Use of Dataloggers in Science Learning in Singapore Schools

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Abstract

This paper reports the findings from an online survey administered to 593 science teachers including heads of science departments in 2004. This survey is part of a study initiated in December 2003 to examine the implementation, efficacy and use of dataloggers in Singapore science curricula. Dataloggers were introduced to all Singapore schools during the First Masterplan for IT in Education (1997-2002) to support science learning and experimentation. The aim of the survey is to find out how secondary schools and junior colleges have been supporting and integrating the use of these dataloggers in the teaching and learning of science. The findings from this survey address:

- profile of schools and teachers using dataloggers
- ways in which dataloggers are used in the science curriculum
- teachers’ perceptions on whether pupils were able to interpret and analyse graphs
- roles of teachers in preparing pupils and guiding them when using dataloggers in set experiments and inquiry based science experiments

Introduction

The implementation of the First Masterplan for IT in Education (1997 – 2002) (MP1) in Singapore saw the provision of dataloggers to all secondary schools and junior colleges in 1997 and primary schools in 1998 to facilitate science learning and experimentation. The broad aims of this provision included exposing pupils to new technology for science learning and providing them with the opportunities to use them; providing a tool for pupils to engage in science inquiry in which pupils use higher order skills like planning, predicting, analyzing and reflecting; and promoting science learning in authentic settings. Training on the use of dataloggers for all science teachers which focused largely on technical know-how, was conducted mainly by vendors. Teachers were guided through set experiments as given in the instructional manuals supplied by the vendors. The Ministry of Education, through its Educational Technology Division, conducted workshops to help teachers integrate the use of dataloggers into the various disciplines in science, namely, physics, chemistry and biology. Fieldwork and projects, such as the Birds in Wetland Reserves, Mesocyclops Project, were initiated to engage pupils in investigative activities in authentic settings using the dataloggers.

Given the significant investment made in equipping schools with dataloggers, this study was carried out to find out the extent of usage, how the tool has been used to support science learning and what are some good practices among schools that could be shared with teachers in other schools. The survey was conducted in July 2004 and formed part of

a larger study to understand how dataloggers could be used to support an inquiry approach to science learning. This paper reports on some of the findings from the online survey on 593 science teachers (among them, 114 heads of science department) from 137 secondary schools and 14 junior colleges in Singapore. In particular, the findings shared will provide information on the profile of users of these dataloggers, the type of activities in which dataloggers are used, teachers’ perceptions of whether pupils were able to interpret and analyse the graphs and the role of the teacher in preparing and guiding pupils as they embarked on set experiments and inquiry based activities with dataloggers.

**Background**

As we know, the “fundamental nature of science is embedded in inquiry-based learning” (Jarrett, 1999) and practical work in our science curriculum is one excellent platform to encourage inquiry based activities. With increasing emphasis on an investigative and discovery learning, it is imperative that teachers and pupils are provided with the appropriate tools to support them in this endeavour. Dataloggers or data logging systems (also known as microcomputer based laboratory) are one technology that presents great potential in facilitating the data gathering and analysis processes and also allows pupils greater responsibility in their science investigations (Newton, 2000). Such technology has been shown to bring about significant benefits to an investigative and exploratory learning environment (Rogers, 1994; Barton, 1997a).

Data logging is a term used to describe an activity in which data are collected by the use of sensors during an experiment and sent to a computer for processing and analysis. A data logging system comprises sensors or probes to detect changes in variables such as temperature, pH, light, an interface or datalogger to collect or store the information, a computer to display the information and a software program for further analysis of the data (Barton, 1997a). Such systems enable both instant capturing of data which can be displayed in real time in the form of tables and graphs on a computer screen and also remote logging which extends practical activities beyond the science laboratory into the field. They also allows for longer term monitoring of variable changes over hours, days or even weeks.

Studies have shown that the use of dataloggers with an inquiry-based approach was found to be an effective way to acquire science content and develop understanding of the nature of science (Gipps, 2002). Data logging systems free pupils from the mundane chores of recording, tabulating and plotting data and hence make available time for productive science thinking (Rogers & Wild, 1994). Quality time could be spent on more demanding tasks like discussing, analyzing and interpreting data – asking questions about the data, making predictions, making comparisons, looking for trends, making links between experiment and results, and establishing relationships between variables (Rogers & Wild, 1994, 1996; Rogers, 1997; Barton, 1997a; Newton, 2000). However, for pupils to fully benefit from the time saved from data collection, the teacher plays a critical role in structuring the learning environment and equipping pupils with the necessary skills to explore the data (Rogers & Wild, 1994, 1996; Newton, 1997; Barton, 1997a). The teacher needs to set clear learning goals, design learning activities in which pupils assume greater ownership, guide pupils through probing and open ended questions to foster thinking, encourage and promote a questioning culture among pupils. Pupils must be equipped with skills to pose their own questions, think critically about their data, conduct effective discussions and tap the capabilities of the software to explore the data obtained. Teachers,
thus, assume the multiple roles of guide, innovator, motivator and mentor in this technology supported learning environment (Crawford, 2000).

