Uses and effects of The Le@rning Federation's learning objects

An experimental and observational study

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Participants in the study

The participation of principals, teachers, parents and students from the schools involved in the research is appreciated.

The Le@rning Federation's contact liaison officers, in supporting the research team in identifying schools for the site visits and in accessing data, made a significant contribution to the study.

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Executive summary

This report draws and builds on earlier reports describing evaluations of the efficacy of the learning objects component of The Le@rning Federation initiative. It describes an extended national field experiment and a series of site visits.

The experiment reported builds on the findings of the previous field experiment in extending the experiment to Science as well as Mathematics; and in expanding the design of the experiment to include two different contexts for the use of learning objects – one with no specified guidelines for delivery systems or structures (as in the previous experiment) and the other using the learning objects within a learning management system (Moodle).

The report begins with describing the background to The Le@rning Federation initiative and summarising the scope of its work to date; and presenting a review of the most recent research and theory related to the perceived and actual efficacy of classroom use of information and communication technologies (ICT). This is followed by a description of the design of the new field experiment, and analyses and findings arising from its conduct. A separate but related research exercise is then summarised: observations made during site visits to 10 schools to document variations in the uses of learning objects in classrooms. More extensive and site-specific reports form the Appendix.

In summary, the results of the field experiment are that:

- There were predictably significant, strong, and consistent effects for differences in entry levels (pre-test scores) on the post-test results, with no indication or trend for any diminution of their advantage as a result of using either learning objects or Moodle.
- There were significant positive effects for the use of learning objects in Science. These effects were clear and relatively consistent.
- There was no advantage for the group using learning objects within a Moodle learning management system in Science over the group using the learning objects only or the control group, whether overall or for any component of the Science test.
- With one exception there were no reliable significant effects for either learning object use or Moodle use in Mathematics.

- The exception was that there was a statistically reliable advantage for the Moodle group on items relating to Linear functions. No effects were evident on post-tests for Pronumerals, Number patterns, and Non-linear functions.

Some explanations are offered and supported by direct quotes from the teachers concerning the relative difficulties of topic areas and the differential benefits of using the learning objects and the Moodle learning management system.

From the site visits, the following conclusions were drawn:

- Secondary schools were less likely to have adopted a whole-school approach to implementation of TLF content than were primary schools.
- A strategic approach to building teachers' capacity to integrate ICT, and particularly learning objects, into their learning and teaching programs does not typically take the form of cohesive professional development in at the jurisdiction level.
- There is little evidence of schools' providing students with broadly based and sophisticated access to curriculum-driven access to ICT or learning objects.
- The number of interactive whiteboards in classrooms, particularly in primary schools is increasing rapidly. However, the affordances of this hardware are often little understood by teachers beyond rudimentary operation.
- Designated ICT / e-learning positions are present in most schools, but the responsibilities and efficacy of these people vary from school to school.
- The importance of teachers working together to support one another in acquiring greater confidence in classroom use of ICT was a noteworthy feature of interviews with school leaders.
- A plan that embodies the school's vision for ICT integration into learning and teaching was in evidence in those schools where progress was more advanced.
- Where schools have made their supporting communities aware of their aims with regard to the integration of ICT into learning and teaching programs, there is enthusiasm on the part of the parent population, particularly in low socioeconomic communities.
- The versatility, flexible nature and multimodal affordances of the content of learning objects were common themes.
- Saving-state for learning objects was requested, particularly for literacy and Studies of Australia content.

- Some teachers and school leaders valued the learning objects for the new knowledge they gained from them.
- The provision of adequate hardware in schools in still a significant issue, with high levels of variability in evidence.

Among the implications drawn from the findings of the experiment and the site visits were that more detailed observations of actual classroom usage now need to accompany these more formal evaluations and that intervention research is needed on the matter of building take-up, familiarity and confidence among teachers in their use of digital and online materials.

Introduction

This report draws and builds on a sequence of earlier reports that evaluated the efficacy, perceived and actual, of the learning objects produced as one component of The Le@rning Federation initiative. The findings of those earlier reports (see Freebody 2005, 2006; Freebody, Muspratt & McRae 2007 and Freebody, Muspratt & McRae in press) were based on data from surveys, site visits, interviews and, in the case of the most recent report (Freebody, Muspratt & McRae 2007), a field experiment involving groups of Mathematics students in years 5 and 7. In that experiment students who used learning objects were found to obtain significant advantages on standardised measures of mathematical knowledge relating to key topics in the syllabuses at both year levels, compared with a group who did not use learning objects.

This report builds on the findings of the previous field experiment in extending the experiment to Science as well as Mathematics; and in expanding the design of the experiment to include two different contexts for the use of learning objects – one with no specified guidelines for delivery systems or structures (as in the previous experiment) and the other using the learning objects within a learning management system (Moodle).

This report begins with describing the background to The Le@rning Federation initiative and summarising the scope of its work to date; and presenting a review of the most recent research and theory related to the perceived and actual efficacy of classroom use of information and communication technologies (ICT). This is followed by a description of the design of the new field experiment, and analyses and findings arising from its conduct. A separate but related research exercise is then summarised: observations made during site visits to 10 schools to document variations in the uses of learning objects in classrooms. Findings from the new field experiment and findings from the site visits form the basis of the conclusions drawn in the report.

Background: The Le@rning Federation initiative

The Le@rning Federation (henceforth TLF) was established in 2001 by the Australian Ministerial Council on Education, Employment, Training and Youth Affairs. In 2007, the targets for Phase 3 of the initiative are:

- A further 4 000 items of high quality, globally recognised, online curriculum content for all Australian and New Zealand schools
- A workable framework, standards and structure for the sharing of online curriculum content between jurisdictions within Australia and New Zealand and with other countries
- An interoperable framework to enable sharing and peer-reviewing of teacher-initiated online resources
- Brokered arrangements with vendors to support distribution and use of online curriculum content in schools
- Consolidated schooling-sector support for a local education digital content industry.

Learning objects component

TLF has defined learning objects as files or modules of learning material that:

- involve teachers and learners in interactive learning activities
- may include texts, and/or graphic, audio or animated materials
- are usable in many different educational settings for multiple purposes
- are usable in educational settings as elements within larger units of work that may comprise other digital and non-digital materials
- are accessible from digital repositories as referenced, located, and accessed by metadata descriptors.

TLF does not provide any specifications, guidelines, or preferences for the educational use of its learning objects. The approach taken by TLF is based on the following principles (following Atkins & Jones 2004, pp 2–7):

- The learning object component of the initiative will have a strong learner focus, addressing the needs of all students in an inclusive way.

- The content of the learning objects will have integrity with regard to the particular knowledge domain, ensuring domain-related accuracy, authenticity and purposefulness.
- The materials will be readily usable with accessible interaction design features and accessible and meaningful sequences.
- The learning objects will be accessible to categories of students generally regarded as educationally disadvantaged.

The learning framework that guides the development of TLF’s learning objects is based on:

- problem-based learning;
- inquiry-based and investigative learning;
- authentic, situated contexts for learning; and
- constructive and tailored feedback.

Elaborations and illustrations of the above principles and learning framework are provided on TLF’s website. At the time of writing (November 2007) TLF had developed more than 3000 learning objects for use in Australian and New Zealand schools. Prior to release, each new learning object had undergone field trials in classrooms and revision in the light of feedback from teachers and researchers.

A study of students’ perceptions of the learning objects they use (Muspratt & Freebody, 2007) found that students prefer learning objects that allow them to interact with the learning object, that allow them control over their progress through the learning object, that do not look like conventional classroom activities and that, generally, are game-like. However, it is argued in that report that it was not solely the responsibility of developers to meet students' expectations for interaction and engagement; that teachers, too, have a role to play. It is argued that teachers need to incorporate learning objects into classroom practices in ways that disperse the spaces for interaction and engagement into the surrounding environment. In this way, the participation structures of that surrounding environment itself can be reshaped by an understanding of the potential affordances of ICT-based learning.

Digital resources component

A second component of the TLF initiative is development of a bank of digital resources that is accessible, through searchable repositories, to all schools in Australia and New

Zealand. The use of these digital resources within curriculum programs, schemes of work or individual lesson activities is quite different from the use of learning objects. TLF’s digital resources rely on the teacher (or the student) contextualising the material by establishing its purpose and meaning within the conduct of the lesson or unit of work. Compared with the learning object component of the TLF initiative, the digital resources component has received less attention and, in general, less publicity in schools and school systems. A small-scale study of teachers’ use of TLF’s digital resources, undertaken in late 2006 (see Freebody & Muspratt 2007), indicated that take-up and usage patterns of the digital resources has been patchy. The findings of the study, which given the size of the study should be taken as only indicative, were:

- On the whole, teachers found the digital resources to be educationally useful and valuable, accessible and easy to use, and helpful for motivating students.
- The descriptions and guidelines that accompany the digital resources were seen as a crucial aspect of their usefulness and were regarded as clear, helpful and informative.
- Teachers suggested that their use of the digital resources would benefit from the search engine being refined so as to allow more precise location of relevant materials; and from an expansion of the very limited range of materials in some areas where digital resources would have high curricular value.

Review of recent related research

In the context of rapidly developing digital forms of communication and information storage, it has become urgent to consider the relationship between how students learn and are taught in schools and how people learn in non-institutionalised educational settings. Below is a brief discussion of the most recent research and theory related to the perceived and actual efficacy of classroom use of information and communication technologies (ICT). For more extensive coverage, see British Educational Communicational and Technology Agency (BECTA) 2005; Cox, Abbott, Webb, Blakeley, Beauchamp & Rhodes 2003; Mitchell & Savill-Smith 2004; Owen, Calnin & Lambert 2002; and Parr 2006.

As noted in our previous reports, an air of disappointment pervades many of the research reports. Effort and expenditure is not seen as paying dividends in observed levels of dissemination, creative use and efficacy of ICT use in schools (see, for example, Ofsted 2004; Russell et al 2005; Vrasidas & Glass 2005). This disappointment is captured in Nichol and Watson's (2003) conclusion, following extensive examination of the educational uses of ICT in the United Kingdom:

> ... the role and nature of ICT in schools is problematic, with minimal involvement of ICT across the curriculum in the everyday teaching of pupils … Rarely in the history of education has so much been spent by so many for so long, with so little to show for the blood, sweat and tears expended. (pp 132–3)

Similarly, Jamieson-Proctor and others (2006) concluded their surveys of ICT usage in classrooms in Queensland, Australia, in this way:

> … there is evidence of significant resistance to using ICT to align curriculum with new times and new technologies … current initiatives with ICT are having uneven and less than the desired results system wide. (p 511)

However, while it is clear that researchers are generally not sanguine about the recent introduction of ICT-based materials in classrooms, the urgent need for more effective ICT education is evident from the growing body of theory and opinion devoted to enumerating the changes that are needed for new forms of economic and civil life (see, for example, CEO Forum 2000). Pittard and Bannister (2005), in reporting rates of uptake of ICT across a range of curriculum domains in the United Kingdom, show that rates of usage have not increased consistently across curriculum domains. Increased usage in Mathematics and Science has not been matched in English and other Arts/Humanities subjects.

As we have summarised elsewhere (Freebody, Muspratt & McRae in press), Pittard and Bannister warn that while some promising outcomes may develop only after some considerable time has passed, some immediate gains may disappear over time.

Pittard and Banister account for the minor gains observed in some studies in terms of the following three features of ICT that meaningfully incorporate digital technology into teaching and learning:

- Enhanced presentational capabilities for lesson and assignment work (see also Abidin & Hartley 1998; Dori & Barak 2001)
- Enhanced range of resources for supporting students' and teachers' research
- Immediacy of feedback for self-evaluation (see also Marzano, Gaddy & Dean 2000).

Many of the findings of our earlier reports, especially from surveys of teachers and students, are compatible with other research on the perceived efficacy of ICT in formal educational settings. Passey and others (2003), for example, documented the views of principals, teachers, pupils, parents, social workers, teacher aides and students on the educational uses of ICT. They used case study, interview and survey data to present three key findings:

1 ICT use by pupils and teachers led to improvement in students' motivation through developing their confidence in research skills and in managing complex tasks (see, for example, Walton & Archer 2004).

2 Improvements in students' motivation were frequently associated with ICT being used to support engagement, research, and the writing, editing and presentation of work.

3 Evidence of students' motivation being heightened through use of ICT, included their citing class time as more interesting, their completion of homework, and increased confidence and independence in their learning.

The somewhat ambiguous nature of the overall findings is found also in the research related specifically to use of learning objects in educational settings. For instance, McCormick and Li (2006) evaluated a project conducted by the European Union involving 500 schools across six countries. They found teachers to be generally receptive to learning objects, and in some cases enthusiastic about their potential. A recurring recommendation, however, was:

> ... having some element of pedagogy within the learning object is not supported. The fact that teachers use learning objects in a variety of

> contrasting ways means that they are likely to be able to superimpose their own pedagogy on any learning object, almost whatever the 'designed' pedagogy. (p 229)

While pedagogical conservatism is a theme in much of the research on the use of online digital materials, aiming to produce technologies and materials that merely support teacher-centred, transmissionist, factual instruction will fail to capitalise on what digital materials can offer educational practice (Jonassen 2004; Wiley et al 2004).

The findings of three studies conducted by Nurmi and Jaakkola (2006) into the effectiveness of learning objects in a range of instructional settings are generally similar to the findings of our research reported here. Using learning objects from the curriculum area of Science, Nurmi and Jaakkola make the case that, in order to be effective, learning objects require explicitly tailored learning environments and teaching approaches. They show that the use of learning objects of itself does not necessarily support effective learning; and that it is the educational setting of that use that determines the value of learning objects for teachers and learners. Their conclusions foreshadow some of the issues that arise later in this report:

> The results of the studies show that learning objects offer new possibilities for teaching and the potential to improve student learning if used in a meaningful way. However, using learning objects to replicate traditional teaching activities, stressing knowledge presentation, transmission, exercising and reproduction, does not seem to be fruitful; traditional learning materials and working methods may be more suitable for this. As studies I and II indicated, traditional classroom teaching is at least as effective as one employing learning objects in implementing more fact-oriented expository teaching–learning activities. According to the findings of study III it appears that learning objects are valuable in supporting more student-centred learning activities, emphasizing discovery learning, knowledge construction and collaboration … Only through sophisticated implementation can learning objects improve teaching and learning practices. (p 246)

We hypothesised, then, that the following categories of variables would be relevant to the anticipated range of findings over years 5 and 7, and in relation to both Science and Mathematics:

1. Teachers' familiarity with the selected content
2. Teachers' approaches to the use of learning objects and/or a learning management system, including their inclination to control scope and sequence
3. Teachers' perceptions of the pedagogical opportunities and limitations presented by selected learning objects
4. The relative significance to the goals of the unit of work with regard to 'emphasizing discovery learning, knowledge construction and collaboration'.

These hypotheses are revisited in the Findings section and also in the overall Conclusions section of this report.

The field experiment

Design of the study

The study was designed to test the effects of using learning objects on students' learning outcomes in lower-secondary Mathematics classrooms and upper-primary Science classrooms. In the lower-secondary Mathematics classrooms an algebra topic was focused on number patterns, pronumerals and linear and non-linear functions. The upper-primary Science classes studied lunar cycles. The participation of classes in the study was voluntary.

In each curriculum area, classrooms were assigned to one of three conditions:

1 Control group – In these 'business-as-usual' classrooms, teachers used whatever digital and non-digital materials they would normally use for the topic, as long as they did **not** use learning objects.

2 Learning object group – In these classrooms, teachers used specified learning objects in their treatment of the topic.

3 Moodle group – In these classrooms, teachers used specified learning objects **and also** a set of additional resource material that was embedded within the Moodle learning management system. As students worked through the learning objects, Moodle directed them to complete quizzes and to undertake additional activities on the basis of their quiz responses.

The additional resources provided within Moodle, which included both digital web-based material and non-digital material, were made accessible to teachers in the other two groups, who could use any or as little of the material as they saw fit. All three groups were encouraged to move beyond the materials provided by TLF.

It should be pointed out that classrooms in each of the three conditions were not necessarily equivalent in either resource provision or in the treatment accorded them by the research team. Classrooms in the Moodle condition were necessarily selected from schools that had adequate IT resources (including high-speed Internet access) for running Moodle. As well, after assignment to their condition status, teachers assigned to the control condition took part in a 30-minute teleconference during which expectations of their participation were outlined; while teachers assigned to the learning object condition and the Moodle condition took part in a two-day program (held in Adelaide, Perth, Hobart and Wellington) to familiarise themselves with the learning objects and the Moodle system. During this two-day program, teachers could begin developing their programs of work, and could seek guidance from TLF personnel. As well, classrooms assigned to the learning object condition and Moodle condition were visited by TLF personnel at least once and generally twice during the course of the study, whereas the control group received no visits.

The schools

Table 1 (left column) and Figure 1 show the geographic spread of the schools taking part of the study across New Zealand and the Australian states (that is, excluding the Northern Territory and Australian Capital Territory). Table 1 shows that schools were evenly spread across urban and rural locations and that the schools belonged mostly to state jurisdictions, although some Catholic and Independent schools were included. As some schools had more than one classroom participating in the study, the number of classes participating in the study exceeds the number of schools in the study.

Table 1: Number of schools by state, jurisdiction, and location

State			**Jurisdiction**			**Location**		
	Sci	Maths		Sci	Maths		Sci	Maths
Qld	1	3	State	21	22	Urban	14	14
NSW	3	1	Catholic	2	1	Rural	13	14
Vic	4	3	Independent	4	5			
Tas	4	6						
SA	2	5						
WA	13	4						
NZ		6						

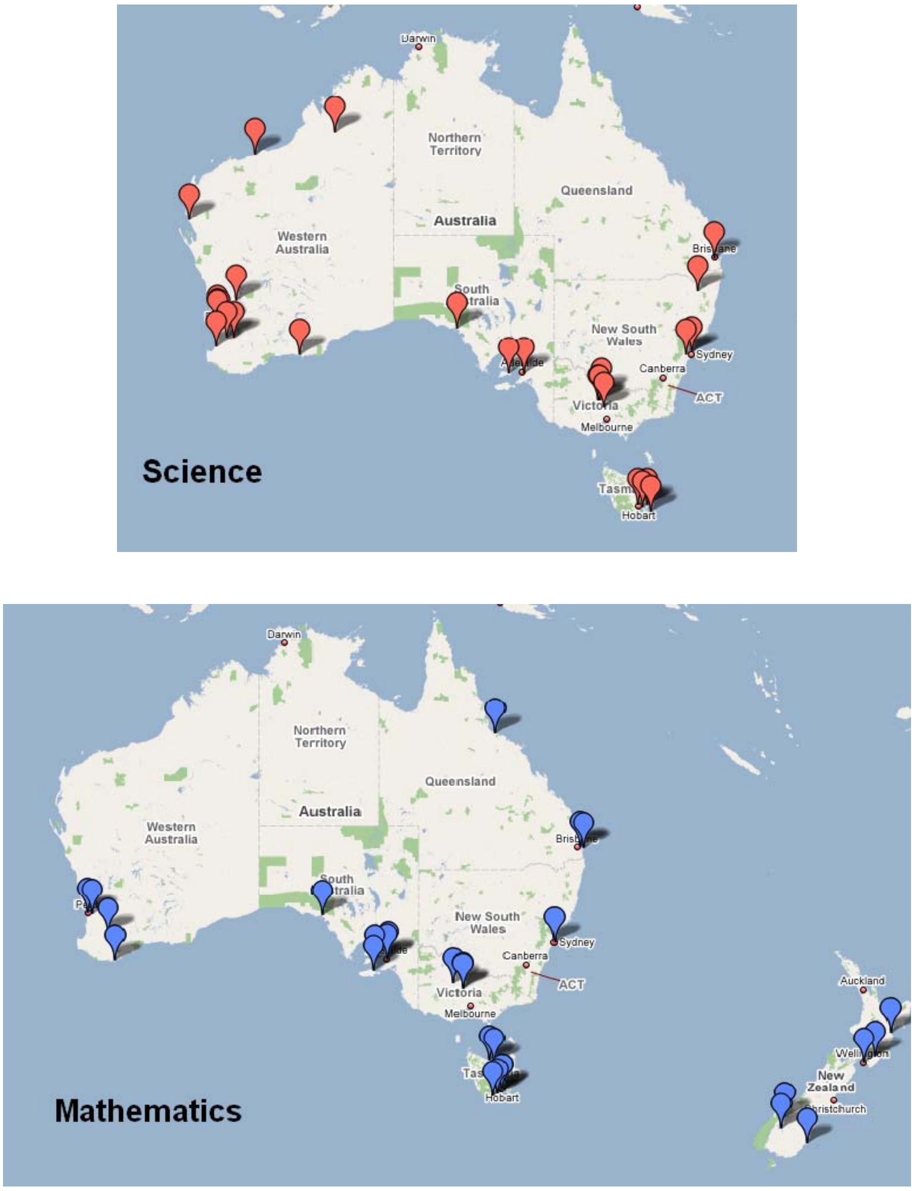

Figure 1: Location of schools

The teachers

A total of 31 primary teachers (Science) and 33 secondary teachers (Mathematics) took part in the study. The number of male teachers and female teachers in the Mathematics component (all secondary schools) of the study was roughly the same (18 female; 15 male), but in the Science component (all primary schools) there were about three times more female teachers than male teachers: (23 female; 8 male).

Figure 2 shows the distribution of teachers according to the extent of their teaching experience. The left side of the graph shows that while some in the sample were in their first year of teaching, a high proportion of both primary and secondary teachers were highly experienced. The right side of the graph shows that most teachers in the sample had spent less than five years in their *current* schools.

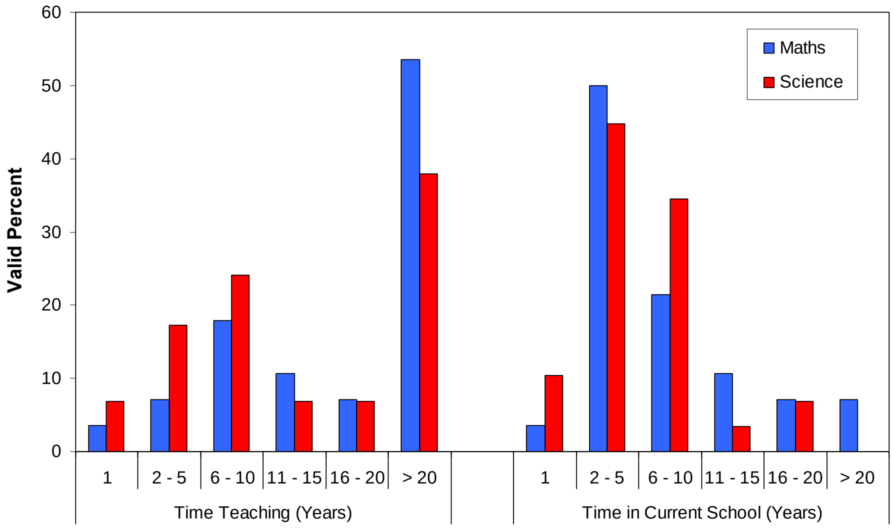

Figure 2: Number of years of teaching experience (total) and number at current school
Note: This data is based on teachers' completion of a short survey. However, the survey form was not returned by 7 teachers, all of whom came from the control group (five Mathemtics teachers and two Science teachers).

