities	7	7	0	7	7	0
Mean	27.8	57.9	5.1	27.9	56.0	2.5

*D = developing, R = routine, C = comprehensive

was developing approaches that targeted each of the learning attributes (except for physical disabilities). Further, typically schools had at least one teacher who was routinely incorporating ICT supported activities, or at least developing this to target each of the learning attributes (refer to *ICT Use* column in Table 5). Most often, this was the same teacher across most of the attributes.

In the evaluation study, data were collected once a year for three or four years, allowing for comparisons over time. For example, Tables 4 and 5 show the results for a sample of schools for the 'first comparison' dataset and similar tables were constructed for the baseline dataset. It was then possible to compare results between years of data collection and, in particular, the average proportion of teachers facilitating computer use (combining mean % for *Definite* and *Routine* in Table 4) for these LOPA attributes. However, this was only a crude comparison between school means and often masked substantial changes that occurred in individual schools because marked improvements in a few schools were counterbalanced with a regression in others. A set of results similar to that shown in Tables 4 and 5 was created for each individual school, the unit of measure in this study, to be used in making holistic judgments about the school, comparing the school with the sample of schools and providing recommendations to the school.

The compilation of LOPA ratings for each school and sample of schools into tables such as Table 4 allowed the calculation of the mean percentage over all the LOPA attributes, provided at the bottom of each column. From this, a *School LOPA Score* was calculated for each attribute by summing weighted percentages across the rating levels with *Routine* use (R) nominated as the desirable rating and given a weighting of 1, *Developing* use (D) weighted at 0.5, and *Possible* use (P) weighted as 0.25 (i.e. $LOPA\ Score = R + 0.5 \times D + 0.25 \times P$). In the absence of any compelling alternative a simple linear interpolation was used to generate these weighting coefficients from 1 for the target of *Routine* use and 0 for *No Evidence* of use. For the example in Table 4, this gives a *School LOPA Score* for the *Reality* attribute of $6 + 0.5 \times 27 + 0.25 \times 29$ or approximately 26.8. The unit of measure is a percentage of teachers, and this was used as a measure to approximate the proportion of teachers facilitating the use of ICT by students in meaningful ways likely to lead to an improvement of learning outcomes.

This summary measure was developed to assist in identifying significant differences between schools and samples of schools as this longitudinal evaluation continued. When this was done for each of the sample schools, the spread of scores for each attribute for a dataset was graphically represented as shown in Figure 2. Comparisons between datasets were also possible. Figure 3 provides a graphical demonstration for one sample school over two time periods, where marked improvements were noted (nearly all statistically significant) for nearly all the LOPA attributes. The interviewing researcher for that school had already identified this school as making significant progress (with factors including a new ICT-aware principal, a better-supported coordinator, and improved central support).

In a similar manner a *Sample LOPA Score* was calculated by summing the weighted mean percentages at the bottom of Table 4 (i.e. *Sample LOPA Score* =

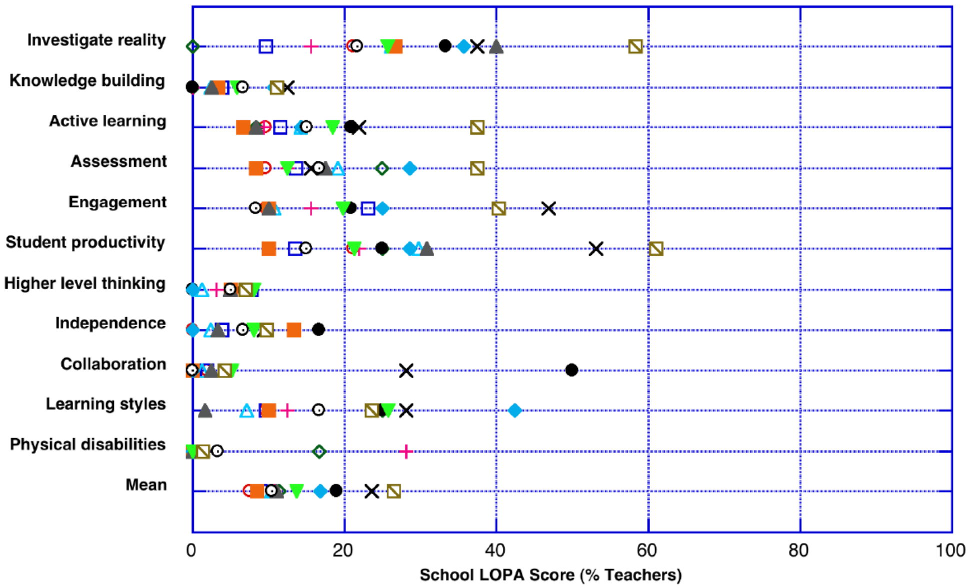

Figure 2. A graph showing the distribution of LOPA scores for a sample of schools (each symbol represents a school).