Despite the well established benefits of using data logging systems for science learning, schools in UK have noted a low adoption rate by science teachers (Rogers & Wild, 1996). The reasons cited for this low usage include access to the equipment, reliability of the equipment, the lack of support structures such as technical support, funds, training opportunities, the confidence level of the teachers in using these tools to facilitate science learning and limited awareness of the benefits of such tools (Rogers & Wild, 1994; Rogers & Wild, 1996). Through our online survey, we were interested to explore the adoption rate of dataloggers among the science teachers in our local context and examine the roles our teachers play as they facilitate investigative science activities supported by the use of these dataloggers.

**The Survey**

The survey was carried out online with the Heads of Science Department (HODs) and science teachers. The questions in the survey covered the following aspects:

- demographics on the background of teachers
- whether they use dataloggers in their science lessons
- the type of activities dataloggers were used with
- the roles of pupils and teachers in the data logging activities
- how pupils were prepared to work with dataloggers
- teachers’ perceptions on whether pupils were able to interpret and explain graphs
- how pupils were guided in their interpretation of graphs
- whether pupils were involved in inquiry based investigations
- support structures deemed important to help teachers use dataloggers
- type of training that would help teachers integrate use of dataloggers
- teachers’ perceptions of the usefulness of dataloggers
- the difficulties teachers faced when using the dataloggers

**Implementation**

The items in the survey instrument were finalized after two pilot trials. Two versions of the earlier questionnaires were trialed and tested over six months from Jan to June 2004 to gather possible responses and obtain feedback on the clarity of questions. Trial 1, comprising mostly open ended questions, was carried out with 5 HODs and 17 teachers from 12 secondary schools and 2 junior colleges who were attending professional development graduate programs at the National Institute of Education. From the data gathered from the first trial, the instrument was refined to include more multiple-choice questions where options or choices were derived from the participants’ responses. The second version of the survey was tested with 2 HODs and 10 teachers from 4 secondary schools to get another round of feedback.

In the final survey instrument, the respondents were allowed to select more than one choice for most of the multiple choice questions and an ‘others’ option was provided for respondents to state other responses not given in the options. A small number of free response questions were retained for teachers to respond to less defined issues like how teachers help pupils overcome difficulties in analyzing graphs, what they perceived were
problems faced by pupils when carrying out inquiry-based investigations and how they helped them overcome the difficulties.

The actual survey was posted online for access by schools for a period of 5 weeks. 158 secondary schools, 16 junior colleges and 1 centralised institute were invited to respond to the online survey. Letters and emails were sent out to Principals and the Science HODs requesting for 6 teachers, including the science head from each school to take part. At the close of the survey, responses were received from 114 HODs (65.1% of an expected number of 175) and 479 science teachers (54.7% of an expected number of 875 teachers) from 151 schools. The overall response rate to the survey was 56.5%.

Survey Findings

Teachers and HODs who took part in the survey came from 14 junior colleges (2 year programme which prepares 17-18 year olds for “A” level examination), 7 independent schools (4 year secondary education for 13-16 year olds which enjoy full autonomy in implementation of school programmes and administration), 19 autonomous schools (4-5 secondary education for 13-17 year olds which have some autonomy to provide a wider range of innovative and enrichment activities) and 111 other secondary schools (inclusive of government and government aided schools, which prepares 13-17 years old for “O” level examination). The highest response rates were from the independent schools (62.5%, 7 out of 8 independent schools) and junior colleges (66.7%, 14 out of 16 JCs).

Profile of users, past users and non-users

In our analysis, the respondents were classified into 3 categories, namely the users (teachers who used the dataloggers in the recent 1-2 years), past users (those who used dataloggers more than 2 years ago), and non-users (those who never used dataloggers). Among the 593 respondents, 66.4% (394) were users, 15.3% (91) past users and 18.2% (108) never used dataloggers. The highest percentage of users came from the independent schools (90.0%, 27 out of 30 respondents), followed by junior colleges (76.5%, 52 out of 68 respondents) and the autonomous schools (75.6%, 59 out of 78 respondents). About 85% of 392 respondents indicated that they used dataloggers only in one to three topics in their science syllabi.