Figure 3 shows teachers' responses to a set of questions concerning their familiarity with ICT in general, online curriculum resources and learning objects; and concerning the professional development they had received in relation to the same three teaching resources. Figure 3 shows that, on average, teachers claim to be familiar with all three areas and to have received professional development in all three areas, although there is a decline in familiarity and the extent to which professional development has been received for online curriculum resources in general and learning objects in particular.

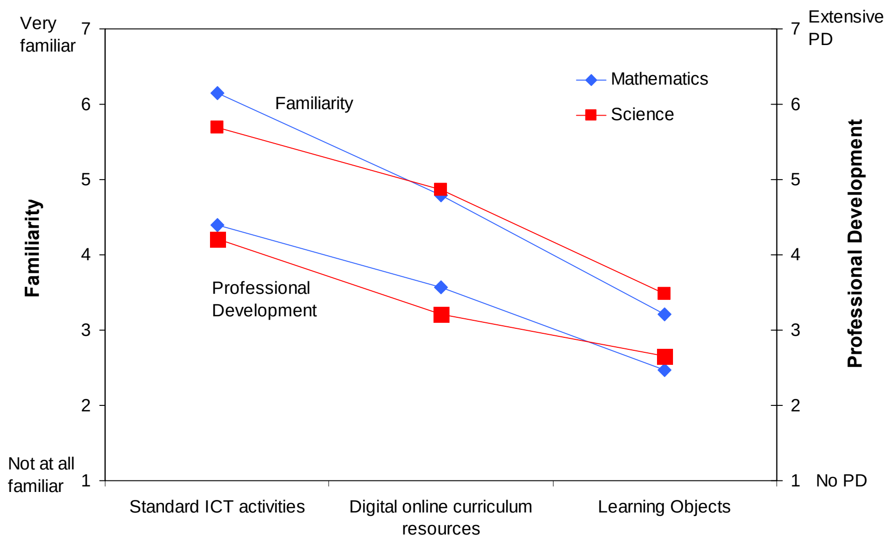

Figure 3: Familiarity with ICT resources and professional development in ICT

The learning objects

Science

Figure 4 shows screen shots of the four learning objects used in the Science classrooms. Below is a short description of the learning objectives for each:

- 'Moon phases': Students estimate the Moon's orbit position from its visible shape; determine the visible shape of the Moon from its orbit position and relate this to commonly used phase names; and use a model to calculate the length of time for the Moon to orbit Earth.
- 'Man in the Moon': Students realise that there is not a 'dark' side of the Moon; recognise that the Moon rotates once during its orbit of Earth; and recognise that only one side of the Moon can be seen from Earth.
- 'Moonrise': Students predict the Moon phase from a given time of moonrise or moonset; and predict the time of moonrise and moonset for a given Moon phase.
- 'Earth glow': Students identify that a Moon 'day' and 'night' each occur for half a lunar orbital period; identify the Moon phase given a lunar view of Earth; and use a model to investigate how the Moon is regularly lit by reflected earthlight.

Mathematics

Figure 5 shows screen shots of the five learning objects used in the Mathematics classrooms. Below is a short description of the learning objectives for each:

- 'Bridge builder': Students solve problems by selecting and applying efficient multiplicative strategies; use tables and graphs to create formulas and explore relationships between tabular, graphical and algebraic forms; and identify and extend spatial and number patterns.

- ‘Circus tower’: Students observe how spatial patterns may be represented in tables, graphs, text and mathematical symbols; and identify and extend spatial and number patterns.
- ‘Mobile phone plan’: Students calculate costs from cost–time graphs; construct and interpret line graphs; interpret and compare graphs showing different relationships between specified variables; enter data into tables and interpret line graphs; and calculate and interpret graphs showing different relationships between specified variables.
- ‘Filling glasses’: Students match variously shaped vessels with the line graphs representing their filling rates; create and interpret graphs that represent the relationship between quantities and show the rates of change; and match line graphs representing filling rates with different composite-shaped glasses.
- ‘Squirt’: Students express proportional relationships using mathematical notation; use the transitive property of equality to find the relationship between two variables and three variables; and use proportions to represent quantitative relationships.

Figure 4: Screen shots from the four Science learning objects

Figure 5: Screen shots from five Mathematics learning objects
(Clockwise from top-left: Bridge Builder, Circus Towers, Squirt, Filling Glasses, Mobile Phone Plan)

Analytic strategy

The study has a quasi-experimental design based on a pre-test and a post-test. The quasi-experimental nature of the design of the current study needs to be taken into account in assessing its findings. In a true experimental design, students would be randomly assigned to the control group and any treatment groups, and the outcomes assessed on at least two occasions (prior to the initiation of the treatment, and at the conclusion of the treatment). Considerable attention has been given to methods of analysis for such true experimental designs (see Rausch, Maxwell & Kelly 2003 for a recent review). Methods include:

(a) ANOVA testing for group differences at the post-test only (because random assignment should result in equivalent pre-test means for the control and treatment groups)

(b) ANOVA testing for group differences in change scores (that is, the difference between post-test and pre-test scores)

(c) ANCOVA or regression analysis testing for group differences at the post-test covarying the pre-test

(d) ANCOVA or regression analysis testing for group differences in change scores covarying the pre-test.

Generally, method (c) is advanced as having the greatest power.

The design of the current study is quasi-experimental because class groups, not individual students, were assigned to its control and treatment groups. As students within any particular classroom are likely to be more alike with respect to outcomes (as well as to other, mostly unmeasured, characteristics) relative to students in other classrooms, an assumption of conventional analytic procedures (independence of observations) is not applicable when students are clustered within classrooms. As students are not educated individually, it is advisable to employ techniques that relax the assumption of independence of observations, that acknowledge that the class group to which students belong can have an effect on their attainments; and that these effects can change from classroom to classroom (Nash, Kupper & Fraser 2004).

Inferences derived from analyses that ignore these within-classroom effects tend to be biased because the standard errors used to calculate test statistics tend to be too small, causing the test statistics to be too large, which results in an inflated Type I error rate that increases the chance of incorrectly rejecting the null hypothesis.

Multilevel modelling is an analytic technique that takes account of within-classroom effects by acknowledging that the research setting involves levels of clustering (such as students within classrooms). As multilevel modelling allows variables to be defined at any level within the structure, for the current design, students' pre-test and post-test scores are student-level variables, and the experimental groups (control, learning object, Moodle) treated as classroom-level variables (because intact classrooms, not students, were assigned to each group). Multilevel analyses operate at both levels simultaneously, and return results that are relevant at the student level and at the classroom level.

For example, consider the following basic multilevel model:

$$\text{PostTest}_{ij} = \beta_0 + u_j + e_{ij}$$

where PostTest_{ij} is the post-test score for the i^{th} student in the j^{th} classroom.

According to the model, each score can be considered to be composed of three components: an overall mean (β_0); each classroom's deviation from the overall mean (u_j); and each student's deviation (e_{ij}) from their classroom's mean.

This model is sometimes referred to as the variance components model because it returns variance measures for the within-classroom component and the between-classroom component. The classrooms' deviations from the overall mean are assumed to have a normal distribution with a mean of zero and a variance of σ_u^2; and similarly, students' deviations from their classroom's mean are assumed to have a normal distribution with mean of zero and a variance of σ_e^2. The analysis returns, in addition to β_0 (the overall mean), σ_u^2 – the variance at the classroom level, and σ^2_e – the variance at the individual student level. The variance components model does not attempt to predict any of the classroom-level or student-level variation; rather it partitions the total variance into the two components. Once the variance has been partitioned, the variance partition coefficient (VPC), a measure of the proportion of total variance that can be attributed to the classroom level, can be calculated:

$$\text{VPC} = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_e^2}$$

The variance components model is extended by adding terms that represent the effect of the pre-test and the effect of group membership on the post-test scores:

$$\begin{aligned} PostTest_{ij} = {} & \beta_{0j} + \beta_{1j}\, PreTest_{ij} + \beta_2\, LO_j + \beta_3\, Moodle_j + \\ & \beta_4\, LO \cdot PreTest_{ij} + \beta_5\, Moodle \cdot PreTest_{ij} + e_{ij} \end{aligned}$$

where $\beta_{0j} = \beta_0 + u_{0j}$, and $\beta_{01j} = \beta_1 + u_{1j}$

The first line of the model is directly comparable to a standard regression equation. It shows a linear relationship between pre-test and the post-test scores (β_0 and β_1 represent the intercept and slope respectively) for classrooms assigned to the control group. The effects of being a member of a learning object classroom or a Moodle classroom are given by β_2 or β_3 respectively ($\beta_0 + \beta_2$ is the mean intercept for learning object classrooms, and $\beta_0 + \beta_3$ is the mean intercept for Moodle classrooms). The effects of the group-by-pre-test interaction are given by β_4 and β_5 ($\beta_1 + \beta_4$ is the mean slope for learning object classrooms, and $\beta_1 + \beta_5$ is the mean slope for Moodle classrooms). The second and third lines of the model show that the intercepts and slopes (β_0 and β_1) are allowed to vary across the classrooms.

Thus the model is similar to method (c) described above, the preferred method for the analysis of true experimental designs. It allows testing for statistically significant group differences at the post-test covarying for the pre-test. The model differs from method (c), however, in that it allows classroom membership to influence a student's post-test score, and allows those influences to vary from classroom to classroom (Klar & Darlington 2004).

However, in the context of the current study, testing for statistical significance requires careful consideration. With a large number of level 2 units (classroom groups), maximum likelihood estimation procedures can be used. Maximum likelihood, among its estimates, returns a deviance statistic – a measure of how well a model fits the data. Deviance statistics for nested models can be compared to determine which model has better fit for the data (the difference between two deviances follows a χ^2 distribution with degrees of freedom equal to the difference in degrees of freedom for the two models).

One method for determining an optimal model is to begin with the variance components model; then add terms in sets that progressively account for more and more of the student-level and classroom-level variance (pre-test, groups, groups-by-pre-test interaction); and then, at each step, test the change in deviance for statistical significance. If a more complex model has better fit for the data, the more complex model is retained. If, on the other hand, the two models fit the data equally well, then in the interests of parsimony the simpler model is preferred. This method is generally taken to be preferable (Goldstein 2003) to a procedure in which a model is hypothesised and then each term in the model tested for statistical significance separately in the conventional way of dividing the estimate by its standard error.

Whereas maximum likelihood estimation is a procedure suited to large samples, by the standards of multilevel modelling, the number of classrooms in the current sample is small. An alternative to maximum likelihood estimation is to embed the analysis within a Bayesian framework and to use Markov chain Monte Carlo procedures (MCMC). However, MCMC procedures do not generate hypothesis tests. MCMC procedures draw chains of values from a distribution. Typically, tens of thousands of chains are drawn, thus producing tens of thousands of deviance statistics. Therefore, two models cannot be compared by testing for a significant difference in model fit. An alternative is to combine the average deviance with model complexity (the effective number of parameters) to obtain a Bayesian deviance information criterion (DIC). DIC corresponds to the Akaike information criterion (AIC) in likelihood-based methods: for both AIC and DIC, a smaller value indicates a better fitting model. This is not direct hypothesis testing and there are also difficulties with the procedure. MCMC methods are complex mathematical procedures, and even with high-speed computers, it can take hours or days to complete an analysis. Running four or five models for the purpose of comparing their Bayesian DICs can be a time-consuming process. Also, the use of the procedure for model selection has been criticised in the literature (see, for instance, the discussion of the paper in which Spiegelhalter, Best, Carlin & van der Linde (2002) announced the procedure). In the next section (Results) we report the Bayesian DICs, but we do not depend upon them for model selection.

For each estimate, the mode of the distribution of the tens of thousands of chains is treated as a point estimate and the central 95% of values is treated as if it were a 95% confidence interval. Like confidence intervals, central intervals emphasise the uncertainty surrounding an estimate, and give the significance of the estimate (if the 95% central interval spans zero, the estimate is taken to be, in effect, zero). Thus, a model could be hypothesised, and each term tested separately for ‘significance’. The procedure in not preferred, as noted earlier, and a difficulty with this approach is that MCMC estimates of variance can never be negative, and so the 95% central interval will always be positive, and thus the MCMC equivalent of testing for the statistical significance of a variance cannot be done (or at least small variances cannot be tested; and some of the variances in the data for the current study are small).

For the analysis of the data at hand, we adopted a compromise. First, maximum likelihood estimation was used to determine the optimal model and to test for the statistical significance of variances. Second, MCMC estimation was applied to the optimal model to obtain point estimates and their 95% central intervals. All models were analysed using *MLwiN* (Rasbash, Steele, Browne & Prosser 2005), which has implemented MCMC procedures (Browne 2005).

MCMC is a Bayesian procedure and thus requires the specification of a prior distribution (a distribution which, when combined with the data, generates a posterior distribution from which the chains are drawn). But, as is usual, we had no prior information about the distribution of the estimates. Thus the priors were set to *MLwiN*'s default uninformative priors (which assume a uniform distribution whereby all values are equally likely, and therefore they have little influence on the posterior distribution). MCMC needs to converge on a target distribution, and so the chains drawn during convergence (the burn-in period) are discarded. For the data at hand, a burn-in period of 10,000 iterations was sufficient. Diagnostics obtained from initial runs suggested that a large number of chains was required because, for some estimates, the chains were highly correlated. A total of 1,000,000 chains was monitored, with a thinning factor of 20 to reduce the correlations (that is, 50,000 chains were stored).

In summary, multilevel regression was used to analyse the data: 'regression' because it allows the effect of one variable to be obtained while controlling for the influence of other variables in the analysis; and 'multilevel' because it takes account of the within-classroom effects. Because the number of classrooms in the sample was somewhat smaller than recommended for maximum likelihood procedures, MCMC procedures were used.

Results

Descriptive statistics

Science

Table 2, which gives descriptive statistics for the three groups (control, learning object, and Moodle) and Figure 6, which provides a graphic display of the pre-test and post-test means, show that the pre-test means for each of the three groups are similar, but that the post-test mean for the learning object group is above the post-test means for the other two groups. It appears that only those students in the learning object group make substantial gains over and above their pre-test scores. A similar conclusion can be drawn from an examination of Figure 7, a plot of pre-test and post-test means for each classroom in the sample, which shows that the pre-test means across the 31 classrooms, irrespective of the groups to which classrooms were assigned, are roughly equivalent; that the post-test means for the learning object group are all above their corresponding pre-test means; and that there is a mixed pattern of pre-test and post-test means for the control group and the Moodle group.

Table 2: Group means and standard deviations for the Science pre-test and post-test

Group		**Number**		**Mean**	**Std Deviation**
		Students	Classrooms		
Control	Pre-test Post-test	189	10	7.3 7.9	2.8 3.3
Learning object	Pre-test Post-test	199	9	7.1 11.1	2.5 3.7
Moodle	Pre-test Post-test	344	12	7.7 8.9	2.7 3.5
Total	**Pre-test** **Post-test**	**732**	**31**	**7.4** **9.2**	**2.6** **3.7**

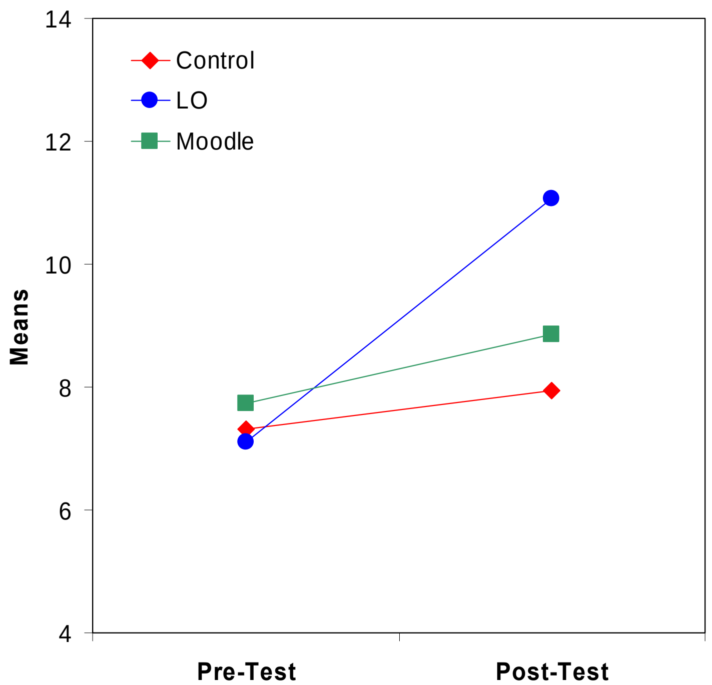

Figure 6: Group means for the Science pre-test and post-test

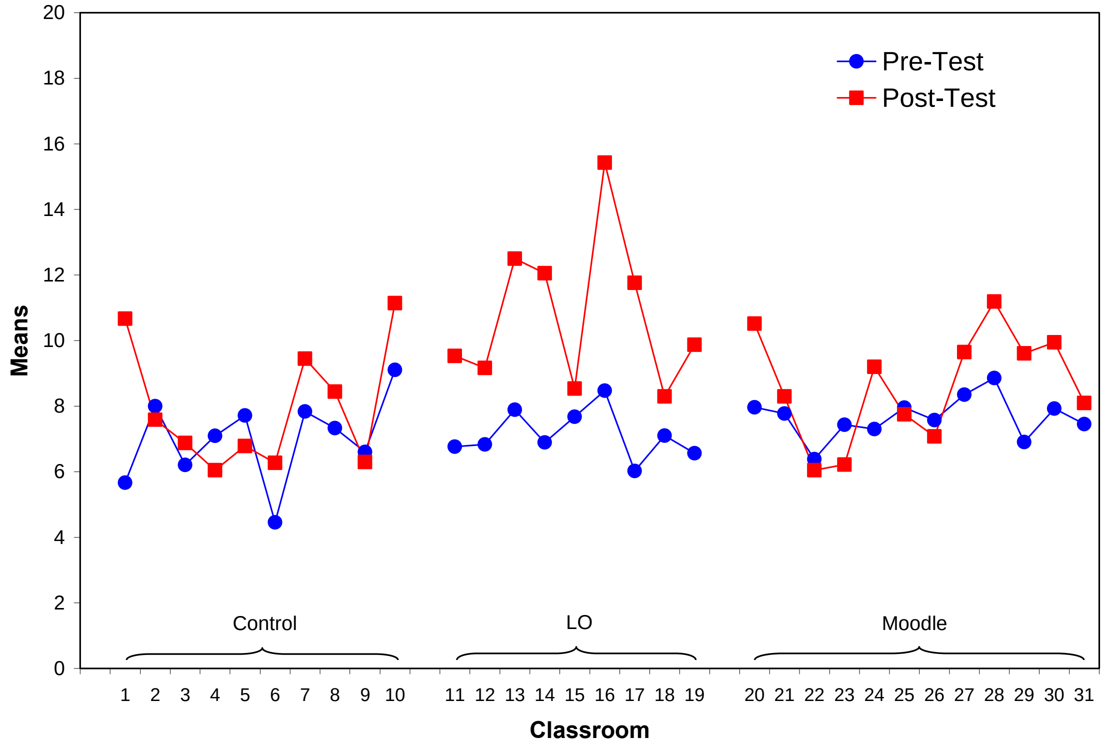

Figure 7: Science pre-test and post-test means for each classroom

Mathematics

A somewhat different pattern obtains for the Mathematics classrooms. Table 3 (descriptive statistics) and Figure 8 (a plot of pre-test and post-test means for the three groups) show that although each of the three groups' post-test means are higher than their pre-test means, the Moodle group's post-test mean is even higher again. Figure 9 shows the pre-test and post-test means for each classroom in the sample. Unlike the Science classrooms, there is considerable variation among the classrooms at both the pre-test and the post-test, but Figure 9 indicates that almost all of the Moodle classrooms showed an improvement in the post-test over the pre-test.

Multilevel modelling is now applied to the data to assess which, if any, of the apparent effects suggested by the tables and figures in this section simply reflect random sampling error.