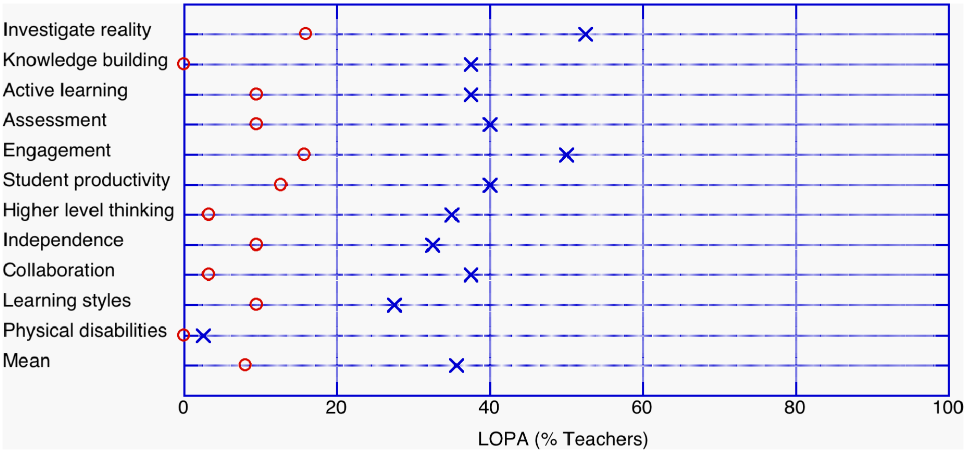

Figure 3. A graph showing the distribution of LOPA scores for an example school calculated for two datasets collected in different years (o: Baseline, ×: Comparison dataset).

$\bar{R} + 0.5 \times \bar{D} + 0.25 \times \bar{P}$) and a *School LOPA Score* was calculated for each school. For the example in Table 4, this would give a *Sample LOPA Score* of $2.0 + 0.5 \times 11.2 + 0.25 \times 24.5$ or approximately 13.7. These scores are the *Mean* scores shown in the graphs in Figures 2 and 3.

A *Teacher LOPA Score* was also calculated in a similar manner, with a unit value added for each attribute judged to be routine (R), 0.5 for each judged to be developing (D), and 0.25 for each judged to be possible (P). This gave a maximum possible score of 11 and a minimum of 0. That is, if a teacher were routinely facilitating computer use to enhance all of the LOPA attributes, then a score of 11 would result. The same was done using the teacher interview data where there was a possible comprehensive (C) judgment that was scored with 1.25. Thus, the maximum possible score was 13.75, although it was unrealistic to expect a score above 10; so 10 was set as the target (it is unlikely that a regular teacher would encounter a significant amount of student physical disabilities). Finally, for both sets of judgments an adjustment was calculated based on the estimated proportion of available teaching time the teacher facilitated student use of computers. The rationale for such an adjustment is the emerging understanding that up to a limit, the amount of time students use ICT has an impact on the learning effectiveness (e.g. Lei & Zhao, 2007). This gave rise to an *Adjusted LOPA Score* for each teacher. If the proportion of time ICT use was facilitated was estimated to be below 50%, a proportional multiplier from 1.0 for 50% use down to 0.0 for no use of ICT, was applied (e.g. 25% time using ICT would give a multiplier of 0.5). For the questionnaire, a response of *Daily* use was regarded as equivalent to 50% use. The results of these calculations for the sample of schools are summarized in Table 6 and displayed graphically in Figure 4.

Table 6. A summary of the mean, standard deviations and ranges of Teacher LOPA and Adjusted LOPA scores, based on questionnaire and interview data, for a sample of schools and an example school.

	Teacher LOPA Score			Adjusted LOPA Score		
	Questionnaire		Interview	Questionnaire		Interview
	Mean (SD)	Range	Mean of School Max.	Mean (SD)	Range	Mean of School Max.
Example School	2.7 (2.0)	0.3–9.3	10.0	2.2 (2.2)	0.0–9.3	10.0
All Schools	1.5 (1.3)	0.0–5.8	8.0	1.0 (1.3)	0.0–5.8	3.6

Note: The LOPA scale scores have a maximum of 4 and minimum of 1.

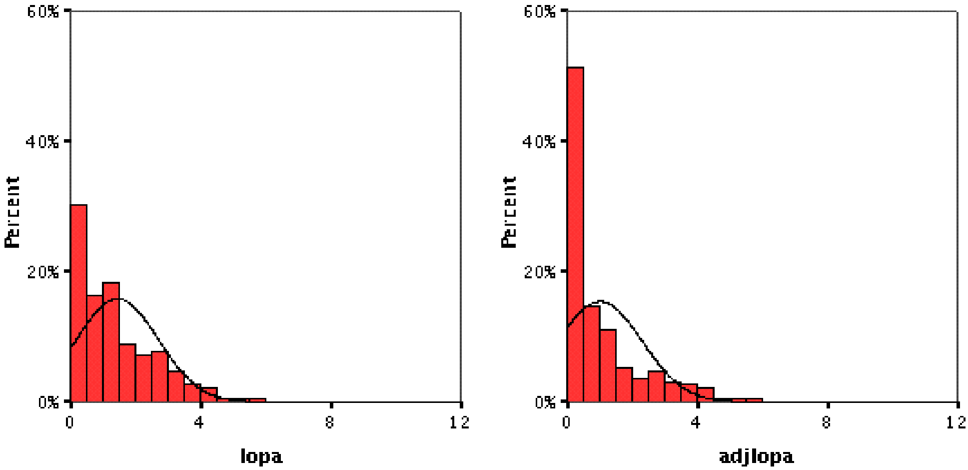

Figure 4. Histograms showing the distribution of Teacher LOPA scores and Adjusted LOPA scores from a dataset for a sample of schools.