Teachers with less than 5 years of teaching experience formed the largest group among the respondents (36.0%, 214 out of 593). However, it was interesting to note that teachers with more than 20 years of experience in science teaching formed the highest proportion of users (75.7% of 115 respondents) in contrast to the youngest group of teachers with less than 5 years of teaching experience who formed the smallest percentage of users (57.5% out of 214 respondents). One would expect younger teachers to be more IT savvy than their older colleagues and thus be more ready to experiment with technology. One HOD remarked that as new teachers, the less experienced teachers were probably adjusting to the demands of the schools and unable to find time to experiment with the use of technology. Unlike the younger teachers, the more experienced teachers were also trained in using the specific brand of dataloggers by vendors when the dataloggers were disseminated to schools, and many could also have attended workshops on integrating the use of these dataloggers into the various science disciplines.
When asked why they stopped using dataloggers, the 91 past users cited the lack of time (47.1%) and equipment-related issues (35.1%) like insufficient notebook computers, the dataloggers are cumbersome to set up and involved too much troubleshooting, as the two main deterrents. Besides the need for time to complete syllabuses, many past users expressed that designing the task, setting up the dataloggers, training pupils to use them and interpret data are all time consuming factors. Though they have never used dataloggers, 81.3% of the 108 non-users saw potential in the use of dataloggers for science learning, particularly, for demonstrations, in project work, fieldwork and enrichment.

Use of dataloggers

Survey findings show all users (both current and past) used dataloggers mainly for demonstrations (59.4%) and set experiments from workbook and worksheets (56.3%). Usage is much less in activities like enrichment (19.6%), fieldwork/project work (19.0%), student initiated investigations (11.5%) and co-curricular activities (5.6%). This trend is common across users from the different types of school, among respondents with different years of science teaching experience and across the 3 science disciplines. Thus, it can be seen that the use of dataloggers in our science classroom is still largely teacher-directed and mainly for verification experiments. There is very little evidence to show that the potential of the tool is tapped to engage pupils in inquiry based activities.

Preparing pupils to work with dataloggers

In preparing pupils to work with experiments using dataloggers, all users generally showed pupils how to set up and use the sensors (84.3%) and explained the functions of the different components e.g. sensors, logger, software (72.0%). As reflected from the data in Table 1, more teachers were concerned about familiarizing pupils with the technical skills of operating the dataloggers rather than training pupils to interpret and discuss their results. However, it was noted that a comparatively larger percentage of respondents from the junior colleges taught their pupils how to analyse and explain data as compared to their colleagues from the secondary schools.

Table 1. Ways in which respondents from different types of schools prepare pupils to work with dataloggers

<table>
<thead>
<tr>
<th>Type of school</th>
<th>Explain functions of components</th>
<th>Show how to navigate software</th>
<th>Show how to use sensors</th>
<th>Teach pupils to analyse and explain graphs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous (n=70)</td>
<td>50 (71.4%)</td>
<td>48 (68.6%)</td>
<td>57 (81.4%)</td>
<td>43 (61.4%)</td>
</tr>
<tr>
<td>Independent (n=28)</td>
<td>23 (82.1%)</td>
<td>23 (82.1%)</td>
<td>27 (96.4%)</td>
<td>22 (78.6%)</td>
</tr>
<tr>
<td>Other secondary (n=322)</td>
<td>226 (70.2%)</td>
<td>209 (64.9%)</td>
<td>263 (81.7%)</td>
<td>209 (64.9%)</td>
</tr>
<tr>
<td>Junior College (n=62)</td>
<td>47 (75.8%)</td>
<td>48 (77.4%)</td>
<td>60 (96.8%)</td>
<td>51 (62.3%)</td>
</tr>
<tr>
<td>All users (n=485)</td>
<td>349 (72.0%)</td>
<td>330 (68.0%)</td>
<td>409 (84.3%)</td>
<td>327 (67.4%)</td>
</tr>
</tbody>
</table>

A respondent may tick more than one type of activities

Pupils’ interpretation of graphs

A high percentage of teachers (82.9%) indicated that their pupils were able to interpret the graphs generated by the data logging systems and also explain them. More current users (87.3%) perceived that their pupils were able to interpret graphs as compared
to past users (63.7%). All respondents from independent schools as well as those teaching junior colleges showed greater confidence in their pupils’ ability to make sense of the graphs obtained.