Table 3: Group means and standard deviations for the Mathematics pre-test and post-test

Group		Number		Mean	Std Deviation
		Students	Classrooms		
Control	Pre-test Post-test	202	12	11.06 12.83	4.27 4.27
Learning object	Pre-test Post-test	187	10	10.73 12.09	3.55 4.50
Moodle	Pre-test Post-test	270	11	11.83 14.10	3.75 3.87
Total	**Pre-test** **Post-test**	**659**	**33**	**11.29** **13.14**	**3.89** **4.26**

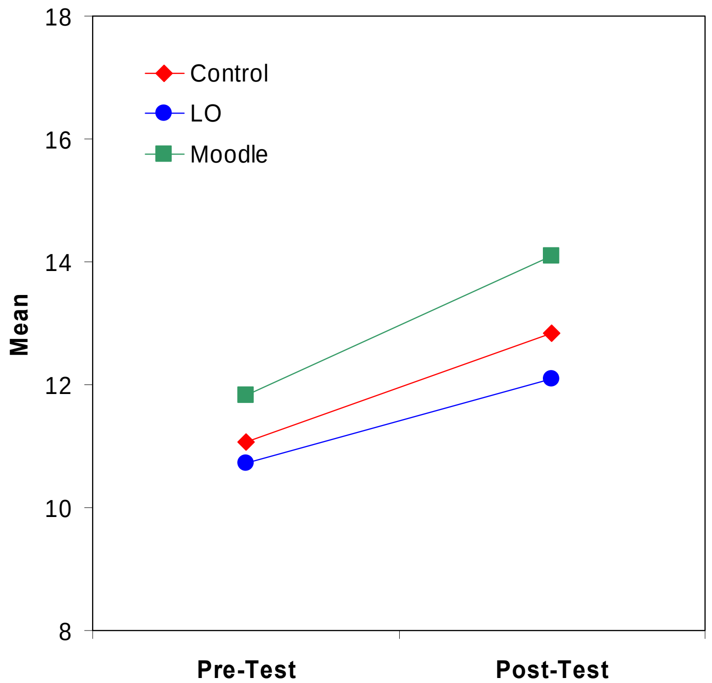

Figure 8: Group means for the Mathematics pre-test and post-test

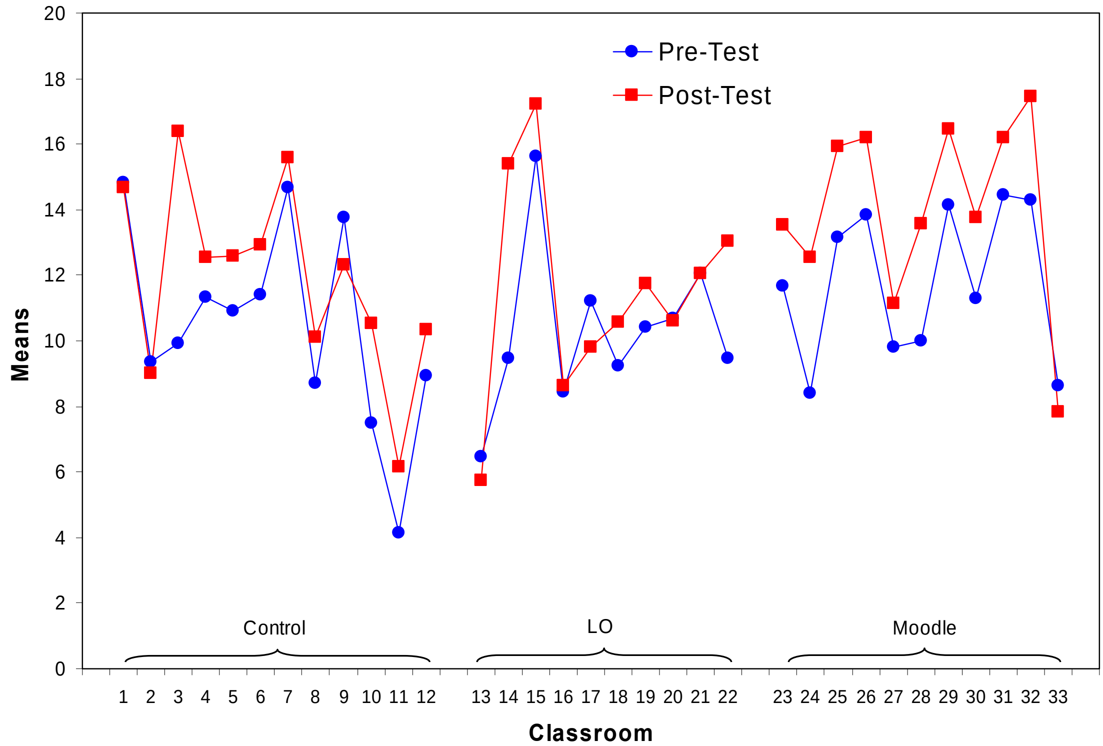

Figure 9: Mathematics pre-test and post-test means for each classroom

Multilevel analyses

Analysis of pre-test scores

Before commencing the analyses of the post-test data, a preliminary analysis of the pre-test data is presented. For each of the two curriculum areas, two multilevel models were run: a variance components model to determine whether the within-classroom effects are significant; and a model with the experimental groups added to determine whether the three groups are equivalent with respect to the pre-test. The two models are represented as:

Variance components: $\mathrm{PreTest}_{ij} = \beta_0 + u_{0j} + e_{ij}$

Groups: $\mathrm{PreTest}_{ij} = \beta_0 + \beta_1 \mathrm{LO}_j + \beta_2 \mathrm{Moodle}_j + u_{0j} + e_{ij}$

Tables 4 and 5 give the maximum likelihood and MCMC estimates for Science and Mathematics respectively. The maximum likelihood estimates in both tables are close to the MCMC estimates, except for the 95% CI for the classroom-level variance. For Science, the classroom-level variance is especially small, but for both Science and Mathematics, the maximum likelihood 95% CIs indicate that the two variances are statistically greater than zero.

Table 4: Modelling pre-test scores – Science

	Variance components	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	7.37 (7.06, 7.68)	7.38 (7.04, 7.69)
Random		
σ_e^2	6.52 (5.83, 7.20)	6.52 (5.90, 7.27)
σ_u^2	0.48 (0.09, 0.86)	0.46 (0.18, 1.11)
VPC	0.07	0.07 (0.03, 0.15)
	Deviance: 3479.4	DIC: 3472.4

	Groups	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	7.17 (6.62, 7.72)	7.17 (6.56, 7.75)
Groups:		
Learning object	-0.04 (-0.82, 0.82)	-0.04 (-0.87, 0.84)
Moodle	0.51 (-0.21, 1.22)	0.50 (-0.25, 1.30)
Random		
σ_e^2	6.52 (5.83, 7.20)	6.52 (5.90, 7.27)
σ_u^2	0.41 (0.06, 0.76)	0.42 (0.16, 1.11)
	Deviance: 3476.6	DIC: 3473.0
	Δ Deviance: 2.82	
	df: 2	
	p: 0.244	

Table 5: Modelling pre-test scores – Mathematics

	Variance components	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	10.90 (10.02, 11.78)	10.91 (9.97, 11.82)
Random		
σ_e^2	9.84 (8.75, 10.96)	9.83 (8.85, 11.02)
σ_u^2	6.05 (2.96, 9.24)	6.25 (3.78, 11.32)
VPC	0.38	0.39 (0.27, 0.54)
	Deviance: 3459.9	DIC: 3409.4

	Groups	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	10.53 (9.11, 11.96)	10.55 (8.98, 12.07)
Groups:		
Learning object	-0.19 (-2.29, 1.91)	-0.19 (-2.49, 2.12)
Moodle	1.26 (-0.78, 3.30)	1.25 (-0.97, 3.49)
Random		
σ_e^2	9.84 (8.75, 10.93)	9.82 (8.84, 11.04)
σ_u^2	5.65 (2.65, 8.64)	6.16 (3.75, 11.61)
	Deviance: 3457.7	DIC: 3409.6
	ΔD: 2.14	
	df: 2	
	p: 0.343	

The VPCs for the two curriculum areas are different: for Science only 7 per cent of the variance in pre-test scores is at the classroom level whereas, for Mathematics, 39 per cent of the variance in pre-test scores is at the classroom level. For Science classrooms, VPC is not large, indicating that nearly all of the variance is at the student level. For Mathematics, VPC is large, indicating that the grouping of students into classrooms leads to an important similarity among the pre-test scores.

The variance components model estimates the pre-test mean for Science to be 7.38. The student-level residuals (e_{ij}) have a variance (σ_e^2) of 6.52, and the classroom-level residuals (u_j) have a variance (σ_u^2) of 0.46. Thus, the model estimated value for the standard deviation, given by the square root of the total variance:

$\sigma = \sqrt{\sigma_u^2 + \sigma_e^2}$ is 2.64.

Similarly, the model-estimated values for the pre-test mean and standard deviation for Mathematics are 10.90 and 4.01 respectively. The means and standard deviations estimated by the variance components models are close to but not identical with the pre-test means and standard deviations given in Tables 2 and 3. The reason for the differences is that the variance components estimates (Tables 4 and 5) take account of the within-classroom effects – effects that were ignored in the earlier calculations (Tables 2 and 3).

The second model in each table gives the estimates of the pre-test means for the three experimental groups: β_0 is the mean of the control group; and β_1 and β_2 are the differences between the mean for the control group and the means for the learning object and Moodle groups respectively (or alternatively, $\beta_0 + \beta_1$ and $\beta_0 + \beta_2$ are the means for learning object classrooms and Moodle classrooms respectively). For Science, the means for the three groups are 7.17, 7.13, and 7.67. Clearly, the differences are small, and indeed, the difference in deviance statistics indicates that the second model fits the data no better than the first model ($\Delta D_{df=2} = 2.82$, $p = 0.244$). Therefore, in the interests of parsimony, the first model, the model without the group effects, is the preferred model. Also, it is noted that the MCMC-estimated 95% CIs for β_1 and β_2 span zero in both cases. Thus the pre-test means for the three groups of Science classrooms are, in effect, equal.

For Mathematics, the pre-test means for the three groups are 10.55, 10.36, and 11.80; and again, the differences are small. The difference in the maximum likelihood deviance statistics ($\Delta D_{df=2} = 2.14$, $p = 0.343$) and the MCMC-estimated 95% CIs indicates that the pre-test means for the three groups of Mathematics classrooms are also, in effect, equal.

In summary, the multilevel analyses of the pre-test scores indicate that, for both curriculum areas, there are no significant differences among the means. That is, the treatment groups are statistically equivalent to the control group prior to the start of the intervention. While there is significant variation at the classroom level, for Science, this classroom-level variation is small.

Analysis of post-test scores

Earlier we described the process for model selection: beginning with the variance components model, a series of increasingly more complex models is run to test for significant changes in the maximum likelihood deviance statistics at each step. Table 6 shows the results of these tests for the two curriculum areas. For Science, Model 2 is the optimal model. Model 3, with the interactions, does not fit the data significantly better than Model 2. Also, Model 2 allows the intercepts to vary across classrooms but the slopes are held constant (that is, M_{1b} does not fit the data significantly better than M_{1a}). For Mathematics, both the intercepts and the slopes are allowed to vary across the classrooms (that is, M_{1b} fits the data significantly better than M_{1a}). However, taking account of the experimental groups does not significantly improve the model fit (M_2 does not fit the data significantly better than M_{1b}). Also, the interactions do not significantly improve the model fit (that is, M_3 is not significantly better than M_{1b}).

Table 6: Model selection

Science	Deviance	Models contrasted	ΔD	df	p
M_0: Variance components	3815.8				
M_{1a}: M_0 + Pre-test (slopes constant)	3710.0	$M_{1a} – M_0$	105.9	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	3708.5	$M_{1b} – M_{1a}$	1.5	2	0.473
M_2: M_{1a} + Groups	3696.9	$M_2 – M_{1a}$	13.0	2	0.001
M_3: M_2 + Interactions	3694.4	$M_3 – M_2$	2.5	2	0.280
Mathematics					
M_0: Variance components	3529.8				
M_{1a}: M_0 + Pre-test (slopes constant)	3274.9	$M_{1a} – M_0$	254.9	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	3259.9	$M_{1b} – M_{1a}$	14.9	2	0.001
M_2: M_{1b} + Groups	3257.9	$M_2 – M_{1b}$	2.1	2	0.355
M_3: M_2 + Interactions	3251.2	$M_3 – M_{1b}$	8.7	4	0.069

Thus for the Science data there are significant group differences at the post-test after covarying the pre-test. The model is represented as:

$$\mathrm{PostTest}_{ij} = \beta_0 + \beta_1 \mathrm{PreTest}_{ij} + \beta_2 \mathrm{LO}_j + \beta_3 \mathrm{Moodle}_j + u_{0j} + e_{ij}$$

in which β_0 is the mean intercept for the control group; β_1 is the slope of the regression lines held constant across the schools; and $\beta_0 + \beta_2$ and $\beta_0 + \beta_3$ are the mean intercepts for the learning object group and Moodle group respectively.

For the Mathematics data, there are no significant group differences at the post-test. The model is represented as:

$$\mathrm{PostTest}_{ij} = \beta_0 + \beta_1 \mathrm{PreTest}_{ij} + u_{0j} + u_{1j} + e_{ij}$$

in which β_0 and β_1 are the mean intercept and mean slope of the regression lines.

The maximum likelihood and MCMC estimates for the optimal models and the variance components models for mathematics and science are shown in Tables 7 and 8.

Table 7: Effect of experimental groups on post-test scores, controlling for pre-test scores – Science

	Variance components	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	9.05 (8.28, 9.82)	9.06 (8.24, 9.86)
Random		
σ^2_e	9.73 (8.71, 10.75)	9.71 (8.79, 10.82)
σ^2_{uo}	4.27 (1.91, 6.65)	4.37 (2.64, 8.19)
VPC	0.31	0.31 (0.21, 0.46)
		DIC: 3772.9

	Pre-test and groups	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	8.09 (7.04, 9.14)	8.10 (6.96, 9.23)
Pre-test[1]	0.46 (0.38, 0.54)	0.46 (0.38, 0.54)
Groups:		
Learning object	2.91 (1.40, 4.41)	2.90 (1.24, 4.52)
Moodle	0.47 (-0.96, 1.86)	0.47 (-1.08, 1.98)
Random		
σ^2_e	8.41 (7.53, 9.29)	7.44 (6.68, 8.35)
σ^2_{uo}	2.34 (0.97, 3.71)	2.52 (1.47, 5.17)
		DIC: 3667.8

[1] Pre-test scores are centred on the grand mean (that is, the intercept is the post-test score for an average pre-test score).

Table 8: Regression of pre-test scores on post-test scores – Mathematics

	Variance components	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	12.56 (11.53, 13.60)	12.57 (11.47, 13.65)
Random		
σ^2_e	10.81 (9.61, 12.01)	10.80 (9.72, 12.12)
σ^2_{uo}	8.56 (4.13, 12.99)	8.86 (5.40, 15.86)
VPC	0.44	0.45 (0.33, 0.60)
		DIC: 3472.1

	Pre-test	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	12.98 (12.28, 13.68)	12.98 (12.23, 13.73)
Pre-test[1]	0.60 (0.50, 0.69)	0.60 (0.50, 0.70)
Random		
σ^2_e	7.14 (6.33, 7.94)	7.15 (6.419, 8.05)
σ^2_{uo}	3.70 (1.66, 5.75)	3.90 (2.37, 7.26)
σ^2_{u1}	0.04 (.003, 0.08)	0.04 (0.02, 0.10)
$\sigma_{u0.1}$	-0.26 (-0.47, -0.04)	-0.26 (-0.61, -0.08)
		DIC: 3212.0

[1] Pre-test scores are centred on the grand mean.

We focus briefly on the variance components models. The VPCs for Science and Mathematics are 0.31 and 0.45 respectively (compared to 0.07 and 0.39 for the pre-test). The indication is that for both Mathematics and Science, the grouping of students into classrooms leads to an important similarity between the post-test scores of students. For Science, a substantial proportion of the student-level and classroom-level variance[1] is accounted for by the pre-test scores and the experimental groups ($R_1^2 = 0.293$ and $R_2^2 = 0.404$; meaning that 29% of the student-level variance and 40% of the classroom level variance is accounted for by these variables). For Mathematics, only the pre-test scores account for student-level and classroom-level variance ($R_1^2 = 0.431$, $R_2^2 = 0.567$).

The lower parts of Tables 7 and 8 show the estimates for the two optimal models. For Science, there were significant effects due to group membership, but the estimates indicate that the effect applies to the learning object group only (the 95% CI for the Moodle group spans zero, indicating that there is no statistical difference between the Moodle group and the control group). Figure 10 shows the three regression lines predicted by the analysis:

- The lines are parallel (because the interactions were not significant).
- The line for the learning object group is displaced above the other two lines (because there is a significant effect for the learning object group).
- Lines for the control group and the Moodle group are close together (indeed, the analysis suggests that the two lines should overlap because there is, in effect, no difference between the two groups).

---

[1] The concept of explained variance is well known in regression analysis. The usual measure for the explained proportion of variance is the squared multiple correlation coefficient (R^2). In multilevel linear models, the concept is somewhat problematic. Snijders and Bosker (1999) provide expressions for approximate R^2-like measures for the explained proportion of variance at each level in the analysis.

For a random intercept model, level 1 R^2 is given by: $R_1^2 = 1 - \frac{\sigma^2_{e\ \text{fitted model}} + \sigma^2_{u\ \text{fitted model}}}{\sigma^2_{e\ \text{null model}} + \sigma^2_{u\ \text{null model}}}$

and level 2 R^2 is given by: $R_2^2 = 1 - \frac{\frac{\sigma^2_{e\ \text{fitted model}}}{n} + \sigma^2_{u\ \text{fitted model}}}{\frac{\sigma^2_{e\ \text{null model}}}{n} + \sigma^2_{u\ \text{null model}}}$ where n is the harmonic mean of the cluster sizes. For models with random slopes, Snijders and Bosker recommend re-estimating the model as a random intercept model (but with the same fixed parts), and calculating the R^2s as if the fitted model was a random intercept model.

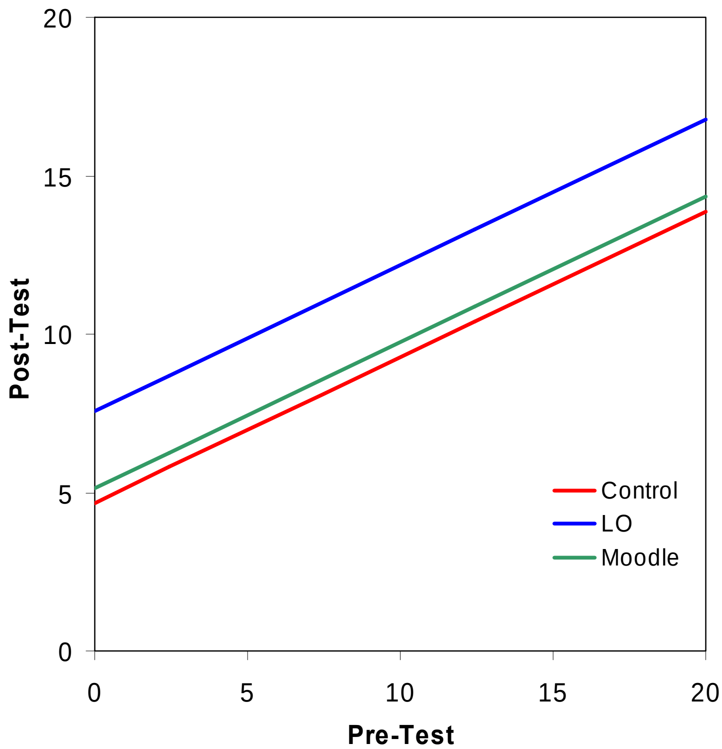

Figure 10: Regression lines for post-test scores predicted by pre-test scores for all three experimental groups – Science

For Mathematics, the relationship is much simpler. There are no differences among the three experimental groups in either main effects or interactions and, as shown in Figure 11, the regression lines for the three groups cannot be distinguished. The model allowed both the intercepts and the slopes to vary across the schools. As a consequence, the analysis returns classroom level variances for the intercepts and the slopes. But Table 8 shows a third random term at the classroom level – a covariance between the intercepts and the slopes ($\sigma_{u0.1}$). The covariance can be converted to a more convenient correlation:

$$\rho = \frac{\sigma_{u0.1}}{\sqrt{\sigma_{u0}^2 + \sigma_{u1}^2}}$$

The correlation is -0.66, but the effect is more easily seen in Figure 12, which shows the regression lines for each classroom. The correlation is negative, indicating that as the intercepts increase, the slopes tend to decrease. The effect is seen in Figure 12 as the lines tending to converge at high pre-test scores. An interpretation of the effect is that, for high pre-test scores, there is not much room for improvement in the post-test scores.

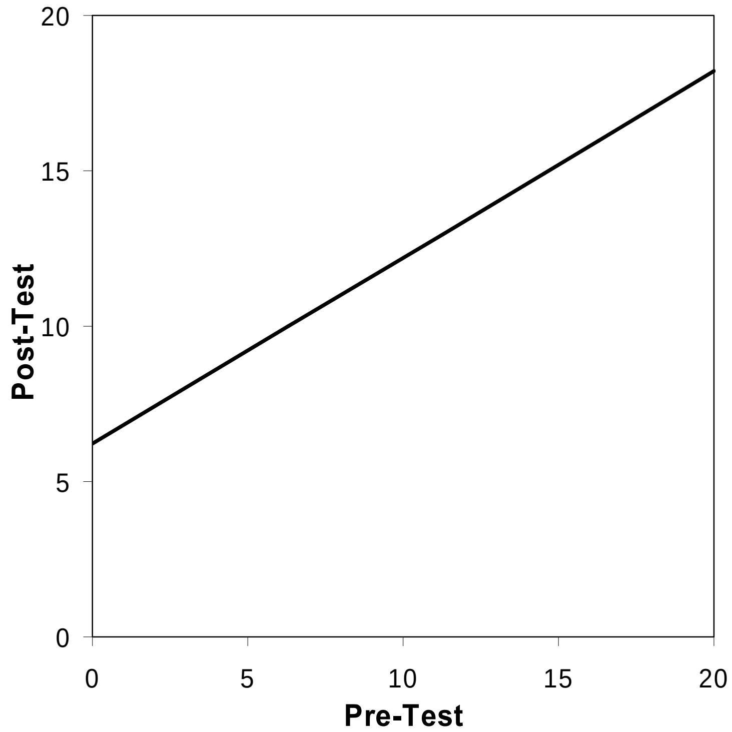

Figure 11: Regression line for post-test scores predicted by pre-test scores – Mathematics

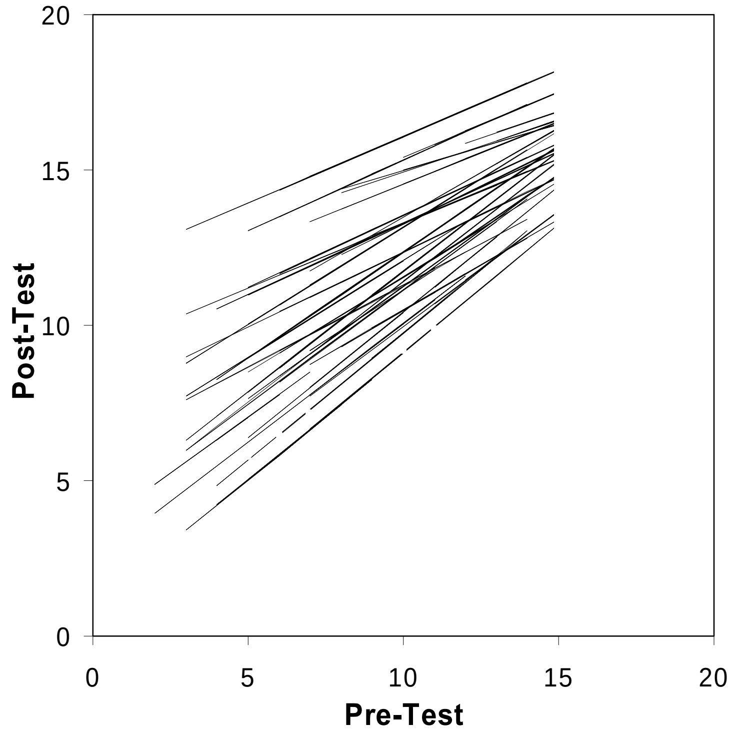

Figure 12: Regression lines for each Mathematics classroom, showing a negative correlation between intercepts and slopes

Although there is no overall effect for experimental group membership for Mathematics, there could be effects for one or more components of the Mathematics test. The learning objects, the pre-test and the post-test were all structured around four algebra content areas: Number patterns, Pronumerals, Linear functions, and Non-linear functions. Figure 13 shows the pre-test and post-test means for each component. Among the effects suggested in Figure 13, multilevel modelling indicates that only one is statistically significant. Applying the same procedures as outlined earlier, Table 9 gives the results for testing for significant changes in the maximum likelihood deviance statistics for sequential models for each component. There are no group effects for Number patterns, Pronumerals, and Non-linear functions; for these three components, the only influence on the post-test scores was pre-test scores. The only component that showed a significant group effect was for Linear functions, for which Table 10 gives the maximum likelihood and MCMC estimates for the model.