4. Discussion of the Applications of the LOPA Measures

The range of LOPA measures and representations introduced in this paper were and are being used in the evaluation study to support conclusions and recommendations. The measures included a weighted LOPA score that could be calculated for individuals and also their schools. The mean scores are useful in a number of ways, including providing possible benchmarks for schools to use as they plan their development. It was noted that triangulation was an important way to confirm the quality of the LOPA ratings, and all researchers indicated that there was overwhelming concordance between the LOPA data and other related data collected at their schools, asserting the validity of the LOPA measures.

Consider the results presented in Table 6 for an example school and a sample of schools. The *Teacher LOPA Scores* (ranging from 1 to 10) were generally low for the whole sample of schools, with the mean and range from the questionnaire data (mean of 1.5 and highest value of 5.8) well below that for the exemplary school.

This is also evident in the graphs in Figure 3, where the *Teacher LOPA Scores* and *Adjusted LOPA Scores* for the entire sample are strongly skewed, implying that few teachers had begun to address these attributes with their facilitation of ICT usage. However, the mean *School LOPA Score* across the sample had increased from the baseline, up from 10% to 14%; and the 'leading edge' from the interviewed teachers for the example school was higher than the mean for the entire sample of schools. Further, there were statistically significant increases in mean scores for the components of the *LOPA* aligned with the *Investigate Reality* and *Learning Styles* attributes, with the components aligned with the *Engagement* and *Student Productivity* attributes all being around 20% of teachers. However, these increases were dominated by increases in means for four of the schools, with little change, and, in some cases, small decreases for the other schools. Such variations seemed reasonable and conformed to other variations observed by the evaluation study researchers, implying apparent reliability on the LOPA instrument. This will be further investigated as the study comes to an end.

Therefore, it was concluded that for this sample of schools the meaningful application of ICT to enhance learning was relatively low. However, there had been an average small increase from the baseline but that this varied considerably across the schools and teachers in those schools dependent on localized factors. While in most schools there were one or two outstanding examples of teachers facilitating the use of ICT to support learning, most teachers were not yet at the stage of critically integrating the use of ICT and therefore with little likelihood of a positive impact on student learning outcomes.

5. Conclusions

This paper has introduced the theoretical construct of the *Learning Environment Attributes* (LEA) dimension as part of a 'New ICT Supporting Schooling' (NISS) framework for evaluating and planning the use of ICT in schools to support student learning. The construct is demonstrably well supported by a review of the research literature over the past two decades. Within the context of a large longitudinal evaluation study, the construct was successfully operationalized as a measure called LOPA, leading to the development of a number of LOPA measures and methods of representing the construct. The results of these analyses appear to be to be both valid and reliable, and the dimension itself was found to be useful in profiling schools, comparing schools, and describing progress for schools and teachers. As such, the dimension as part of the framework has been used to inform school development and policy, and teacher practice in the evaluation schools, with positive feedback from teachers and school leaders.

It should be noted that the sample data used here has simply allowed the introduction of the LOPA measure, which is theorized as a valid and meaningful variable. The longitudinal data does not represent the direct intervention of any researchers but is part of an ongoing long-term evaluation, and so no data showing improvements, significant or otherwise, is relevant in this context. Instead the data has allowed the researchers in the evaluation team to fine-tune and clarify the constructs around which the evaluation is being conducted. This theory-building process has been detailed for one of the constructs to identify aspects of its nature and to enhance discussion with the schools, leadership and teachers involved in the important area of ICT-mediated learning.

In conclusion, this paper has begun a richly layered theory-based approach to describing and supporting ICT-as-learning in schools. The LEA dimension presented here within the NISS framework has provided a multifaceted approach to evaluating the use of ICT to improve student learning in schools while addressing the complexity of issues involved. Particularly important is the counter-intuitive observation that the construct, its measures and representations are complex — the complexity reflects the real world in which it is situated, that should not be oversimplified. Instead of aggregating and therefore ignoring variation as part of 'real world' data, the NISS model attempts to characterize them. However, it is flexible, largely rubric-based and sufficiently multifaceted to be used by individual teachers, groups, whole schools or educational authorities. Thus, it accommodates varying levels of investment available to devote to the process. Furthermore, its use can be implemented in a staged manner, with initial efforts providing helpful starting points for subsequent investigations. However, this theory building is at an early stage. While the LOPA measures have been trialed with at least 45 schools, over four years using data collected from over a thousand teachers and many thousands of students, further trialing is warranted, particularly in different jurisdictions and with other teams of researchers.

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