Table 2. Distribution of respondents from different types of schools on pupils’ ability to interpret and explain graphs

<table>
<thead>
<tr>
<th>Type of school</th>
<th>Yes/possibly</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous (n=70)</td>
<td>60 (85.7%)</td>
<td>5 (7.1%)</td>
</tr>
<tr>
<td>Independent (n=28)</td>
<td>28 (100.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Other secondary (n=322)</td>
<td>255 (79.25%)</td>
<td>51 (15.8%)</td>
</tr>
<tr>
<td>Junior College (n=62)</td>
<td>57 (91.9%)</td>
<td>5 (8.1%)</td>
</tr>
<tr>
<td>All respondents (n=485)</td>
<td>402 (82.9%)</td>
<td>63 (12.8%)</td>
</tr>
</tbody>
</table>

To gain a better understanding of what led teachers to perceive that their pupils were able to interpret graphs, teachers were asked to cite one situation in which pupils exhibited such ability. The 285 positive responses could be broadly grouped into the following categories. In general, pupils were observed to be able to:

- read off (e.g. maximum or minimum value, intercept values, pH) or derive values (gradient for velocity/acceleration, period, frequency) or identify segments (plateau showing change of state) from the graphs and explain the conceptual meaning of these values (24.6%)
- correlate experimental data with theoretical concepts (11.9%)
- infer and derive conceptual understanding from the shape of the graph obtained (54.7%)
- deduce the relationship between two variables (effect of the independent variable(s) on the dependent variable) (8.8%)

Teachers’ beliefs that their pupils were able to interpret graphs were largely based on their observations though it is unclear how teachers ascertain the extent of pupil understanding or could it just be a general sense derived from choral responses. There are also quite many examples cited which (24.6%) merely require pupils to identify certain values which are significant to concepts learnt or calculate values of the desired variables from the graphs as required by the worksheets which hardly constitute interpretations. However, one observation from the examples cited is that with lesser time spent on recording data and plotting graphs which is one key affordance of the dataloggers, more time could be freed for teachers to discuss the significance of the graphs with pupils. Doing the experiment alongside with the graphs displayed instantly by the dataloggers enabled the pupils to better visualize and explain the phenomenon happening in the experiments. This could be one crucial step to close the perceived “gap” between theory and practical science among many of our pupils.

Among the 61 teachers who indicated that their pupils were unable to interpret graphs, 51 (83.6%) respondents were from the ‘other secondary schools’. It could be gathered from the 55 responses on the common difficulties encountered by pupils were that they were not able to make sense from the graphs and explain the trends observed (23.6%), some were unable to make connections between the graphs with what they learnt in theory (21.8%) and there were those who are lacking in mathematical concepts in graphing (10.9%). To help pupils overcome these difficulties, steps taken by teachers included explaining to pupils the meaning of the graphs obtained, reinforcing the theory behind the graphs, asking guiding questions on what pupils can expect to see from the graphs and even showing them model answers. In cases where the pupils were weak in
mathematical concepts, teachers also took time to explain basic graph concepts or resorted to using mainly the simplest graph functions available in the software.

**Inquiry based investigations – pupil initiated experiments**

Only 22.5% (out of 485 respondents) involved their pupils in planning and carrying out pupil initiated experiments. This low figure affirmed earlier findings on the use of dataloggers which showed that respondents involved their pupils mainly in verification type of experiments. However, it was noted that a higher percentage of junior college teachers involve their pupils in pupil initiated inquiry activities. That could be attributed to the greater emphasis on project work at the ‘A’ levels. More Biology teachers (31.8% of 110) involved their pupils in inquiry based activities than Chemistry (21.1% of 185) or Physics (21.2% of 245) teachers. The findings also showed a rising trend in the number of teachers involving pupils in inquiry based activities from the past to the current users across all 3 science disciplines.

Respondents indicated that pupils were given the opportunity to plan their own experiments using dataloggers during project work, practical sessions on skill 4 (SPA), science competitions, science fairs, enrichment modules for lower secondary, science research and co-curricular activities (CCA). Thus, it is evident that pupil directed activities happened predominantly in co-curricular activities. When planning these experiments, pupils were largely involved in selecting and control of variables and determining procedures as shown in Table 3.