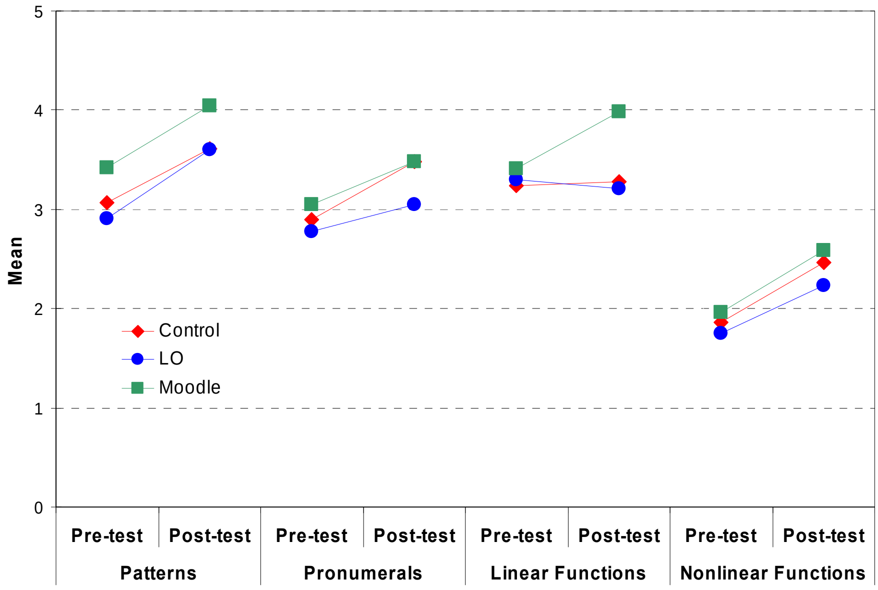

Figure 13: Pre-test and post-test means for Mathematics component

Table 9: Model selection for each component of the Mathematics program

Model	Deviance	Models contrasted	ΔD	df	p
Number patterns					
M_0: Variance components	2135.3				
M_{1a}: M_0 + Pre-test (slopes constant)	1991.1	$M_{1a} – M_0$	144.2	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	1968.9	$M_{1b} – M_{1a}$	22.1	1	<0.001
M_2: M_{1b} + Groups	1966.8	$M_2 – M_{1b}$	2.1	1	0.344
M_3: M_2 + Interactions	1964.3	$M_3 – M_{1b}$	4.6	4	0.331
Pronumerals					
M_0: Variance components	2167.8				
M_{1a}: M_0 + Pre-test (slopes constant)	2035.5	$M_{1a} – M_0$	132.3	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	2031.8	$M_{1b} – M_{1a}$	3.6	2	0.163
M_2: M_{1b} + Groups	2032.7	$M_2 – M_{1a}$	2.8	2	0.251
M_3: M_2 + Interactions	2031.0	$M_3 – M_{1a}$	4.5	4	0.347
Linear functions					
M_0: Variance Components	1950.8				
M_{1a}: M_0 + Pre-test (slopes constant)	1899.4	$M_{1a} – M_0$	51.4	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	1888.8	$M_{1b} – M_{1a}$	10.6	2	0.005
M_2: M_{1b} + Groups	1881.0	$M_2 – M_{1b}$	7.8	2	0.020
M_3: M_2 + Interactions	1879.4	$M_3 – M_2$	1.6	2	0.452
M_{2b}: M_2 without covariance	1883.8	$M_{2b} – M_2$	2.8	1	0.096
Non-linear functions					
M_0: Variance components	2209.2				
M_{1a}: M_0 + Pre-test (slopes constant)	2167.6	$M_{1a} – M_0$	41.7	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	(2159.2)	$M_{1b} – M_{1a}$			
M_2: M_{1b} + Groups	2165.8	$M_2 – M_{1a}$	1.7	2	0.419
M_3: M_2 + Interactions	2159.5	$M_3 – M_{1a}$	8.1	4	0.089

Table 10: Effect of experimental groups on post-test scores, controlling for pre-test scores – Linear functions

	Variance components	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	3.38 (3.06, 3.67)	3.37 (3.04, 3.69)
Random		
σ^2_e	0.99 (0.88, 1.10)	0.99 (0.89, 1.11)
σ^2_{uo}	0.74 (0.36, 1.12)	0.76 (0.47, 1.37)
VPC	0.43	0.44 (0.32, 0.58)
		DIC: 1894.8

	Pre-test and Groups	
	Maximum likelihood estimates	**MCMC estimates**
	Coeff (95% CI)	Coeff (95% CI)
Fixed		
Intercept	3.16 (2.75, 3.56)	3.16 (2.71, 3.60)
PreTest	0.26 (0.16, 0.36)	0.26 (0.16, 0.36)
Groups:		
learning object	-0.06 (-0.66, 0.53)	-0.07 (-0.71, 0.60)
Moodle	0.78 (0.20, 1.35)	0.77 (0.15, 1.41)
Random		
σ^2_e	0.88 (0.78, 0.98)	0.88 (0.79, 1.00)
σ^2_{uo}	0.44 (0.20, 0.68)	0.49 (0.28, 0.92)
σ^2_{u1}	0.04 (-.001, 0.08)	0.03 (0.00, 0.10)
		DIC: 1836.7

Figure 14 shows the three regression lines predicted by the analysis:

- The lines are parallel (because there are no interactions).
- The line for the Moodle group is displaced above the other two lines (because there is a significant effect for the Moodle group).
- Lines for the control group and the learning object group, in effect, overlap (because there is no effect for the learning object group).

A substantial proportion of the student-level and classroom-level variance is accounted for by the pre-test scores for Linear functions and by the experimental groups ($R_1^2 = 0.194$ and $R_2^2 = 0.337$; meaning that 19% of the student-level variance and 34% of the classroom-level variance is accounted for by these variables). By way of contrast, the pre-test scores for the other Mathematics components account for substantial proportions of student-level and classroom-level variance (Number patterns: $R_1^2 = 0.269$ and $R_2^2 = 0.597$; Pronumerals: $R_1^2 = 0.280$ and $R_2^2 = 0.493$; Non-linear functions: $R_1^2 = 0.107$ and $R_2^2 = 0.221$), but the experimental groups, in effect, account for none.

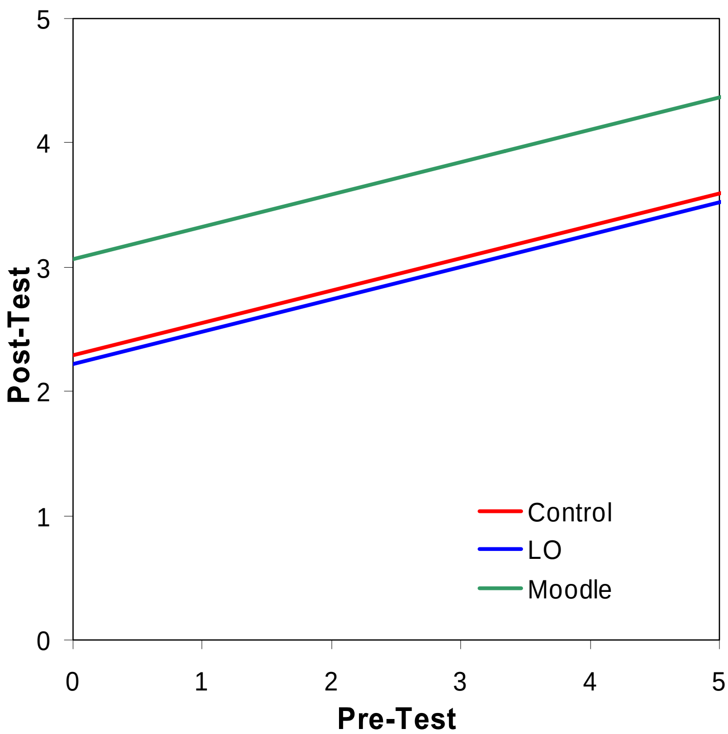

Figure 14: Regression lines for post-test scores predicted by pre-test scores for three experimental groups – Linear functions

As the pre-test, post-test and learning objects for Science also had four components, for purposes of completeness we present a similar analysis for each Science component. The means for the pre-test and post-test for each component are presented in Figure 15. Unlike the means for the Mathematics components, the means for the Science components show roughly the same pattern regardless of the component: for each of the four components the pre-test means are comparable, and the learning object group made gains on its pre-test means.

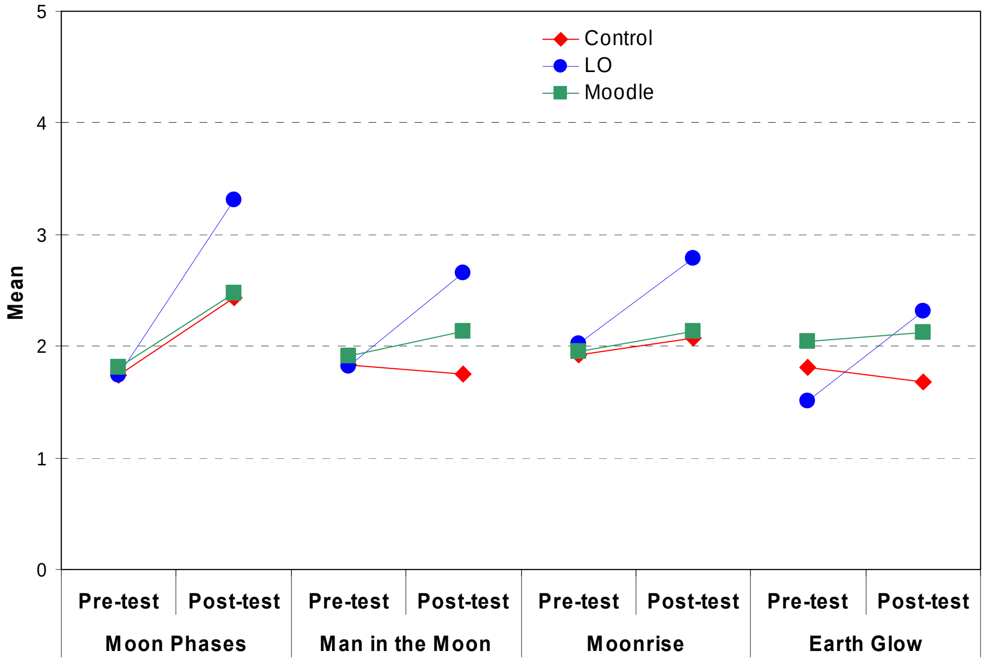

Figure 15: Pre-test and post-test means for the four Science components

The effects suggested in Figure 15 were tested in a series of multilevel models. Table 11, which gives the results for testing sequentially for significant changes in the maximum likelihood deviance statistics for each component, shows that there are group differences on the post-test after covarying for the pre-test. Table 12, which gives the MCMC estimates for the optimal model, shows that, with one exception, the learning object group outperforms the control group and the Moodle group. In the exception, the 'Earth glow' component, both the learning object group and the Moodle group outperform the control group. Substantial proportions of classroom-level and student-level variance in the post-test scores are accounted for by the pre-test scores and the experimental groups ('Moon phases': $R_1^2 = 0.079$ and $R_2^2 = 0.204$; 'Man in the Moon': $R_1^2 = 0.065$ and $R_2^2 = 0.197$; 'Moonrise': $R_1^2 = 0.073$ and $R_2^2 = 0.365$; 'Earth glow': $R_1^2 = 0.098$ and $R_2^2 = 0.327$).

Table 11: Model selection for each component of the Science program

Model	Deviance	Models contrasted	ΔD	df	p
'Moon phases'					
M_0: Variance components	2507.0				
M_{1a}: M_0 + Pre-test (slopes constant)	2485.8	$M_{1a} – M_0$	21.3	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	2482.0	$M_{1b} – M_{1a}$	3.8	2	0.151
M_2: M_{1b} + Groups	2478.1	$M_2 – M_{1a}$	7.7	2	0.021
M_3: M_2 + Interactions	2477.9	$M_3 – M_2$	0.1	2	0.931
'Man in the Moon'					
M_0: Variance components	2410.6				
M_{1a}: M_0 + Pre-test (slopes constant)	2395.4	$M_{1a} – M_0$	15.3	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	2393.3	$M_{1b} – M_{1a}$	2.1	2	0.351
M_2: M_{1b} + Groups	2388.0	$M_2 – M_{1a}$	7.4	2	0.025
M_3: M_2 + Interactions	2386.5	$M_3 – M_2$	1.5	2	0.479
'Moonrise'					
M_0: Variance components	2342.2				
M_{1a}: M_0 + Pre-test (slopes constant)	2328.5	$M_{1a} – M_0$	13.6	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	2327.8	$M_{1b} – M_{1a}$	0.7	2	0.704
M_2: M_{1b} + Groups	2315.4	$M_2 – M_{1a}$	13.2	2	0.001
M_3: M_2 + Interactions	2315.0	$M_3 – M_2$	0.3	2	0.841
'Earth glow'					
M_0: Variance components	2220.3				
M_{1a}: M_0 + Pre-test (slopes constant)	2191.1	$M_{1a} – M_0$	29.2	1	<0.001
M_{1b}: M_0 + Pre-test (slopes random)	2190.0	$M_{1b} – M_{1a}$	1.1	2	0.574
M_2: M_{1b} + Groups	2180.2	$M_2 – M_{1a}$	11.0	2	0.004
M_3: M_2 + Interactions	2177.1	$M_3 – M_2$	3.1	2	0.214

Table 12: Effect of experimental groups on post-test scores, controlling for pre-test scores for each Science component

	'Moon phases'	**'Man in the Moon'**	**'Moonrise'**	**'Earth glow'**
	Coeff (95% CI)	Coeff (95% CI)	Coeff (95% CI)	Coeff (95% CI)
Fixed				
Intercept	2.55 (2.08, 3.04)	1.76 (1.35, 2.18)	2.06 (1.78, 2.33)	1.63 (1.32, 1.92)
PreTest	0.20 (0.12, 0.29)	0.16 (0.08, 0.24)	0.14 (0.07, 0.22)	0.21 (0.14, 0.29)
Groups:				
Learning object	0.75 (0.04, 1.44)	0.81 (0.21, 1.41)	0.67 (0.27, 1.06)	0.73 (0.30, 1.15)
Moodle	-0.12 (-0.77, 0.52)	0.30 (-0.27, 0.85)	0.04 (-0.33, 0.39)	0.41 (0.02, 0.81)
Random				
σ_e^2	1.60 (1.44, 1.78)	1.42 (1.29, 1.59)	1.33 (1.21, 1.49)	1.09 (0.99, 1.22)
σ_{uo}^2	0.46 (0.25, 0.92)	0.33 (0.18, 0.68)	0.10 (0.04, 0.24)	0.15 (0.07, 0.32)
DIC	2450.75	2365.12	2312.26	2168.05

Finally, the regression lines estimated by the models are shown in Figure 16. Regardless of the component, the lines follow the same pattern as displayed in Figure 10 (Regression lines for post-test scores predicted by pre-test scores for all three experimental groups – Science):

- The lines are parallel (because there are no interactions);
- The learning object lines are displaced above the other lines (because there is an effect for the learning object group);
- Lines for the control group and Moodle group are close together (for three of the components, the analysis indicates that there is no difference between the two groups), the exception being for 'Earth glow', where the regression lines for both the learning object group and the Moodle group are displaced above the line for the control group.

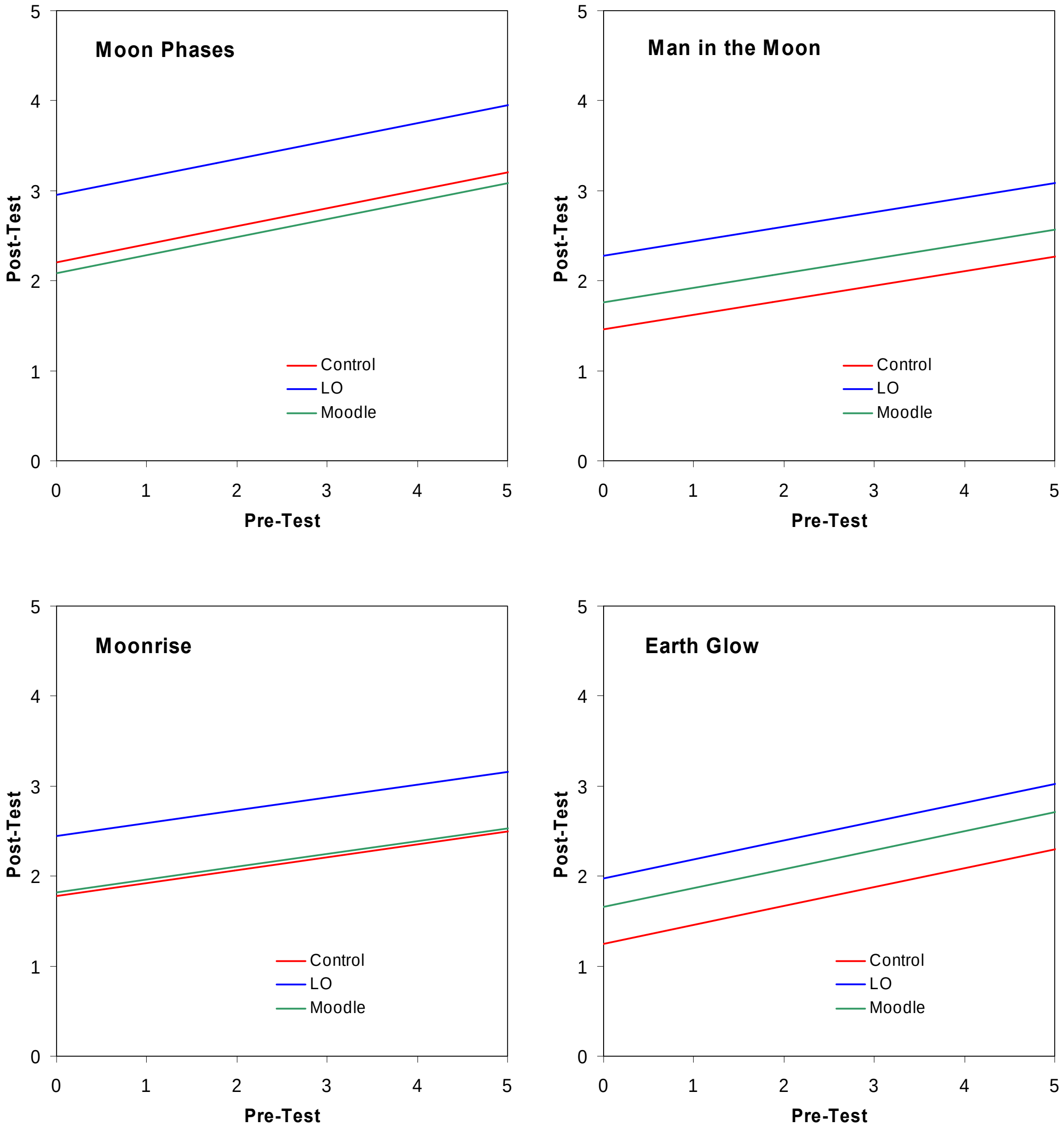

Figure 16: Regression lines for post-test scores predicted by pre-test scores for the three experimental groups, for each Science component

Findings

Table 13 shows the four major findings of the analyses of the experimental data. As well, it should be noted that entry levels (pre-test scores) had significant, strong, and consistent effects on the post-test results, in that students who entered the six-week intervention period with the higher pre-test scores were those who also obtained the higher post-test scores. There was no indication or trend for any diminution of their advantage as a result of using either learning objects or Moodle.

Table 13: Major findings from the field experiment

1. *There were significant positive effects for the use of learning objects in Science*. These effects were clear and relatively consistent.

2. *There was no advantage for the group using learning objects within a Moodle learning management system in Science over the group using the learning objects only or the control group, whether overall or for any component of the Science test*. On the post-test for Science the performance of the Moodle group was statistically indistinguishable from that of the control group.

3. *With one exception there were no reliable significant effects for either learning object use or Moodle use in Mathematics*. On the post-test for Mathematics, there was comparable performance across the board and within each component of the test except for the Linear functions component.

4. The exception was that *there was a statistically reliable advantage for the Moodle group on post-test items relating to Linear functions*. No effects were evident on post-tests for Pronumerals, Number patterns or Non-linear functions.

These findings suggest that there are complex relationships between the uses of learning objects, the learning systems in which they may be housed and organised, and learning in Science and Mathematics. As noted at the end of 'Review of recent, related research', the four factors listed below had been hypothesised, singly and in combination, as explanations of anticipated variations across year levels, curriculum areas, and topics of varying complexity and difficulty to teach. They are restated below, now accompanied by a brief account of their possible effects on the findings reported above.

1 Teachers' familiarity with the selected content

In interviews conducted by the research team, Science teachers reported lower than usual levels of familiarity with some aspects of the Science content used in this study, as indicated in the following three excerpts of interview that are typical of teachers' responses.

1

T: This is a very difficult concept for students' understanding. And for me too. I think … and I hold most of those misconceptions and I'm an adult. So I'm learning too, so from that perspective it's good. But it's been difficult. It's been a challenging topic.

2

T: When we're looking at constructing learning units, if we were teaching, for example, things to do with space, we would [include the sun and] planets. It would be a total program. We wouldn't concentrate just on, say, the lunar cycles. That would probably be more in a high school where you get a lot more specific with your science learning.

3

T: That took a lot of time, going on to the learning objects and getting our head around it and also a lot of research on computers to make sure we had understanding of the knowledge we were passing on.

I: In that sense you'd suggest that there should be some accessible support materials that might be able to back up the [learning] objects in terms of the content knowledge and how you might be able to use them?

T: Yeah, definitely. I've got that written down here. We're using units at the moment called Primary Connections [developed by the Australian Academy of Science, Canberra], and they are fantastic in that they have all that knowledge. They have example questions. They have lists of resources. Very teacher-friendly … Try and get all that information in the ['Lunar cycles'] unit across … was quite rushed, and probably didn't allow for those good things such as deep knowledge and understanding that we like to be teaching the children.

The Mathematics teachers, on the other hand, made no comparable comments, possibly because they were highly familiar with the content of the Mathematics program. One hypothesis is that the level of teachers' knowledge, and the confidence it implies, meant that any potential advantages for the intervention groups were levelled out. In Freebody, Muspratt and McRae (2007) it was found that the Mathematics topic with which teachers reported most difficulty was associated with significant advantages for the group using learning objects.

2 Teacher's approaches to the use of the learning objects and/or the learning management system, including their inclination to control scope and sequence

Mathematics teachers reported that their own content and pedagogical knowledge often led them to remove the Moodle control over the presentation sequences of learning objects. For instance, the following dialogue arose from a comparison between the learning management system and the teacher's usual approach:

4

T: Not even close.

I: You'd do it better?

T: In my own mind, I think I would, yeah.

I: Higher intensity?

T: And drilling in and focusing on the blocks and building it up. Doing a lot of the transposition stuff early on. And I do the graphing with my computer and overheads, and I actually get the kids to draw the graph where they think it should be, and then we, because it's on the board, on the whiteboard, we've got … 'So this is what it's like?', 'Now where do you reckon the next one might be?', and I've developed it over a few years, and I think that works well for the graphing, and I'm a bit worried where this one is going to go with that, I really am.

One hypothesis here, with respect to the Mathematics classrooms in this study, is that the materials were managed best by the teachers without any need for a learning management system, allowing them to mix, match, delete, or sequence the learning objects however they pleased. The following comment on the learning management system was typical:

5

T And the other aspect obviously is that there are things that I think aren't covered to the extent that I need them covered within the materials, and there are things that I'll want to draw out. So … I'm sort of supplementing and going to work with the whole class on a few different activities. And I pull off some of the ones that the package refers to, too, because I thought they were actually quite good value. So even if the kids aren't directed to them I'll make sure that they have some experience with them because they look like quite worthwhile things. And certainly I can see in the long term that I will use some of the [Moodle] aspects [outside the] Moodle kind of environment but … I'll be trying to get the kids to do them as we go through the algebra, because some of the activities are, I think, great. And I think combined with the way I normally do business they'll work in quite well. I'm expecting that … it'll work quite nicely long-term for me.

While the Science teachers using the learning management system may have been tempted to let it manage the more complex materials, there were, even among this group of teachers, comments concerning the limitations of the learning management system that became apparent as the teachers came to grips with their own solutions to these difficult-to-teach concepts:

6

T There are a couple of activities the kids need to do with overhead projectors, torches, balls and stuff. But I think I've been a bit reluctant to go too far because I know it's got to be what's coming out of the computers. And I wasn't sure how far I could go [in] giving the kids other resources, so I really haven't because I'm assuming I'm not supposed to with this one … But I think it would be really good to combine both. That's the impression I'm getting at the moment. What's coming out of this is really good, but I think I could do a lot more as well. But I still see this as a basis and see [it] as what the kids need to know.

The clear advantage for the learning object group in the Science topic, which was notable, was not predicted. Perhaps some teachers' lack of familiarity with Moodle, or with learning management systems generally, may be relevant.

3 The pedagogical opportunities and limitations presented by the learning objects

Several teachers made explicit comparisons regarding the relative ease or difficulty of teaching various components of the curricular materials used in this study. For instance, the comments below from two Science teachers concern the way in which use of the learning objects helped them overcome some pedagogical complexities in staging the topic:

7

T I think Science should be more hands-on, and I think the kids would get more out of that. But then obviously there are some things you can't teach hands-on, so in that regard they'd probably benefit more from [the learning objects].

8

T Instead of having to have lots and lots of hands-on resources, the actual fact that you can have a moving picture of it, or … photo or something online for the kids to actually to look at, has really worked well. It gives the kids a really good idea about how it actually works … Having the visual elements that you need to be able to show the kids, I mean it's a very good format for doing it, so it's a big advantage. Compared to the traditional sort of way … it's quick, it's easy, you don't have to chase after resources like you normally have to … We're expected to do so much these days as teachers in classrooms, and finding time to be actually able to get all those resources together to do a traditional sort of lesson obviously is difficult. But clicking on it in the context of a learning object and having the information come up straightaway and … in a format the kids really enjoy and are motivated by – it's very good.

Nevertheless, Science teachers and Mathematics teachers commented on the potential limitations of the learning objects, and the need to support and extend the material presented in the learning objects. In the examples below, two Science teachers comment on the need to cater for different learning styles, and on the need to integrate the content into other curriculum areas; while the Mathematics teacher claims that learning objects offer no advantage over a traditional approach:

9

T I think they still need hands-on tasks in order to back up the learning objects. They need hands-on tasks because I feel the learning objects don't necessarily cater for all different learning styles. The children that are more tactile, [who] need to be making models and actually doing, [are] not catered [for] well if you were just to use the learning objects. I feel they need to be integrated with other strategies and activities as well.

10

T The other thing I did was to integrate it into our language because I didn't want it just to remain a science activity … I selected from a variety of different sources (newspaper articles, various children's textbooks and a poem I found) to get them to have a look at different texts and how they were constructed for different audiences and … written in a particular way … and that gave them additional information which some of them referred back to when they were doing their models. And, for example, when they had to do the model identifying the phases, there's a page in the Moodle information [about] shining the torch and that sort of thing. I sent two groups off to have a go … I didn't think I was getting the depth that I wanted. It … was just staying in the Science room and I didn't want it to stay there. I wanted to get into the whole aspect of it.

11

T There's certainly aspects, like the line graphing, [that] I will never [change] from doing as a whole-class thing … I did this investigation where … I set them up to do tables of values, then graph them, and then try … to figure out what the gradient was. But they just didn't get it, even the good kids didn't get it. So … I've got to stand up and say 'Okay, let's look at this more – at what happens here' … So there are some things you need to do as a class, working and drawing out of them and … developing some processes for them that they can use.

4 The relative significance to the goals of the unit of work with regard to 'emphasizing discovery learning, knowledge construction and collaboration'

Following Nurmi and Jaakkola's (2006) argument, the nature of the engagement called upon in the Science program seems to have brought about an advantage for the learning object group over both the control group and the Moodle group. One teacher presented the following case for why learning objects need to be supplemented by practical activities:

12

T I think I discovered, in this particular activity, [that] having the learning objects is great, but you still need to back-up with some practical demonstrations. Because when [students are] actually involved with doing something, rather than just looking, the memory process switches in because there's so many more activities going on in the brain and they memorise things better and they can put themselves in that situation and <u>be</u> the object, and <u>feel</u> the difference of where it goes and what's affecting it … [but] you need some real practical objects, to link to the learning object. The learning object is great, but it's not the end for everything. It [has] a key role, and the practical examples are good stimuli to get them really motivated to go and do what they might do anyway.

There appeared to be no enhancement of learning arising from the use of learning objects within the organising and sequencing framework of the Moodle learning management system. The ability of teachers and students to do for themselves the kinds of work done by Moodle might have been one of the important causes of the relatively more successful learning of Science shown by the learning object group.

There is no attempt here to specify the particular features of the above four factors in accounting for the findings shown in Table 13. That is for a later project with a more specific research design. The hypotheses driving the design of this study related generally to the increased efficacy of learning objects when used to teach more complex concepts (where that complexity is related to multimodalities and to abstraction). There was also an interest in documenting any enhancing or flattening effects of the embedding of learning objects in a learning management system, again with regard to the differential effects of this on more or less complex materials, or to differences in pedagogies typically in place in years 5 and 7 Mathematics and Science. The findings do not give a clear indication of a simple pathway through this set of potentially intersecting variables, but they do point to the need for a more finely differentiated set of contrasting conditions in future research on both learning objects and learning management systems.

Site visits

To meet the requirements of maintaining a repository of best practice, part of the brief prepared for TLF's 2007 research activities, the research team visited 10 schools suggested by senior colleagues or by TLF contact liaison officers as featuring good practice in the use of learning objects and general use of ICT in classrooms. In each case the visit was at the invitation of the school leadership and with the agreement of the teachers. Figure 17 shows the location of the 10 school sites across Australia and New Zealand. The schools varied widely in locale, in the demographics of their catchment area, and in teachers' levels of experience and their classroom innovation. None of these 10 schools had taken part in the field experiment study.

Figure 17: Location of schools visited

For reports of the site visits, including brief descriptions of the context of each school and excerpts of interviews with teachers, see the Appendix. Below is a summary of findings from the site visits.

Findings

1 Secondary schools were less likely to have adopted a whole-school approach to implementation of TLF content than were primary schools. In interviews, the reasons given for the lower likelihood of secondary schools to adopt a whole-school approach to implementation of TLF content were:

a. Secondary school approaches to curriculum implementation are compartmentalised and faculty-based. Their take-up of TLF content usually occurs at a faculty level where an enthusiast (‘champion’) has influence. However, in secondary schools, it is unusual for that person’s influence to extend beyond the faculty.
b. The whole-school concerns of secondary school leaders and executives are oriented to organisational and procedural matters, and only rarely to curriculum matters.
c. At secondary schools, students’ access to computers occurs mainly through sessions in computer ‘labs’ for which computer-oriented subjects are given booking priority. Particularly in bigger schools, most subject areas have very limited access and some subject areas almost none.
d. Interactive whiteboards, found in other TLF research to be drivers of broader ICT-related take-up in a school, are not widely used in secondary schools.

2. At the jurisdiction level there is little cohesive professional development directed to building teachers’ capacity to integrate ICT, and particularly learning objects, into their learning and teaching programs. Checklists for teacher skills and understandings are on offer. Disparate programs, many offered by external providers, focus on building teachers’ capacity to use particular software programs (such as PowerPoint) to support preparation of resources for incorporation into learning and teaching programs; or to use hardware such as interactive whiteboards; or to support student production through means such as Claymation.
3. Some jurisdictions place an emphasis on producing learning and teaching exemplars that incorporate ICT and on fostering ‘lighthouse’ schools. Some schools encourage staff take-up of ICT by mandating computer use for operational tasks such as report writing or marking the roll. Such initiatives, however valuable, do not provide students with curriculum-driven access to ICT or learning objects.
4. While the number of interactive whiteboards in classrooms, particularly in primary schools, is increasing rapidly, teachers’ appreciation of the capabilities of this hardware is often restricted to rudimentary operation. Although interactive whiteboards can powerfully focus a whole class or a group on demonstration and modelling of TLF content, student-managed use of the facility was rarely observed.

Most commonly, the teacher controlled use of the interactive whiteboard, with students taking turns, round-robin style, in moving through the learning object.

5 While there were designated ICT/e-learning positions in most of the ten schools, some were only token positions that existed simply to meet system requirements. To be effective, specialist ICT teachers in primary schools need to work with staff to build capacity in the integration of ICT into learning and teaching programs. Otherwise ICT lessons are directed to developing skills that are unconnected to students' regular class programs. Teachers' confidence is developed through having the specialist ICT teacher model how to incorporate ICT, including TLF content, into classroom programs. In some instances the specialist ICT teacher had responsibility for school-wide selection of TLF content for classroom use, so as to avoid unintentional duplication in the use of TLF content. As Mike Roach of Hamilton Secondary College stated: 'We want to avoid duplication. Otherwise the students will quickly tell you they have used them.'

6 The importance of teachers working together to support one another in acquiring greater confidence in classroom use of ICT was noted in many interviews with school executives.

7 That wider introduction of ICT can drive productive pedagogical change was a notion embraced by many of the schools' leaders and executives interviewed – often expressed in terms of 'catering for individual student differences' so as to provide better learning experiences for all students. The schools that showed evidence of the most progress in integrating ICT into learning and teaching, such as Jervis Bay and Stuart, had all developed a school vision and plan for doing so. Many of the school leaders see their schools 'on a journey' in classroom use of ICT. Some are concerned about the expense of keeping up with the demands of ICT provision.

9 Where schools have taken their communities with them on their journey to integrate ICT into their learning and teaching programs, parents are particularly enthusiastic about it. Of the 10 schools visited, this enthusiasm was particularly evident in the school communities of low socioeconomic status, where parents appear to recognise the importance of harnessing the power of ICT for learning, for the modern economy and for general living.

10 Schools serving communities of low socioeconomic status reported a low incidence of computers in students' homes – but extensive use of Playstations.

11 A feature of the schools that were successfully integrating ICT into classrooms was their planning for professional development in this area and planning for use of ICT resources, both hardware and software.

12 During the site visits a number of teachers stressed the need to familiarise themselves with a learning object prior to using it with students, so as to be clear about its purposes and able to prepare adjunct material to support the learning object. In some instances teachers claimed that this was an essential part of being able to deliver differentiated learning.

13 Learning object content was commonly reported to be versatile, flexible and multimodal. However, many teachers requested a ‘save’ facility so that they could resume the learning object at the point at which they had left it. This facility would be particularly welcome for content in literacy and Studies of Australia. Some teachers and school leaders also valued the learning objects for the new knowledge they gained from them.

14 None of the younger (recently appointed) teachers interviewed had received any pre-service training in the integration of ICT into learning and teaching programs. In some instances their training had extended to simple operations such as developing a PowerPoint presentation.

15 Digital resources other than learning objects were observed in use at only one of the schools, and referred to at another. The slow take-up may be due to the need for teachers to use these stand-alone resources within their own learning design. The increasing knowledge of multiliteracies among teachers may support greater take-up.

16 The provision of adequate hardware in schools remains a significant issue, with evidence of high levels of difference from one school to another. In some schools, hardware is limited to computers in a computer lab while others, such as Schofields, are close to having an interactive whiteboard in every classroom.

Conclusions

Through the use of a carefully constructed field experiment, involving a large number of participants, we have established a positive effect for the use of learning objects in Science, and evidence of advantage in their free and unspecified use over their use within a learning management system such as Moodle. Our hypothesised four factors that would account for variation in the results over year levels, curriculum areas and topics of varying complexity and difficulty to teach, were shown to be relevant. These factors, developed from the research literature and our previous interviews and site visits, were:

1. Teachers' familiarity with the selected content
2. Teachers' approaches to the use of learning objects and/or a learning management system, including their inclination to control scope and sequence
3. Teachers' perceptions of the pedagogical opportunities and limitations presented by selected learning objects
4. The relative significance to the goals of the unit of work with regard to 'emphasizing discovery learning, knowledge construction and collaboration'.

The findings of the field experiment and site visits of this study, combined with the findings of the earlier studies in this series, suggest the likely futility of attempting to make a simple case for or against the efficacy of learning objects, learning management systems, or their combination. If, as Parrish (2004) has pointed out in the case of learning objects, most significant educational problems are not soluble simply by the provision of better technologies, then the kinds of variations found in this study and previous studies are to be expected. They point to the need for more detailed, curriculum-specific and task-specific trials, research, and formal evaluation.

An implication is that further, detailed observations of actual classroom usage now need to accompany the evaluations conducted so far. Among the issues that should be central to an understanding of classroom use of learning objects are the ways in which teachers foreground and contextualise the nature and intended uses of the learning objects in different curriculum areas and for different kinds of learners; the closeness with which they monitor use; the ways in which they recruit students' engagement and their factual or conceptual learning; and the enhanced capacity for transfer experienced via learning objects.

Learning, with or without learning objects, occurs in social, interactional settings, the features of which set up both opportunities for, and limitations on, the possible learning outcomes for students. A major research and development effort should now be directed to how learning objects can afford new interactional features and thereby new kinds of learning, and how those features can be put in place, in various ways, by teachers in various teaching contexts.

An additional major research and development interest arises from the findings of the site visits: how to build ICT take-up, familiarity and confidence among teachers. This issue connects closely with the general research on ICT dissemination and adoption. It also links with the previously stated need for detailed studies of actual and mature use of ICT: it is only through increased dissemination and adoption that evaluation programs will be able to move beyond the scrutiny of immature practice. Until that happens, an appreciation of the potential benefits of ICT innovation, including those of TLF's learning objects, is unlikely to attract the attention of those who determine educational policy and decisions.

References

Abidin, B & Hartley, JR 1998, 'Developing mathematical problem solving skills', *Journal of Computer Assisted Learning*, vol 14, pp 278–91.

Atkins, S & Jones, D 2004, *Considerations for Learning Design*, The Le@rning Federation, Melbourne, http://www.thelearningfederation.edu.au/tlf2/showMe.asp?nodeID=73 (retrieved 6 November 2007).

British Educational Communicational and Technology Agency (BECTA) 2005, *Evidence on the Progress of ICT in Education,* BECTA, Coventry, UK.

Browne, W 2005, *MCMC estimation in MLwiN*, Centre for Multilevel Modelling, University of Bristol, www.cmm.bristol.ac.uk/ MLwiN/download/manuals.shtml (retrieved 6 November 2007).

CEO Forum on Education and Technology 2000, 'The power of digital learning: Integrating digital content', *School Technology and Readiness Report,* Year 3, http://www.ceoforum.org/downloads/report3.pdf (retrieved 6 November 2007).

Cox, M, Abbott, C, Webb, M, Blakeley, B, Beauchamp, T & Rhodes, V 2003, *ICT and Attainment: A Review of the Research Literature*, ICT in Schools Research and Evaluation Series, no 17, BECTA/DIES, London, www.becta.org.uk/page_documents/research/ict_attainment_summary.pdf (retrieved 6 November 2007).

Dori, YJ & Barak, M 2001, 'Virtual and physical molecular modeling: Fostering model perception and spatial understanding', *Educational Technology and Society,* vol 4, pp 61–74.

Freebody, P 2005, 'Does the use of online curriculum content enhance motivation, engagement and learning? The Le@rning Federation trial review', report to Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA), http://www.thelearningfederation.edu.au/tlf2/showMe.asp?nodeID=67 (retrieved 6 November 2007).

Freebody, P 2006, 'Early-stage use of The Le@rning Federation's learning objects in schools: Results of a field review', Ministerial Council on Education, Employment, Training and Youth Affairs (MCEETYA) http://www.thelearningfederation.edu.au/tlf2/showMe.asp?nodeID=891 (retrieved 6 November 2007).

Freebody, P & Muspratt, S 2007, 'The Le@rning Federation's digital resources: A preliminary study of access, use and value', Curriculum Corporation, Melbourne, www.thelearningfederation.edu.au/ tlf2/showMe.asp?nodeID=891 (accessed 6 November 2007).

Freebody, P, Muspratt, S & McRae, D 2007, 'Evaluating The Le@rning Federation's online curriculum content initiative', Curriculum Corporation, Melbourne, www.thelearningfederation.edu.au/ tlf2/showMe.asp?nodeID=891 (retrieved 6 November 2007).

Freebody, P, Muspratt, S & McRae, D (in press), 'Technology, curriculum and pedagogy: Evaluating an online content program in Australasia', in L Lockyer, S Bennett, S Agostinho & B Harper (eds) *International Handbook of Research on*

Learning Design and Learning Objects: Issues, Applications and Technologies, Information Science Reference, Hershey, PA.

Goldstein, H 2003, *Multilevel Statistical Models*, 3rd edn, Arnold, London.

Jamieson-Proctor, RM, Burnett, PC, Finger, G & Watson, G 2006, 'ICT integration and teachers' confidence in using ICT for teaching and learning in Queensland state schools', *Australasian Journal of Educational Technology*, vol 22, pp 511–30.

Jonassen, D 2004, 'Model building for conceptual change: Using computers as cognitive tools', in M Gregoriadou, A Rapti, S Vosniadou & C Kynigos (eds), *Information and Communication Technologies in Education*, New Technologies Publications, Athens, Greece, pp 3–17.

Klar, N & Darlington, G 2004, 'Methods for modelling change in cluster randomization trials', *Statistics in Medicine*, vol *23*, pp 2341–57.

Marzano, RJ, Gaddy, BB & Dean, C 2000, *What Works in Classroom Instruction*, Midcontinent Research for Education and Learning, Aurora, CO.

McCormick, R & Li, N 2006, 'An evaluation of European learning objects in use', *Learning, Media and Technology*, vol 31, pp 213–31.

Mitchell, A & Savill-Smith, C 2004, *The Use of Computer and Video Games for Learning: A Review of the Literature*, Learning and Skills Development Agency, London.

Muspratt, S & Freebody, P 2007, 'Students' evaluations of learning objects: Challenge, graduated difficulty, and interactivity', The Le@rning Federation, Melbourne, www.thelearningfederation.edu.au/ tlf2/showMe.asp?nodeID=891 (retrieved 6 November 2007).

Nash, J, Kupper, L & Fraser, M 2004, 'Using multilevel statistical models in social work intervention research', *Journal of Social Service Research*, vol 30, no 3, pp 35–54.

Nichol, J & Watson, K 2003, special issue devoted to 'Rhetoric and reality: The present and future of ICT in education', *British Journal of Educational Technology*, vol 34, no 2.

Nurmi, S & Jaakkola, T 2006, 'Effectiveness of learning objects in various instructional settings', *Learning, Media and Technology*, vol 31 no 3, pp 233–47.

Ofsted 2004, *Impact of Government Initiatives Five Years On*, Ofsted publication no 2050, Office for Standards in Education, UK, www.ofsted.gov.uk/publications/index.cfm?fuseaction=pubs.displayfile&id=3652&type=pdf (retrieved 6 November 2007).

Owen, JM, Calnin, GT & Lambert FC 2002, 'Evaluation of information technology', in JW Altschuld & DD Kumar (eds), *Evaluation of Science and Technology Education at the Dawn of a New Millennium*, Kluwer Academic/Plenum Publishers, New York, pp 133–64.

Parr, J 2006 *Review of the Literature on Computer-assisted Learning*, Auckland, www.minedu.govt.nz/print_doc.cfm?layout=document&documentid=5499&fro (retrieved 7 December 2006).

Parrish, P 2004, 'The trouble with learning objects', *Educational Technology, Research and Development*, vol *52*, no 1, pp 49–67.

Passey, D, Rogers, CG, Machell, J, McHugh, G & Allaway, D 2003, *The Motivational Effect of ICT on Pupils: Emerging Findings*, UK Department for Education and Skills, London.

Pittard, V & Bannister, P 2005, *Understanding the Impact of ICT*, BECTA, London.

Rasbash, J, Steele, F, Browne, W & Prosser, B 2005, *A User's Guide to MLwiN,* version 2, Centre for Multilevel Modelling, University of Bristol, www.cmm.bristol.ac.uk/MLwiN/download/manuals.shtml (retrieved 6 November 2007).

Rausch, J, Maxwell, S & Kelly, K 2003, 'Analytic methods for questions pertaining to a randomized pretest, posttest, follow-up design', *Journal of Clinical Child and Adolescent Psychology*, vol *32*, no 3, pp 467–86.

Russell, M, Bebell, D & O'Dwyer, L 2005, 'Tracking the arc of new teachers' technology use', in C Vrasidas & G Glass (eds), *Preparing Teachers to Teach with Technology*, Information Age Publishing, Greenwich, pp 45–63.

Snijders, T & Bosker, R 1999, *Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modelling*, Sage, London.

Spiegelhalter, D, Best, N, Carlin, B & van der Linde, A 2002 , 'Bayesian measures of model complexity and fit', *Journal of the Royal Statistical Society, Series B*, vol 64, no 4, pp 583–639.

Vrasidas, C & Glass, G (eds) 2005, *Preparing Teachers to Teach with Technology*, Information Age Publishing, Greenwich, pp 45–63.

Walton, M & Archer, A 2004, 'The Web and information literacy: Scaffolding the use of Web sources in a project-based curriculum', *British Journal of Educational Technology*, vol 35, pp 173–86.

Wiley, D, Waters, S, Dawson, D, Lambert, B, Barclay, M, Wade, D & Nelson, L 2004, 'Overcoming the limitations of learning objects', *Journal of Educational Multimedia and Hypermedia*, vol 13, pp 507–21.

Appendix: Reports of visits to school sites

Anula Primary School

Anula Primary School is a 20-minute drive north of the centre of Darwin. The school has 498 students of whom sixty-six are Indigenous and ninety-eight are refugees or other recent arrivals in Australia whose first language is not English. Altogether, 45 per cent of the school's enrolment is from non-English-speaking backgrounds. These students may spend up to 12 months in Anula's Intensive English Unit, after which they may choose to stay at Anula or transfer to a school nearer their homes. The student population is spread across the socio-economic spectrum.

Classes are organised on a composite basis that is designed to accommodate a diverse and transient student population, a practice that is commonplace in the Northern Territory, where it is usual to have such school populations.

Sandy Cartwright, the school's principal since April 2007, had previously occupied a senior position in the central office of Northern Territory's Department of Education Employment and Training.

After struggling to build its information and communication technologies (ICT) infrastructure the school is now working to progressively incorporate ICT into its learning and teaching programs. However, while all teachers are now required to use computers to record student attendance, there is still some distance to go before all teachers are using ICT for learning and teaching.

Recently the school has acquired four laptop trolleys that together provide 40 laptops to supplement the three computers in each classroom, and four interactive whiteboards. Some teachers' meetings are now conducted using an interactive whiteboard.

Sandy visits classrooms to work with teachers and demonstrate ways of integrating ICT into the learning and teaching program. She says:

> You need to get the hardware right, get the access right and then link back to the curriculum. It must happen as part of the classroom program, not as an extra [that is] apart from that program.

Sandy explained that integration of ICT into the school's learning and teaching program was occurring 'bit by bit'. With learning teams having been set up to analyse and recommend action in areas such as Data (related to students' performance) and

Students' portfolios. Sandy is keen that there be a team for ICT. However, there have been no volunteers so far. Sandy said. 'I'm not pushing it'.

At the time of our visit, two of Anula's teachers were undertaking the Action Learning with learning objects (ALLO object) professional development program. With a view to building school-wide capacity in the use of learning objects, a condition of participation in this program provided by Northern Territory's Department of Education Employment and Training, is that at least two teachers from the same school join in the program. Participating teachers attend four workshops, each of two days duration, over one semester, during which they devise a plan and implement it within their school. The resulting stories are posted on the Explore NT learning management system, which is accessible to all Northern Territory schools. On completion of the program, participants can opt to become peer mentors back in their schools.

Cassy Coggins, Northern Territory's Project Manager Learning Technology, declares that from the first day of the program, the teachers are keen to use The Le@rning Federation's (TLF) online curriculum content.

Use of TLF's learning objects

Years 5 and 6

We observed a lesson taken by Matt Bennett, who teaches years 5 and 6, and who is one of the Anula teachers undertaking the ALLO program. He was using the Mathematics and numeracy learning object 'Dice duels', which comprises a set of dice-based tutorials, activities and games that enable students to explore concepts of even and uneven distribution and bias, using dynamic, interactive tools. He commenced the lesson by using the interactive whiteboard (installed in his room at the same time as he had begun the ALLO program) to walk the students through the learning object, after which they completed it individually. Matt commented:

> It's fantastic … they want to get up to touch it [the whiteboard], be the person controlling it. Then they write up their results individually, including the graphing. They would have really struggled to do the work and grasp the concept as well as they did without the learning object. The points of discussion it [the learning object] gives you, as the kids go through, give them just what they need.

Years 4 and 5

We also observed a lesson taken by Jennifer Lobb who teaches years 4 and 5. She had participated in the ALLO program in the previous year. Originally trained as a librarian, and now in her third year of teaching, her teacher training had not prepared her for integrating ICT into her learning and teaching program. However, the assistant principal in the year when she arrived at the school supported her in doing so. Now she is undertaking a Masters in Education, specialising in ways of integrating technology into the classroom.

> I'm not very good at the technical side. At first, I could see the value of them [learning objects] but I couldn't see how I was going to incorporate them. I started using Learning Activity Management System (LAMS).

Later, when Sandy arrived as principal, she encouraged Jennifer to use E-space, the learning management system used by Northern Territory schools. Jennifer now has E-Space up and running by the time her students arrive at school each day. It outlines all the activities for the day, along with Jennifer's selected links to TLF content. As 90 per cent of the students in that class have home access to their class's section of E-Space, they can share their work with their parents and readily access the chat room that is provided.

On the morning of our visit, Jennifer's class was using 'Dream machine'. Jennifer was sitting behind her students, who were clustered on the floor around the interactive whiteboard that is mounted on the wall as the focal point of the open-plan classroom. She read the modelled text and invited various students' responses, using the keyboard as they worked their way through. There was discussion of grammatical features such as noun groups and how they function to create similes.

Jennifer reported that she and the class become frustrated when they are unable to save their work at particular points in the progression of the learning object. She added that she would like to have more oral language or sound facility in the learning objects, and to have more English material that is 'short, sharp and with a sting'. Of TLF's learning objects generally, Jennifer stated:

> They are engaging, grab students' attention and fit in with the curriculum … [It's important that] you … build something around them, not use them just as time fillers.

To help her find suitable content, Jennifer uses the catalogues on TLF's website and also the 'What's new' section of the website. Once she has the numerical identifier for the material she wants to use, she retrieves it from Explore NT, Northern Territory's repository of TLF learning objects for its schools.

Eaglehawk North Primary School

We are a ‘YOU CAN DO IT’ school, proclaims the prominent notice at the front of the original school building of 1871. A substantial freestanding modern building was added in 1990 and now there are further (relocatable) classrooms on the site.

Eaglehawk, an old gold mining town approximately two hours from Melbourne, has its own identity even though it is now an outer suburb of Bendigo. John Morton, the school’s acting principal, explains that ‘You can do it’ is a program aimed at embedding in students the attributes of persistence, confidence, organisation, emotional resilience and getting along.

The school serves a diverse community, drawing its enrolment of 351 students from beyond Eaglehawk to Bendigo itself, and from the surrounding countryside. With high levels of unemployment in Eaglehawk, 40 per cent of students in the school are deemed eligible for the Education Maintenance Allowance (extra funding from Victoria’s Department of Education and Early Childhood Development for students from low socioeconomic backgrounds).

The school has a large computer lab with a projector, screen and 26 computers for its 351 students. The 15 classrooms also have computers (eight computers for each of the year 6 classrooms and six each for most other classrooms). There is one data projector for every two classrooms. Interactive whiteboards are located in each of two classrooms and interactive palettes, which are portable between classrooms, are also available. The school plans to increase this type of infrastructure. The school uses Microsoft SharePoint to facilitate collaboration, provide content management features, implement business processes, and supply access to information that is essential to organisational goals and processes; and school staff are able to access it from anywhere in the school. Teachers store their units of work on Microsoft SharePoint, where it is accessible to all staff. All formal staff communication is via email.

This school has been participating in the CeLL (Creating eLearning Leaders) Initiative, a partnership between the Victorian Department and Microsoft, in which the participating 28 schools and clusters are provided with professional learning via conferences and leadership forums, and opportunities to explore emerging technologies such as personal digital assistants and interactive white boards.

All members of the school teaching staff have also participated in Intel's Teach to the Future program, a modular professional development program that emphasises integration of ICT with pedagogy.

Principal John Morton believes that any pockets of resistance to integrating ICT into learning and teaching need to be brought on board through strengthening the culture of the school. He opposes having either technicians or ICT fanatics making decisions about the school's teaching and learning practices. Regarding the school's ICT infrastructure, he says:

> You need to be careful and realise what your needs are … You don't always require heavyweight equipment. Some people want Rolls Royce equipment for minor tasks.

For successful take-up and integration of ICT, John recommends the following:

- ICT integration must be valued by the leadership in the school.
- Its potential must be demonstrated to the staff.
- Budget allocations must support the equipment working well.
- Good practice must be acknowledged and recognised.

John points out, however, that successful take-up and integration require time and professional development, citing the leasing of notebook computers, on a three-year replacement cycle, to eligible principals and teachers (with regular contribution fees taken automatically from pre-tax salary) as having been the single most important measure.

> It has happened gradually but it has made teachers confident.

Use of TLF's learning objects

Helen Forrest, the school's ICT coordinator, has been a significant influence in having all Eaglehawk North classes implementing TLF's content into their learning and teaching programs.

In relation to The Le@rning Federation's digital content, John maintains:

> Teachers need to realise the potential and know how to integrate it into the classroom to get the best learning outcomes.

Years 5 and 6 – Bronwyn Coffey

Bronwyn Coffey, whose teacher training did not include ICT use, has been teaching for seven years. On the day of our visit her years 5 and 6 class of 24 students was working on a unit of work, 'Flight fever', that incorporates a host of ICT-based activities that includes making a digital flight tag for their suitcase, their own in-flight entertainment using ‘Super Dooper Music Looper’ and an Internet page to attract customers to buy this flight. They were using TLF’s learning object, ‘Heroes of the air’ in which they learn about two famous flights made by Charles Kingsford Smith and his crew: the first trans-Pacific flight (1928) and the failed trans-Tasman flight of 1935. Content of the flight logs includes photographs, archival moving images and audio files. As follow-up, Bronwyn had prepared an activity sheet on which students recorded the main items of information about Charles Kingsford Smith.

Bronwyn accesses TLF content through the school server and through digiLearn (the Victorian Department’s portal for government schools). She thinks the strengths of TLF content are their interactivity and their combination of text, sound and moving image. She commented:

> This is how many children learn and it caters for different learning styles and stages of learning.

Within her Mathematics and numeracy program, Bronwyn was using the learning object ‘Arrays’, which supports the shift from additive to multiplicative thinking, allowing the exploration of factors, multiples and associated number properties that underlie effective multiplicative strategies. She was able to work intensively with less able students on the learning object that deals with lower numbers while more able students worked independently on more challenging learning objects that deal with higher numbers. Bronwyn stated:

> I use them [learning objects] to boost the learning and teaching program … because they can cater to different learning needs.
>
> It is essential that you go through the learning object before you use it. I can’t help kids out if I don’t know what’s happening. I have to think it is really user-friendly. We all learn by doing, not by reading miles of instructions.

She said that integrating ICT into her teaching had changed her mode of teaching, but warned:

> If your teaching style is one where you’re talking, you’re directing, you’re out the front all the time – then it’s hard to let go.

During a ‘Kids Congress’ hosted by Eaglehawk North Primary School, at which students from surrounding schools came together to share ideas about ICT use, Bronwyn observed the high levels of capability of demonstrated by the students. She places great importance on ensuring that students are able to transfer what they know and learn to other contexts. She continually assesses her students’ progress so that she knows where they need to go next.

Years 5 and 6 – Jason O'Neill

Like Bronwyn, Jason O'Neill is an Intel master trainer. The Intel Teach program is a model that supports a whole-school approach to the integration of ICT across the curriculum by training a master trainer who then returns to their school or cluster of schools to train ten other teachers. The upgrade of his laptop computer (in line with the three-year turnover scheme conducted by the Victorian Department) gives him personal access to TLF content – a feature of the Department's notebook initiative.

A teacher for nine years, Jason's years 5 and 6 class is also working on the topic of flight. During our visit Jason was working with a group of eight, all seated around a table for shared reading about the life of Amelia Earhart, during which features of the text and students' responses to them, were being discussed in detail. Other members of the class were working at the various classroom computers or independently at their desks.

Those working at the computers were using TLF digital resources Jason had inserted into a Microsoft PowerPoint presentation. Students were required to look at each slide, consider what is happening in each, investigate each image, and respond to questions on an activity sheet. Students would search the Internet for information to support them in this activity. Jason encouraged them to use the flight word booklet he had developed for this topic, and to recall the learning object they had used the previous day, 'Heroes of the air'. Once students had completed the work associated with each slide, they could edit the colour and backgrounds, but 'Don't go overboard' the activity sheet recommended.

One of the students, Braydan, thinks working with the slides is good because he gets to do two things at once – look at the slides and type. He says:

> I'm not a fast typer.

Dale declares:

> This is a lot more fun than just sitting down and writing stuff.

Ethan claims:

> It's a bit different. You get to see things you wouldn't usually see and get to describe it. I like working like this.

Tegan states:

> You only have a little bit of information and so you have to search for the rest. You really have to think about it.

Jason thinks that his students gain the most enjoyment and benefit from those learning objects that have minimal text, that are interactive and that provide intuitive learning pathways. As students have a shortcut on the school computers to TLF content, Jason encourages his students to select and suggest particular learning objects for particular purposes. He commented:

> Emma found ‘Decimaster’. It is good for consolidating some of the work we have done on fractions.

While he found some of the audio resources to lack clarity of sound, he thinks the strengths of the digital resources are their capacity to take students back in time through, for example, showing them features of styles of clothing, which students can then compare and contrast with those of today.

> I don’t think kids today care too much about where we’ve come from. They’re a here-and-now generation. The digital resources can provide greater appreciation.

Hamilton Secondary College

Hamilton Secondary College, located in the suburb of Mitchell Park about 20 minutes south-west of Adelaide by car, incorporates a middle school (years 7–9), senior school (years 10–12/13) and a purpose-built specialist centre for years 7–13 students who have severe and multiple disabilities including significant intellectual disabilities. On four nights of the week the school also conducts an adult campus where students from 18 to 60 years of age can undertake secondary-school and vocational courses. Originally Mitchell Park Boys Tech, the college will celebrate 50 years of educational provision in 2008.

The college draws its daytime enrolment from the south-west corner of Adelaide and its evening enrolment from much further afield. Of a total enrolment of just over 400, 16 per cent have non-English speaking backgrounds and 50 per cent are school-card holders (from low-income families who are entitled to financial assistance with educational expenses from South Australia's Department of Education and Children's Services). Now that housing trust accommodation has been demolished and replaced by medium-density housing, an increasing proportion of the enrolment is from more affluent families.

So far, implementation of The Le@rning Federation's (TLF) online curriculum content in the school has been confined to the Science faculty, where Mike Roach (a recipient of the Prime Minster's Prize for Excellence in Science Education) has been an early adopter and enthusiast.

Principal Doug Moyle thinks it unfortunate that implementation of TLF's digital content has been left to each State and Territory:

> All we got was a folder, early this year, with a DVD and an invitation to obtain a site log-in for Digital Learning Bank from the South Australian Department of Education and Children's Services. The strategy we used was to try and provide training and development to our leaders so they could pick what was suitable. I don't think that happened successfully.
>
> The notion of this just landing in schools is an inadequate implementation strategy. Teachers in general were not sitting around waiting for this to happen. Many of our teachers are in their later years of teaching, fully satisfied with what they teach and how they teach. The establishment of e-teachers and LTI (Learning and Teaching with the Internet) coaches preaches to the converted … and they are not hitting the target of those who are satisfied with what they are doing.

Malcolm Hughes, assistant principal for the senior school, agreed. Instead of a top–down model, he recommended a teacher-to-teacher model accompanied by examples of how teachers are successfully using 'the stuff'. He commented:

> You need to grow it from the teacher level sideways.

Growing teachers' competence through having teachers work together and able to take away something they can use in their classrooms was stressed as a successful approach to developing teachers' familiarity with ICT-based pedagogies.

Doug thinks that the current review of the middle school, during which students will be engaged in 10-week-long units for which they will be provided with greater choice and more personalised learning, lends itself to incorporation of TLF content. He has asked for examination of how such ICT integration could occur. He says that while ICT use has changed administrative systems in schools. it has not achieved a similar level of change in curriculum. He sees curriculum leadership as now requiring leadership across a broader area than just management.

Use of TLF's learning objects

Year 10 Science

Mike Roach has been teaching for 35 years, eight of them at Hamilton Secondary College. He is involved in conducting professional development outside this school as part of the Learning and Teaching with the Internet program in the areas of Maths and Science, and in using the Moodle learning management system, where all course content and resources are stored. Through the Australian Science Teachers Association (ASTA), in 2002–03 he took part in writing and trialling some of the early TLF Science learning objects. He is currently working with ASTA (with funding from the Science, ICT and Mathematics Education for Rural and Regional Australia project, a national project supported by the Department of Transport and Regional Services) to provide professional development for rural and remote teachers' use of TLF content.

On the morning of our visit, Mike's year 10 Science class was using the learning object 'Wind farm' as part of a unit of work. In the scenario posed by the learning object, the government wants to build a wind farm in the Hinton district. Students are asked to investigate the pros and cons, drawing on various sources of information including local opinion; and then to decide whether or not a wind farm is the best solution.

Rather than have students use the notebook facility that's built into the learning object to enable students to print a copy at the completion of the object, Mike asked his students to write a detailed summary of each stage (an assessment task) in a separate Microsoft Word document saved to the class's section of the school network. Students could work in pairs and were encouraged to quote the person interviewed and record the facts collected to support their argument, as they went through each stage of the learning object.

At the front of the classroom was a data projector and screen. The middle of the room provided seating and tables. Around the perimeter were 13 computers. All students were engaged with the learning object and appeared very interested in the task they were undertaking. Russ and Nick claimed they enjoy learning like this:

> It teaches you in a fun way. Learning out of a textbook is boring. It [the learning object] makes learning easier.

Jessica stated:

> You get to learn in a better way. We get to like type rather than always writing in our book.

Adam claimed:

> It makes it easier to get an understanding of the knowledge. You get involved in it a bit more as you can actually see what is happening.

Mike also uses learning objects from the Mathematics and numeracy collection, including 'Exploring the laws of exponents' in which students examine the seven laws of exponents (such as the product law and quotient law), adjust variables and explore patterns in the number operations, and identify the order of operations for equations involving exponents. Students solve a group of expressions to uncover dinosaur bones on a dig site and apply all the laws of exponents to uncover four complete dinosaur skeletons. Mike said:

> I reckon I've taught it in half the time I would usually take to teach exponents thanks to the learning object. They [learning objects] are an alternative way of presenting information and knowledge and can be used to reinforce learning in an interesting way. If, for instance, there is a game where students need to use their knowledge, then there is a purpose and that will intrigue them. They make Science look modern.

Mike commented on the importance of getting value from the learning objects through carefully planning why and when to integrate them into classroom programs. Otherwise they can be used just as time-fillers, which he regards as an abuse of these resources. As well, he said:

> We want to avoid duplication. Otherwise the students will quickly tell you they have used them. It's important that we wrap professional learning around them. It's also important that we make ourselves thoroughly familiar with them before we use them.

Jervis Bay School

At this unique primary school situated in Booderee National Park, wallabies graze on the school oval and the bay itself glistens in the background. The school is administered by the ACT Department of Education and funded by the Australian federal government.

Principal Jan Carr describes the school's enrolment in terms of students' families: 16 families from Wreck Bay Indigenous community and 12 from *HMAS Cresswell* – the Australian Navy base situated very close by. A pre-school with an enrolment of 32 is attached to the school. Indigenous education assistants work in each of the five multi-age classrooms and also in the pre-school.

Alyson Whiteoak, the school's special needs teacher who also manages information communication technologies (ICT) at the school, builds staff capacity to integrate ICT into learning and teaching programs through, for example:

- preparing resources for teachers
- demonstrating how to integrate ICT in classrooms
- arranging for designated time at staff meetings for focusing on ICT
- conducting a drop-in café after school for discussing and dealing with teachers' individual ICT needs.

When Alyson surveyed the staff early in the year, the main factors limiting staff use of ICT were stated to be lack of professional development opportunities (31 per cent of all staff) and confidence in their own ability (26 per cent). As well, said Alyson:

> It opened my eyes because a lot of people still saw technology as being word-processing and how to do a spreadsheet. So the main focus for me has been how we integrate and use it as a teaching tool.

The YWCA was asked to run a series of workshops to support the teaching assistants in the use of computers. Alyson explained:

> We actually thought it was better to have an outside body come in … because sometimes that has more weight. It's actually nice to have an outside person come in. They look at it differently.
>
> I've found the best process in getting people to actually incorporate the technology is to go in and model a lesson and show how easy it is and how the kids engage. I also find that preparing resources for people is a really great idea as well because they get the confidence using it with the kids. They see the results and they're more willing to have a go.

Alyson has a strong background in ICT, having had what she described as a 'really inspirational computer teacher at high school' and also having an honours degree that included ICT technology as an area of study. Even so, in the previous year, her attitude to classroom use of ICT was turned on its head when an influential person in the ACT Department of Education and Training introduced her to a universal design approach to learning, which offered a very inclusive approach.

Regarding implementation of The Le@rning Federation (TLF) content in the school, Alyson commented:

> We've had the network put in and we've had six months to play with it. Now it is time for that next evolutionary step. We're very lucky we have staff who are so willing to change. They are very accepting of change and of looking at their practice and improving themselves for the students. The school uses the Myclasses learning management system and has been supported in the introduction by TLF Contact Liaison Officer Mark Huxley.

Jan Carr outlined the strong emphasis in the school on literacy and numeracy and the time dedicated to improving outcomes in these two areas for all students. Embedding ICT in the everyday curriculum has also become an ever-increasing focus. Jan said:

> Students will use computers with the same ease for learning in the future as they do with a book and a pencil today.

It is hoped the school will become the focus of ICT learning within the community. This is already underway with TAFE classes for community members now being conducted in the school's computer lab. The school has a particularly important role in its students gaining ICT skills and knowledge as most of its students do not have access to computers at home.

The school has four computers for every five students (which includes the 10 computers in the lab); an interactive whiteboard in each classroom, the library and the preschool; and four digital cameras for students to use.

Use of TLF's learning objects

Years 2–4

On the morning of our visit, Alyson was using the TLF literacy learning object 'Dream Machine: similes' with Lagoon class, the name for the years 2–4 class. She was guiding students to recognise and use similes to create imagery that enhances the meaning and aesthetics of their writing, in this case, in relation to a bike of their choice. They were also learning about the structure and grammatical features of the description genre. The practical task of ordering a customised bike resulted in each student obtaining a printout of their individual description.

Years 1 and 2

During our visit, Caz Soeters had the Penguins (years 1 and 2) whose morning's lesson was about 'sharing; making sure things are fair'. Caz had the whole class engage in a modelled activity in which treasure is divided fairly among three children. Next, a student divides lollies between two other students, again to ensure fair shares. One group of Caz's class then engaged in a game at their desks, while the others worked on the learning objects 'Divide it up: kittens', in which students interpret a division problem (stated in words) and its solution. They are supported in this task by a tool that models the sharing (division) process and a scaffolded sequence for dealing with remainders of 1. All students appeared engaged as they worked through the learning object.

Pre-school

Vicki Fortescue, the pre-school teacher, had selected the learning object 'Playground rules' in which children in a local playground do not appear to be getting on well together: one child is refusing to share; another is stealing food; one is making fun of another; litter is scattered on the ground; and one child has been left out of a game. As students select each situation they are asked to suggest ways of addressing the concerns. When they have selected their responses, the consequences of their decisions are revealed in the playground setting. Students then arrive at a set of playground rules that promotes sharing, participation and consideration of others.

In Vicki's use of 'Playground rules' on the interactive whiteboard, she encouraged her students to select one of the pictured problems and to articulate the nature of the issue, before having that issue demonstrated; and in the same vein she encouraged students to propose a way of dealing with the issue, before having the consequences of their choice revealed. Students took turns in using the whiteboard, using a step to help them reach it.

Three parents whose children attend the school were there to discuss how the school was moving towards integrating ICT into the curriculum and the associated use of TLF content.

Parent Bev Ardler had the following comments:

> I'm a worker here as well [as a parent] and I don't just parent my son, I parent the mob. Personally from my point of view, being the Indigenous worker here, it's a great way of documenting history and maintaining the connection with the oral history through technology. We've been working with the kids on doing that, and sharing stories with their families – sharing their own personal stories and recording them and making talking books out of them. It's something that's definitely needed in Aboriginal culture – to

> have that history documented. Otherwise it just gets lost. Research has shown that it just gets lost down the line eventually.
>
> For a lot of those parents, [when they were] growing up they wouldn't have had exposure to those sorts of things [ICT], so the kids are teaching the parents. It's not just the parents teaching the kids all the time – and the kids are much more confident to use the hardware and the software.

Parent Felicity Sander said:

> A lot of our kids come from backgrounds where their parents are working with computers or high-tech weaponry or their dad has a BlackBerry, so for parents to then see the children are being taught in a safe environment at school at a level that's appropriate to them is great.
>
> For my son who is in year 2, this is right up his alley. My daughter would rather read a book, but he wants to be on the computer and for him to build that confidence is great. Kids being kids, they're not afraid of breaking it, so they will go that extra mile whereas we wouldn't.
>
> To have all his questions answered on the spot [with] 'this is how you can do it', and being able to repeat things over again I think is such a safe way for them to learn. I know that everyone has been very conscious of appropriate and inappropriate use of content. As a parent I'm really relaxed knowing that when my kids are at school … they're not going to come across things they shouldn't.

Sharon Roberts, another parent at the school, had this to say:

> I'm also a parent of Indigenous children. I personally feel that particularly here at our school we cater for the needs of the Indigenous kids. They are hands-on learners, and not pen-and-paper learners. I feel that with the SmartBoards that we have in the school – and we do have them in all the classrooms – there is more visual learning and that's obviously how to support Indigenous kids to learn. You can see that they are coming along in leaps and bounds now, compared with past generations.
>
> I also feel that with our high number of computers within the school you know that kids have access to the computers everyday in their classrooms. Also, we have a computer lab which is opened everyday at lunchtime … it's good to see them coming into the library at lunchtime and actually following up what they may have been learning in the morning – in their own spare time choosing to actually learn and continue learning on the computers in the computer lab.
>
> They do that often at home too. With their own personal passwords they have access to Myclasses. Those who have their own personal computers get on there and show Mum and Dad or whoever is at home at the time – show them what they're actually doing.

The parents all agreed that the support of staff, particularly Alyson who stays back on Thursday to run the Internet café, has been a huge help. She has also been supportive in helping parents choose appropriate hardware and software. A discussion follows on the merits of email – its importance for linking the home and the school, particularly for the senior students.

Felicity provided a defence family's perspective:

> Our kids will come in for maybe a two-year posting and then they could go anywhere overseas or anywhere in Australia. It's important for defence kids because every two years they feel their life is a completely wiped-clean slate and they've got to start afresh again. Having a computer link, email … is wonderful for our kids.

Felicity had a final commendation of the school:

> My children went to another school, which was much more expensive, in a really affluent area in Perth. That school's got nothing on this school.

Mater Hospital Special School

Principal Vicki Sykes has held the position at this school for 20 years. The school has used information and communication technologies (ICT) for at least 10 of those years. The special needs of its school-age students from both government and non-government schools all over Queensland requires special staff for this Education Queensland facility.

Some students have mental health issues, some others have very fragile medical conditions, others attend the school because they have a parent or sibling who is hospitalised and the family lives outside Brisbane, and yet others, who have returned home, are still unable to attend their mainstream school and so continue to attend the Mater school. The duration of a student's enrolment at the school varies with the nature of their condition, with some enrolled for long, continuous periods while others attend on and off over their whole school life.

Vicki emphasises that the teaching staff need to be professionally flexible for the school to be able to cater for the range of students' needs. They also need to be emotionally resilient. She explained:

> Working with students with acute and chronic medical conditions is emotional. It's not everyone's cup of tea.

With the school staffed according to the average number of daily attendances, staff numbers fluctuate from year to year.

Although the Mater's educational service has existed since 1963, the school's facilities are new and attractive, part of a new children's hospital built only four and a half years ago. Vicki says:

> We are lucky to have a ground-floor position so that the children can have an outside play area.

Space is very tight, however, with one area serving as a staff room, a teacher area, and a kitchen for staff and students.

The school is unable to have wireless installation for computers because it interferes with the monitoring devices of some patients – although the issue is currently being re-examined.

The school has three teaching spaces: one for the early years, one for the middle years, and one for the secondary years. While many students attend the school in beds and wheelchairs, those who are unable to leave their wards are taught in the wards where there are teaching cupboards with laptop computers and other equipment for learning and teaching.

When students commence at the school, and again before they return to their mainstream school, the Mater teachers contact the teacher in the mainstream school to give support to both the student and the school in making the transition. When students return to their mainstream school, Mater teachers may even visit the school, accompanied by a medical person if need be, to run class sessions for fellow students – which can be particularly important if the student–patient has noticeably changed in appearance or behaviour during their absence from the mainstream school.

Use of TLF's learning objects

Because teachers at this school teach across years P to 12 and so require extensive curriculum knowledge, the school is staffed by highly experienced and proven teachers, which was evident in all the lessons we observed at this school. The knowledge and skills of the teachers we observed using The Le@rning Federation's (TLF) content as part of their lessons was exceptional.

We observed Roberta Matlock using 'Nu Minh', a learning object from the Studies of Australia collection. She used a mimio device to transform an ordinary whiteboard into an electronic one – the focus for a wide-ranging discussion of migration and various aspects of culture – during which Roberta constantly extended students' thinking through excellent questioning techniques.

Roberta believes that learning objects are a tremendous way to engage visual, auditory and (when used on an interactive whiteboard) kinaesthetic learning styles. She commented:

> By inviting children to pursue their own curiosity we provide increased opportunities for all students to access the curriculum more readily, leading them to increasingly complex knowledge and sophisticated thinking. When used as primary teaching tools, learning objects provide a powerful opportunity to teach vocabulary and key concepts by linking with children's own life experiences. Learning is best done when a connection between the learner and the curriculum exists – and learning objects facilitate such connections marvellously.

Roberta prefers learning objects that have open-ended responses as they elicit fresh and sometimes even amazing insights and ideas, opening students' minds and enabling teachers and students to build knowledge together. She maintains that because open-ended responses encourage students to see that there is no one opinion or way of considering situations, they encourage acceptance of diversity. She regards learning objects as flexible teaching resources that can accommodate a wide range of individual learning needs.

Annette Keogh’s middle years group was investigating the life cycle of a frog. The lesson started with discussion about where frogs lay eggs. Then Annette presented a box, the contents of which were a mystery, and played a very lively ‘What am I?’ game, in which students asked Annette questions directed to finding out what was in the box. Their questions served to develop and refine their knowledge about the item in the box, with Annette giving the green light to any suggestion that was correct even in a general sense. Eventually Annette revealed that the box contained a model of the endangered species called the Northern Corroboree Frog. Class discussion of the meaning of ‘endangered’ was followed by explanations of why such animals are losing their habitats and how such habitats can be protected.

Three groups then went to work, one group using TLF’s learning object ‘Where frogs lay eggs’, another making an origami frog from cardboard, and the third cutting out labels and applying them in the correct position to a diagram showing the life cycle of a frog.

Following the lesson Annette made the following comments on her use of learning objects:

> High-needs students require one-to-one attention. Learning objects enable me to support independent learning for students at all levels. I select levels that are appropriate, engaging and interesting for each student.
>
> Learning objects, particularly those that have voice prompts, support students who are reading at levels lower than their chronological age.
>
> Printing each student’s work enables me to create a folio of their learning progress.
>
> I always have a defined purpose for using [any learning object] for any particular lesson.
>
> The voices are Australian. That’s important to us.

While the Mater school sees its primary obligation as supporting the program that students bring from their home school, they run a parallel Mater Hospital School program that complements the home-school program and provides cohesion for the students while they are attending the school.

Curriculum planning for the early years and middle years takes the form of units of work that integrate various key learning areas, but with core outcomes delineated for each key learning area. Denise Bond, who is responsible for ICT support at the school, explained:

> Once we have an outline of where we are heading with our term's planning, I then search for appropriate ICT resources such as learning objects and digital resources.

Denise arranges for the selected resources, including TLF content sourced from Education Queensland's Curriculum Exchange, to be on the school's intranet where they are readily accessible to all teachers. She also searches for TLF content and other content to support students' programs in their home schools.

Comprehensive planning for this school, covering whole-school concerns and also specific year groups and individualised learning, is well documented. Vicki commented:

> We go through a reflection process on a regular basis. It's the way we do our curriculum. It's the way we do our review process.

Among the biggest challenges this school faces, Vicki says, is the transient character of its enrolment, which requires getting a program up and running quickly for a particular student, and being able to assess the level at which a student is currently performing.

She thinks that requirements for successfully integrating ICT into learning and teaching are those for successfully managing any change, which are:

- a leader in the administration or a senior position who is committed to the change
- a school culture that is open to change
- high-quality planning of the process.

Rata Street School

Rata Street School, situated in the lower Hutt Valley about half an hour's drive from Wellington, was built in 1951. Within New Zealand's system of decile ranking to denote the socioeconomic level of the students who attend a particular school, ten is the highest level. Rata Street School ranks the lowest, with a score of one. Principal David Appleyard explained. 'the local area that serves the school is predominantly a benefit-driven economy'. He also comments on the school's richly multicultural enrolment: of its 400 students, 30 per cent are Pacifica and 40 per cent Maori. About 20 per cent of the student group, some of them recent arrivals from Africa and Asia, require intensive English language learning.

Like all New Zealand schools, this school has a Board of Trustees that employs the school's staff and has responsibility for the school budget. While the Ministry of Education pays teachers' salaries, each school Board has some discretion in allocating duties. Rata has two deputy principals, neither of whom is a classroom teacher, and who instead work with teachers in their classrooms.

Since 2000–03 this school has emphasised ICT use, with the focus for the past two years mainly on literacy. David said that as a result of data derived initially from the local high school, they realised:

> We've got to do something different. We're tracking way below national means. [Students'] entry literacy levels were so low that the teachers have to 'super teach'. It's exhausting. It means every day you have to be on your game. We have to break this pattern. To do this we need to stay focused and avoid other emphases. Otherwise it's too hard on staff and it waters down the effect of their professional development.

To support that focus the school has the help of Melanie Winthrop from Learning Media, an organisation contracted by the New Zealand Ministry of Education to provide professional development, using an inquiry-based approach that is directed to building teachers' knowledge through observation of their practice and scrutiny of the evidence.

Glenda Stewart, the school's deputy principal and leader of years 3–6, explains that The Le@rning Federation's (TLF) literacy content fits really well with the class literacy program and also provides support in building the teachers' ICT capacity. While the school has used the DVD (produced by TLF and distributed by the Ministry of Education) to access the learning objects, Glenda comments that 'the trouble is finding stuff'. She suggests that aligning TLF content with Assessment Tools for Teaching, a criterion-referenced set of indicators derived from the New Zealand curriculum, would be very helpful.

Glenda leads a weekly syndicate meeting for the years 3–6 teachers. The meeting starts at 3.15 pm and they try to finish by 5 pm. Learning objects to enhance literacy learning are selected and they work through them at the meeting, as a team. At the next meeting, the teachers report on their use of these learning objects. Glenda reported that teachers experience frustration with not being able to save what they have done in a lesson and then return to their point of departure; and also in having to always start at the beginning of the learning object in order to access the section they want.

David, who also works alongside teachers in their classrooms, explained that funding is the biggest challenge for him in providing ICT resources.

> [The budget] not a bottomless pit. The frustration is keeping up to speed with what teachers need, because if they experience frustration [with ICT] they won't use it. So it's a juggling act. Every class would like a digital camera, but it's not possible – so they have to share one between two classrooms.

As far as building teachers' capacity to employ ICT in their learning and teaching programs, David takes the view that school-based professional development is the best route to obtaining maximum impact. At the start of each term, staff members identify their ICT needs via a brainstorm, after which school workshops are organised or support is delivered where needed.

Glenda echoed David's sentiments about professional development, adding:

> We can talk to him. We are not battling to try and convince him. Together we are all analysing, interpreting and using data to improve instruction and monitoring the effectiveness of what we are doing.

As part of the ongoing intensive professional development program, syndicate meetings take place at which teachers each bring for discussion some aspect of their practice that is puzzling them, and also a success story.

Under a scheme in which the school funded 30 per cent of the cost and the Ministry of Education the balance, each teacher at Rata Street has a laptop. Associated expectations include all formal communication within the school occurring via email, students' reports being prepared using laptops, and use of templates for a lot of school planning.

The school has a computer room with 10 computers, while three laptops are available for classroom use.

Students in years 3–6 produce digital portfolios that track their performance against stated goals in both cognitive and affective domains. We observed a portfolio produced by one student, James, who had recently shared his portfolio with his grandmother with whom he lives. She had responded in writing and James had then included her response in his portfolio. He had also included a photo of his pride and joy – a new pair of sports shoes he received for his birthday. A photo of his teacher was included on his friendship page.

Use of TLF's learning objects

Years 4 and 5

June McPherson teaches a class of mainly year 4 students and some year 5s in a 1950s classroom with one computer, a data projector (one of three for the whole school) and a screen. She has selected 'Show and tell: eerie encounter' from TLF's suite of literacy learning objects, accessed on a DVD. June has advanced the learning object to the section she wants to use. Students are sitting on the floor facing the screen, while June is slightly to the side at a small desk that supports the laptop and the projector.

The lesson commenced with discussion of the meaning of 'encounter', followed by consulting a dictionary to support students' understanding. June then used the learning object to support students' understanding of the function of adverbs and adjectives in a piece of writing (a basic recount). Class members then jointly constructed the recount using adjectives and adverbs to enhance the piece of text. At one point June organised for one group of students to move to a withdrawal area off the main classroom to work with the teaching assistant (one per classroom at this school).

Students had previously written a recount of what they had done with the banana supplied to them that day (fruit is supplied daily to students at the school). The teacher typed up each piece of student writing. Some students were invited to share their piece of writing. All remaining students then edited their piece of writing to include more adjectives and adverbs to make the piece more interesting.

Students' responses to use of the learning object included:

> You can see it and its fun.
>
> You can easily fix things up.
>
> I like to see things happening.

June said she likes using learning objects because they are visual and versatile in that she can use them with a whole class, a group, pairs or individuals, commenting:

> ‘Show and tell: eerie encounter’ brings grammar to life. Students are switched on by the sound and the visual elements.

June, who has been teaching for 18 years, said that she now feels:

> I own the computer. It doesn’t own me.

but was quick to add:

> But if you don’t use what you learn, you forget it.

She likes being able to obtain incidental support, as she needs it, for integrating ICT into teaching and learning.

Years 5 and 6

In another 1950s classroom with one computer and a data projector and screen, Anne Cole, a teacher for 40 years and also the school’s teacher–librarian, had a class of years 5 and 6. On the day of our visit, she had chosen ‘Finish the story: bushfire’ from TLF’s literacy suite of learning objects, in which students use adverbs, pronoun reference and ‘saying’ verbs to enhance their narrative.

Using her laptop and the data projector, Anne commenced by clearly stating the purpose of the lesson and reading a poem to the students who were sitting on the floor facing the screen. She modelled what she expected of the students, using the learning object, and then asked students, in pairs, to suggest the ending they preferred and why. Anne provided students with a printout of a screenshot of the learning object, which gave them the opportunity to reinforce and practise what they had understood from engaging with the learning object. The feedback session indicated that the students had engaged and understood the function and usage of the targeted grammatical knowledge. There was a lot of whispering about why some words are better words than others.

Students’ responses to using the learning object included:

> It’s more interesting. You can see it.
>
> It’s better then working from a book, because you can’t change words around in a book.

and the perennial

> It’s fun!

Anne likes the scaffolding and the explicit feedback provided by the learning objects. She thinks they are great for reinforcement. In the lesson we had observed she had appreciated how the students had been able to talk with understanding and coherence;

that they had been able to justify their decisions well; and that there had been a high level of participation. She commented:

> It does make literacy a whole lot more exciting.

She has also used the Mathematics and numeracy learning objects and found them very good for reinforcing concepts. She added:

> The learning objects dealing with area and capacity are great because they [students] can actually see things in a working state and do puzzle-based activities.

Rosetta High School

Located in the northern suburbs of Hobart, Rosetta High School, which caters for years 7 to 10, draws its enrolment of 610 from a wide area that covers urban, rural and broad-acre housing. Indigenous students comprise 11 per cent of the school's population.

Principal Graham Speight explained:

> It is essentially a working-class community and many are aspirational, fuelled by this economy. In the past couple of years, I have noticed that there is a much greater emotional need in the community – people seem to be under greater pressure. At each year level we have at least 20 students who don't live at home.
>
> We are not interested in getting any bigger. Based on space available we are just the right size. People know one another. I can get around and say hi to everyone.

The location of Graham's office, at the centre of the school rather than near the administration at the front of the school, is designed to support access to all staff and students.

From our morning tour of the school, it is clear that ICT is integrated into a range of classroom activities. Recent expansion of the wireless network has made more laptops accessible in more classrooms. The school uses Studywiz as its learning management system. Graham commented:

> We are still in a development phase and we have doubled the computers five times in the six years that I've been here.

Having successfully implemented the Make it Work program to the point where it was no longer needed, the school was now commenced using the Make it Big program. Graham explained:

> We believe that a personalised curriculum centred on each individual's interests and needs is relevant for all our students. As a result, our program for 2007 is based on the idea that we need to establish our educational program one student at a time. The electronic medium is essential to do this stuff.

Each student works with an adviser to negotiate an individual program based around their interests. This program is then captured electronically as part of an individual learning plan, which is tracked using Studywiz. Parents are given passwords so that they too can access this system, which enables them to track their children's progress. Each student's program includes core subjects and electives as in any other school, but rather than being programmed in set classes, students work with their adviser and subject tutors to design their own program.

Ann Stewart, the Advanced Skills Teacher who coordinates learning technology in the school, explained:

> Students are not locked into a class of 28 other students where much time goes into organisation and crowd control.

The great advantage of this approach is that students work at their own pace and get help when they need it, making use of online materials, podcasts and tutorials to assist them along their learning journey. The Le@rning Federation's (TLF) content is used in this mix – as supplementary material, explained Ann.

Make it Big takes up the equivalent of three days of the weekly program and a further two days of out-of-school internships during which students are mentored in the workplace, contribute to the workplace and advance their own learning. Students at Rosetta High School meet the learning requirements designated within the Tasmanian Curriculum Framework and also meet general work requirements that flow from following their interests in the world outside the school.

The school community has embraced the school's approach to teaching and learning. Graham was delighted that 187 parents turned up for the consultation and affirmed the concept. He commented:

> We are in a time of unparallelled change. Our community knows this and they appreciate that we are working to continually keep up to date and improve our programs. They know the reality of the workforce. The world of work has changed forever. Seventy-five per cent of our grade 9s already have a job. They learn a great deal from this real learning and we want to broaden their range of experience and their thinking. These new programs will not only do this, but will develop their vocational skills and work ethic at the same time.

Schofields Primary School

Located in western Sydney between two built-up areas, Schofields Primary School is surrounded by some farms and some big houses on five-acre blocks. Its enrolment of 273 is drawn from backgrounds that range from low socioeconomic to affluent. Some students travel to the school from outside the immediate area.

The area had many Maltese families who were primary producers but who have started to move west in the last year. The school still draws students from families whose Maltese or Anglo grandparents and parents attended the school. Principal Greg Josey, appointed to the school in April 2007, said:

> The school is very well-supported by community with a lot of parent involvement in just about every aspect of the school. This has lots of positives and sometimes negatives.

During 2006, the school's staff had taken part in the Intel Teach to the Future program. 'It's a way of programming to use Microsoft PowerPoint, Microsoft Publisher and web design,' explained Colleen Rodgers-Falk, the school's (three days a week) information AND communication technologies (ICT) teacher who takes a major role in staff professional development related to implementing ICT into learning and teaching programs. She also works in classrooms during the morning as a literacy teacher. She had no special training before taking on the ICT role but has strong technical support at home.

Colleen completed the Intel Teach to the Future master training, as a result of which she was able to conduct the Intel course for the school's staff, which provided staff with the skills to prepare resources as part of their teaching and to devise learning experiences that would enable their students to use Microsoft PowerPoint, Publisher and web design to investigate and demonstrate their learning. Participation in the Intel course requires teachers to spend 40 after-school hours. Colleen commented that if she were to repeat the course she would look to having a narrower range of difference in the capacities that participants brought to the course, as it proved difficult to cater for the broad range she encountered.

The school has also run stand-alone after-school courses that deal with issues such as using email and school-based reporting. Colleen commented:

> The biggest stumbling block is when they [teachers] go to use something and it doesn't work for them. [As with] kids, you have to have small steps. You need to ensure that they have success – otherwise using the computer isn't any faster for them.

Through an informal buddy system, teachers who work at the same year level support each other and share knowledge, particularly with regard to implementing ICT within their learning and teaching programs. The school's executive team now fosters this successful arrangement.

Each class is timetabled to use of the school's computer lab (with 20 computers) once a week, under Colleen's guidance. As the class teacher must accompany their class during that time, there are two teachers to support students during their time in the lab. This arrangement enables Colleen to model and demonstrate practices and procedures to the class teachers, thereby providing them with support and confidence so that they can come back and use the lab independently with their students at times when the lab is available.

Each classroom has at least one computer and two access points to the school network. Colleen stated:

> One-quarter of the school computers was knocked out when the New South Wales Department of Eduction and Training introduced its standard operating system. Ten gigabits were required to run the operating system so there are computers in the room but they are not networked. They are as slow as.

Seven of the 11 classrooms have interactive whiteboards, with a further whiteboard in each of the library and the computer lab. Greg attributes his initial enthusiasm for the whiteboards to observing staff teacher Kerry Wood using it with her class. He commented:

> The way it enthused [students] and changed some of the pedagogy in the classroom was very exciting. It demonstrated to me that we should get on board.

Kerry has subsequently run an after-school session and a further staff development day to introduce other teachers to whiteboard use. Parents were introduced to the whiteboards when the school used a whiteboard to deliver a maths-based program for parents.

In 2006, a survey of all staff members (half of whom have been at the school for fewer than two years), asking them to assess their own ICT capacity, revealed the disparate nature of those capacities and the areas of strongest need.

Greg wants every teacher in the school to have a laptop, so as to push the boundaries. He said:

> Should we wait until everyone is on board and everyone knows how to do it? Let's get on with it. Let's do what we can with what've got.

Use of TLF's learning objects

Ruth Mason from the Centre of Innovation in the New South Wales Department of Education and Training introduced the school's staff to The Le@rning Federation's (TLF) online curriculum content during a staff development day in Term 2 of 2007.

Colleen wants to set up a web-based browser with all the information for teachers on how to operate various pieces equipment and also to link directly to TLF content. She commented:

> We can't afford to have people downloading multiple copies of content on the server and expect it to work at optimum levels.

Colleen thinks the visual digital resources published by TLF can be used in many different ways for many different purposes.

> You can manipulate them in so many different ways. You can use them to write about. You can write on them if you are using the interactive whiteboard or data projector. You can focus them so that every child can see them. They can provide a link to life as it was. This makes them very valuable.

Colleen also understands the frustrations of staff when things don't work, reporting the common cry of:

> It doesn't do that when you aren't here.

Colleen says:

> I've been in that boat and I understand the frustration people experience.

Years 3 and 4

Dannielle Baker, in her second year of teaching, has a years 3 and 4 class. She commenced the lesson by asking the class: 'What is voting?' Students provided a range of responses all of which indicated they had some reasonable idea of the purpose of voting. Dannielle reminded them of a lesson of the previous week in which they had voted for their favourite movie.

She then presented the TLF learning object 'Take a vote: make it fair', from the Studies of Australia suite, on the interactive whiteboard. This learning object deals with an election for a school captain in which three candidates attempt to improve their chances by bribing, intimidating and threatening others, voting more than once, and offering to count the votes. Students consider the fairness of this behaviour and recommend rules to ensure the election is fair. In doing so, students identify some of the fundamental principles of democratic voting in Australia: no bribes allowed; one vote per person; voting must be secret; counting must be undertaken by an independent party; and everyone must vote. Having addressed the unfair behaviour, students observe the outcome of a fair election. Finally, they reflect on the strengths and weaknesses of democratic voting and make suggestions.

Dannielle's students were sitting at their desks throughout the lesson, providing responses and engaging with the outcomes of those responses as they worked their way through the learning object. Dannielle had designed a very good worksheet that provided the students with the opportunity to demonstrate what they understood from the use of the learning object and the subsequent high-quality discussion it had generated.

A feedback session enabled the class to assemble the rules they had agreed would make voting fair. The forthcoming federal election was discussed and, in particular, use of the school premises for the voting. Students who had accompanied their parents on previous elections recounted what they understood to take place. Dannielle expanded on the students' recounts, pointing out special features like getting your name marked off the electoral roll and the location of the ballot boxes. Throughout the lesson Dannielle carefully modelled language, for example 'That was a democratic decision', in ways that expanded the students' understandings. The questioning techniques she applied demonstrated a very sophisticated understanding of how to use questions that expand student knowledge. The lesson culminated in a listing of various examples put forward by the class of how voting is used in their immediate and wider world.

As part of her teacher training, Danielle had taken an optional subject that dealt with operational aspects of computer use such as preparing a Microsoft PowerPoint presentation. However, she had received no preparation for integrating ICT into learning and teaching programs. Danielle said that TLF's learning objects provide her with a scaffold for her lesson, which she can then use to relate to her students' experiences. Over the next few more years she expects to work up her favourites. Before she uses any learning object with her class, she always thoroughly reviews it to know its possibilities. She prefers to use the browse structure rather than the key word search on TALE (the Department's portal). She finds she needs to conduct her search by starting with the relevant key learning area.

Although she has two computers in her classroom, neither is suitable for anything other than word processing. She values her class's 40-minute block with Colleen in the computer lab, stating that she picks up things from Colleen that she hadn't previously known and can reinforce what Colleen has taught her class. She was one of the teachers who requested this arrangement.

Years 1 and 2

During our visit to Bree Stacey's years 1 and 2 class, three groups of students were engaged elsewhere in the room in activities related to fractions while Bree was at the interactive whiteboard with a group of five students who were working their way through TLF's learning object 'Fraction fiddle: matching cake fractions', which deals with filling orders for cakes. As not every customer wants a whole cake, students need to use a circular tool to find the required symbolic fraction and then a dynamic tool to solve the problem, after which they can see their solution displayed in various formats. This learning object delivers visual, sound and textual feedback, and guided support to students experiencing difficulty. Bree used the visual representation to discuss students' choices.

A first-year teacher trained in early childhood education, Bree's only preparation for classroom ICT was a final-year subject that dealt with computer games. She agreed that the learning object she chose was very challenging for the students and that although she had reviewed it beforehand, the object had come up with things she had not encountered in her review. (The learning object's randomisation of the activities is designed to support repeated use.) She sees the learning objects as catering for a range of abilities and a range of learning purposes. However, downloading and unzipping the content is still a challenge for her.

Kindergarten

On our visit to Samantha Mark's kindergarten classroom, she too was using an interactive whiteboard. She commenced the lesson by asking the students, 'What is a need?' After receiving a range of responses from the students, she next asked, 'What is a want?' and again received responses from the students. She then introduced TLF's learning object 'Island life: needs and wants' in which students are prompted to distinguish between needs and wants in ways that they find engaging and fun. To survive on a tropical island, students choose six items to take with them. The consequences of their choices become apparent on their arrival at the island. If they have chosen unwisely, people get sick, the water becomes polluted, rubbish accumulates, trees disappear and buildings fall into disrepair. Students are prompted to revise their selections on subsequent visits to the mainland.

Samantha ensured that the students took turns, each using a step to en them to reach the whiteboard to see the consequences of their decisions. Class discussion about those decisions followed. Later, back at their desks, students cut pictures and glued them in the correct place to reinforce what they had learnt from the learning object. Vocabulary development took place throughout the activity. Samantha said:

> My class is very visual. They love interactive, imaginative and visual material. I use a learning object before I provide it to my students so that I know what they are going to focus on. I got it wrong when I did it the first time. I selected what we used today because it reinforced something that had already been introduced.

Stuart State School

Although only half an hour's drive west of Townsville, on the road to Charters Towers, Stuart State School has a distinctly rural feel. This is an old school by Australian standards. It was built in 1891 to cater for the children of those who serviced the nearby correctional centre. Today it has an enrolment of 100 students drawn from the immediate area where families are mainly of low socioeconomic status, and also from outlying small farms and larger properties from which four buses transport students to the school. Carole Hall, in her third year as (teaching) principal, and another teacher, are two of only five of the school's parents to have had a university education.

A junior team member of the Cowboys, whose photo appears prominently near the administration area and who volunteers his time to conduct sports clinics, visit on sports days and make awards, provides a positive role model for the school's boys.

The eight permanent teaching staff comprise some with as many as 20 years' teaching experience through to some recent graduates. Some of the teachers 'job share' class teaching.

Carole's vision to improve students' self esteem has been the driver for change at the school. Carole explained:

> Students had chronic literacy and numeracy difficulties. If you have very low results there's not a lot of satisfaction.

The school embarked on a journey of success for each individual child. Carole said:

> We don't look at what they *can't* do. We assess what they *can* do and plan the next step in their learning.

One of the vehicles for this change has been information and communication technologies (ICT). A school survey revealed that most students did not have access to computers at home. At best they may have a PlayStation. Carole stated:

> We realised that this was a huge equity issue and that for these students to have access to multiliteracies and computers it would have to come from the school. Otherwise, when they walked into high school, they would be behind the eight ball.

An 'opportunity to push the envelope' as she saw it, presented itself. With the support of parents and community, she applied for funds from the program Investing in our Schools. In developing her submission, she asked students and teachers what they thought would support students to learn better. Students wanted access to laptops and the Internet on their desks. Teachers asked for interactive whiteboards and digital and video cameras.

The submission was successful. The resulting special budget of $110,000 was spent on an interactive whiteboard for every classroom, laptops in classrooms, a wireless network and digital and video cameras. The fantastic display of students' work in the reception area of the school bore testimony to the impact of their use of digital cameras.

Kathy Burchman, a parent at the school, commented that the school's strength in ICT resources and usage had already resulted in more people wanting to send their children to the school.

> We had information go home in letterboxes. It's helping push up our numbers. I think it is such a valuable part of the school. I'm just so excited we got it (the grant), especially given we're just a small school.

Carole pointed out:

> Being an older teacher and not being a digital native, I could genuinely say to my teachers I was on the same journey – if not a bit behind them – and that it would be good if we could go on this journey together. We started the journey before the equipment rolled up.

Based on the notions of slowly building their ICT knowledge and experience and grasping opportunities as they arose, Carole encouraged staff too pursue areas of interest to them. Angelo Palazzolo, who has a years 6 and 7 class, decided on robotics and, on the pupil-free day, was able to provide a course in robotics for the rest of the staff. Katrina Bechstein, who shares a years 2–4 class, has undertaken several projects with The Learning Place (Education Queensland's e-learning environment). Carole said:

> We are a learning community and as such are building a culture of sharing.

The need to share responsibilities is understandable in a school of this size. It is not a case of 'many hands make light work'. Carole, for instance, does bus duty.

The whole staff is currently engaged in the Intel Teach program, conducted after school on a Monday. In addition to 20 hours of attendance, the program requires teachers to produce an assessable unit of work that includes syllabus outcomes and learning activities. As part of the program they must use each of the following as teaching tools: Microsoft PowerPoint; a web page; a Microsoft Publisher document and teaching support material. All the completed units are to be recorded on disc, with a copy provided to every teacher. Successfully completing the Intel Teach program entitles teachers to be awarded the ICT certificate, the first of three levels of accreditation within Education Queensland's ICT Professional Development Framework.

Use of TLF's learning objects

The Le@rning Federation's (TLF) content is seen as one resource among others in the Curriculum Exchange (the Learning Place's digital resource repository), stated Carole, in the course of talking about searching for suitable content for a unit she was devising.

Years 4 to 6

Kimberley Grealy, now in her third year of teaching, became familiar with TLF content (accessed through The Learning Place) while on a teaching round during her training. She searches for content by using the DVD supplied by the Learning Place. Kimberly commented that the strength of the content is that it is 'easy to use and kid-friendly' and that students are able to do a lot of manipulating of the content on the interactive whiteboard. She always makes herself familiar with any learning object before introducing it to her students.

On the day of our visit, her years 4–6 class was learning about three-dimensional shapes and their characteristics. She used the learning object 'Predicting faces' on the interactive whiteboard, which enabled students to visualise objects from all sides and estimate the number of faces belonging to each object. The students' interactions during this lesson indicated a very high degree of engagement, and their responses indicated a good understanding and knowledge of three-dimensional objects. The lesson culminated in students constructing their own three-dimensional rectangular prism.

Kimberley's students were enthusiastic, one boy stating:

> It's fun and its helps you learn.

'You still have to read,' he assured us! One of the girls offered:

> I think it's good because it helps me with my problem solving and with finding the answer to things I didn't understand.

She added categorically:

> It's good for learning.

Years 2 to 4

On our visit to her years 2–4 classroom, Tessa Hardy, commenced her lesson by asking the class: 'What do we need to make a good garden? What helps our garden grow?' Following some responses from the class, Tessa presented TLF's learning object 'How does your garden grow?' on the interactive whiteboard. This learning object provides students with multiple opportunities to explore which combinations of components work together to make particular sorts of gardens grow. Tessa had discovered interactive whiteboards while working in the United Kingdom and was introduced to TLF content by Katrina Bechstein, with whom she shares this class.

Together they are currently undertaking a unit of work, 'Going green', which involves the class in making and tending their own garden, and in managing a worm farm and compost heap where they put all their food scraps. Tessa said:

> Obviously it's a great opportunity for them to understand what makes a good garden. The learning object gives them an opportunity to learn in different modes because it is multimodal. Students can look at it, hear it and talk about it. It caters to all needs.

Years 6 and 7

On our visit to Angelo's years 6 and 7 class, Claire Downie, a final-year student on her teaching round, had 'Get a grip' up on the interactive whiteboard. After a glitch with the operation of the sound, accompanied by various helpful suggestions from students (student willingness to troubleshoot in helpful ways was a common feature in all classes we observed), the properties of friction and force were explicated via riding a bike in different conditions through different terrains.

Integrating ICT into classroom learning hadn't been part of Claire's teacher preparation. Although part of one course she had been required to create a web quest. She had a log-in for Curriculum Exchange, where she has accessed lesson plans. She reported that she was keen to use TLF content.

The class teacher, Angelo Palazzola, a teacher for 18 years, is a confident user of ICT but, until recently, used computers mainly for word processing, Excel and classroom research. Having been introduced to TLF content by Julianne Cervellin, the district Learning Place mentor, Angelo is now adamant that ICT be embedded into the content of the learning and teaching program. Having completed the five-day training course, he had become an Intel Teach master trainer. He also has responsibility for information management services in the school.

Whole school

Carole provided a final word:

> It's no good having equipment if it doesn't work. We are operating at a level that many big schools are operating at, but on a shoestring budget. It's been tough but I've been determined.

The school ICT plan, while developed for a small school, is directed to developing teaching and learning, staff capacity and infrastructure. It has resulted in comprehensive and coherent activities occurring at all levels.

Woodbridge School

Nestled on the banks of the D'Entrecasteaux Channel, and set on nine hectares of delightful grounds, Woodbridge school offers a robust education for the 21st century from kindergarten to year 10, conducted in a tranquil rural setting that is only 45 minutes by car from Hobart. Attached to the school is the Marine Discovery Centre where students from all parts of Tasmania can learn about, discover and care for the marine environment, through diverse shore and sea-based programs. The Centre even boasts its own 13.5 metre research vessel on which students can experience authentic sea-based activities. In 2006 the Centre had 8,000 visitors. Not surprisingly the school has special status when it comes to taking advantage of the wonderful programs and resources on offer at the Centre.

There are other special programs running in the school, including an environmental program that has received awards. 'We recycle everything,' says Alison Grant, the principal of the school. The school runs chooks and was embarking on a partnership with a local organic bulb grower.

The area has a reputation as a pristine area for food products and has the highest incidence of home-based small businesses working from home. While the population has changed in recent times with the arrival of 'sea changers' who are escaping the corporate life of the mainland, a high proportion of the school's enrolment is from families of low socioeconomic status, rental housing being cheap in this area. The parents of some students are into a third generation of unemployment. Indigenous students comprise 15 per cent of the school's enrolment. 'We can do it' is an ethos Alison and the staff encourage – in contrast to the 'deficit' view of their capabilities that has prevailed among many students.

The school of 227 students has 147 computers. As well as those in the computer lab, there are at least five fixed computers in every classroom. Every classroom in the main block of the school has an interactive whiteboard. There is an additional portable whiteboard.

The refurbishing of the school, completed in mid-2006, provided bigger learning spaces than traditional classrooms so as to enable teachers and their students to work together, with smaller areas off the bigger learning spaces. The learning spaces are working well to meet the purposes for which they were designed.

At the time of our visit, the journey to embed information and communication technologies (ICT) into the learning and teaching programs of the school, including extensive use of The Le@rning Federation's (TLF) online curriculum content, was well underway.

Teacher Kurt Memish champions the cause of embedding ICT into the school's classrooms and of employing TLF content within its learning and teaching programs. Kurt's advocacy arose from his work as an online learning tutor for marine science courses he conducts all across Tasmania. Access to online courses, also a feature of what's on offer for secondary students at Woodbridge, provides students with a curriculum offering as broad as most high schools, along with further options, such as aquaculture and boat handling, that are not available elsewhere.

Kurt is an Advanced Skills Teacher and In-school Mentor (each school in Tasmania has such a position) for ICT. The school's ICT plan employs a strategy of starting with those teachers who are comfortable with ICT. 'Willingness to have a go' is a crucial aspect Kurt lists among the factors leading to their success in embedding ICT into learning and teaching.

Professional learning goes on constantly. Alison stated that 'individual needs are met at the time of need' and:

> We had a strong platform to build on in terms of access and the way we have applied it. This was an important part of our capacity building.
>
> The support happening in the school is flexible – Kurt will go into classrooms.

She added:

> [The teachers] use the staffroom as a hub. They are learning from each other. [They] aren't doing this alone.

Alison was also adamant that it is vital to ensure that students can perform certain functions using computers:

> We have some kids who are technophobic – but it's also an equity issue. Some don't have landline phones in the home let alone a computer. It really is important that they have access to the best they can at school.

In preparing for a whole-school approach to ICT use, Kurt has established a digital portfolio on the school network so that for each program in each class the digital content that has been deemed successful is stored for future access. Kurt said:

> That way, we will have a continuous coherent whole-school approach.

The school has a relaxed and friendly atmosphere. In the secondary part of the school students are 'styled'. Mathematics teacher Bruce Duncan is quick to point out that this is not a fancy title for 'streaming'. The arrangements are flexible and students can opt between classes in which the learning is scaffolded and those based on more self-directed learning. For some lessons the two types of classes participate as one class.

Discussion with other teachers, a team approach and being able to access TLF content in their own time are all critical elements of the school's ICT operation.

Use of TLF's learning objects

Kurt provided keen staff members with individual copies of DVDs of TLF content to enable them to search for suitable content at home. He commented that, like any plan, its implementation takes time. 'We are experimenting at the moment,' said Kurt. Part of that experiment includes asking the students what they like about TLF content they have used.

> That helps us focus students more. And as a school we have to plan how we are going to use TLF content so the students don't get the same [ones] year after year.

Alison agreed, saying:

> We need a clear curriculum plan and we need to be strategic about how we use them [TLF's learning objects].

Alison is equally firm in her refreshing views on the status of the school:

> It's the kids' school. It's their facility. If they want to come and sleep in this draughty old place, then good luck to them.

This comment was prompted by a recount of how secondary students and their teacher wanted to come and sleep the night at school last year so that they could watch the World Cup featuring Australia on the big IWB screen.

Primary years

On the day of our visit, students in a number of classes were using learning objects to help build understanding as they worked towards the common assessment tasks that all schools in Tasmania undertake. In year 1 they were making arrays with learning objects and concrete materials, rotating the three groups in the class between computers and the materials. Years 4 and 5 students were also working in rotating groups, in their case on a range of activities that included using learning objects. Years 2 and 3 students were in the computer lab working individually at their own pace.

The school has used a number of numeracy learning objects to provide additional support and develop greater understanding for students prior to the common assessment tasks undertaken across Tasmania as part of Q map (state-wide moderation) day.

Secondary years

Melissa Wagner, who teaches secondary humanities subjects, has used a variety of learning objects with a range of classes and plans to use TLF's digital resources. She reported having used 'To catch a thief' with a year 7 class that she described as a 'varied group'. She had first demonstrated use of the learning object on the interactive whiteboard to the whole class, after which she used the support available within this series of learning objects for students to be able to use increasing levels (1 to 3) of textual difficulty. Students had worked in pairs and progressed through the levels. Melissa had linked her use of 'To catch a thief' to a science topic students were undertaking on forensics and fingerprinting.

At another time, to introduce a creative writing topic, Melissa had used 'Dream machine' to provide students with rich multi-media demonstration of the use of metaphor and simile. She commented:

> The DVD has been great. I can take it home and explore it. The kids are comfortable learning this way and we should make it part of how we teach. Especially when it's stuff that has been tested with someone else and it works. It's great that it is filtering through the whole school.

Mathematics teacher Bruce Duncan offered the following comments on TLF's learning objects:

> Teachers need to make themselves familiar with the content prior to use.
>
> Teachers need to work out, in advance, exactly how they are going to deploy them in the classroom, whether for whole-class demonstration or in some other way.
>
> Teachers need to be clear about their purposes for using the learning objects.
>
> The learning objects are intrinsically motivating for students and they are an efficient use of time.

On the day of our visit, Year 7 students were using the learning object 'Mystery substance', which was followed by an activity in which they listed the substances they had looked at, and what they had found out about them. One year 7 student declared:

> You actually get to do it yourself and see it changing when you added stuff to it. That's much more fun!

Kurt, their teacher, said the same experiments would be set up in the science lab to follow up the focus of the learning object: finding out the nature of the mystery substance.

Kurt uses learning objects in his classes in the school and for the online course he runs, commenting:

> Students' responses to TLF content is generally very good. They tend to want to flip around because they are used to games and want to get into the action. Also they are reluctant to read. The game-like format is very important and they like to have feedback on their results. In some instances I get them to send me a screen grab.
>
> Sometimes I use [a learning object] first at home with my daughter. The concepts they deal with are well tuned to the curriculum. I may use them on the interactive whiteboard with a whole class and with students helping me work my way through, then have them work in groups of three to reinforce that. All students have individual contract sheets and they need to sign off completion.
>
> If I see a student struggling, then I send them back to use it again in another lesson. They simply type the number of the object into Student Freeway, which is accessible to all Tasmanian government school students. Because ICT and TLF content can support working at your own pace, they support learning at this school, which is based on stages, not locked into ages.