<table>
<thead>
<tr>
<th>Craft aim/ objective</th>
<th>Decide on the type of data to collect</th>
<th>Determine the apparatus required</th>
<th>Generate hypothesis</th>
<th>Plan procedures</th>
<th>Select variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number (n=109)</td>
<td>51</td>
<td>67</td>
<td>64</td>
<td>58</td>
<td>74</td>
</tr>
<tr>
<td>Percentage (%)</td>
<td>46.8</td>
<td>61.5</td>
<td>58.7</td>
<td>53.2</td>
<td>67.9</td>
</tr>
</tbody>
</table>

A respondent may tick more than one type of ways

So as to gain a better awareness of the kind of scaffolding teachers provide for pupils in such activities, respondents were asked what kind of guidance they gave to their pupils. Findings in Table 4 showed that a high percentage of respondents provided feedback to their pupils on the feasibility of their experiment. Other forms of assistance included guiding pupils to select and control variables and advising them on the type of data to collect. Fewer teachers in junior colleges explained the steps involved in planning an experiment and gave feedback to their pupils. This could be because the older pupils in junior colleges are expected to manage on their own. Independent school teachers appeared to provide less guidance in variable control, data collection and bringing pupils through the steps in planning as compared to their colleagues in other secondary schools. This is not unexpected as their pupils being intellectually more capable and likely to be more self driven.
Table 4. Percentage of responses showing the guidance teachers gave to help pupil plan their experiments by different types of schools

<table>
<thead>
<tr>
<th>Type of school</th>
<th>Advice on safety issues</th>
<th>Explain the steps involved in planning an experiment</th>
<th>Guide them on data collection</th>
<th>Guide them to select and control of variables</th>
<th>Provide feedback on the feasibility of the experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomous (n=18)</td>
<td>10 (55.6%)</td>
<td>12 (66.7%)</td>
<td>16 (88.9%)</td>
<td>15 (83.3%)</td>
<td>15 (83.3%)</td>
</tr>
<tr>
<td>Independent (n=7)</td>
<td>4 (57.1%)</td>
<td>3 (42.9%)</td>
<td>3 (42.9%)</td>
<td>2 (28.6%)</td>
<td>6 (85.7%)</td>
</tr>
<tr>
<td>Other secondary (n=65)</td>
<td>37 (56.9%)</td>
<td>34 (52.3%)</td>
<td>39 (60.0%)</td>
<td>42 (64.6%)</td>
<td>43 (66.2%)</td>
</tr>
<tr>
<td>Junior College (n=17)</td>
<td>10 (58.8%)</td>
<td>6 (35.3%)</td>
<td>12 (70.6%)</td>
<td>12 (70.6%)</td>
<td>8 (47.1%)</td>
</tr>
<tr>
<td>All respondents (n=109)</td>
<td>63 (57.8%)</td>
<td>57 (52.3%)</td>
<td>72 (66.1%)</td>
<td>73 (67.0%)</td>
<td>74 (67.9%)</td>
</tr>
</tbody>
</table>

A respondent may tick more than one way of guidance.

Analysing data and drawing conclusions

When asked how they helped pupils analyse data and draw conclusions, responses from 60 teachers reflected that they helped to link what the pupils were doing in the experiments to the theory they had learnt previously (25%), examined data together with pupils, checked for consistency in data (33.3%), asked leading and probing questions to set pupils pondering and provided constructive feedback (31.7%). Some help rendered by the teachers were:

- “Elicit by pointing out salient points on graphs”
- “Guiding them to look for trends and patterns in results, discussing anomalous results”
- “Getting them to refer back to the earlier question in their problem definition”
- “Pointing pupils to relevant references, providing facts and background knowledge where appropriate, ask probing questions”
- “Carry out discussions based on data, look for trends in data and infer/explain”

Conclusion

Despite the many potential benefits of dataloggers for supporting science inquiry processes, it is quite evident from the survey findings that teachers have not yet fully exploited the use of dataloggers to support inquiry-based learning of science. Teachers were using them mainly in demonstrations and pupils were largely engaged in laboratory-based verification type of experiments and had few opportunities to participate in inquiry-based activities. Pupils were equipped mainly with the technical skills on how to use the various sensors and briefed on the functions of the different components. Comparatively, little was done to prepare them to examine and discuss graphs and to explore the data with the software. The survey also provided an indication that teachers were generally confident that their pupils were able to interpret and explain graphs.

The findings reflected the very low percentage of teachers who involved their pupils in inquiry based activities and many of these happened outside the regular science curriculum. It was clear from the responses that teachers need to provide pupils with more scaffolding from the conceptualisation of the task through to interpreting data and drawing conclusions. In order to use dataloggers more effectively in science learning, the role of the teacher needs to be reformulated from one of an instructor/disseminator of knowledge to that of coach, resource procurer and mentor (Renzulli, 2004). Hence, to encourage more
pupil initiated activities using dataloggers in science classrooms, in addition to helping teachers integrate the use of dataloggers in the curriculum context, it might be necessary to emphasize the advantages of dataloggers, share exemplary practices of effective use and explore with teachers, effective scaffolding structures and ways of engaging pupils in inquiry based activities. Thus, to encourage wider adoption of the tool, there is a need to routinely support teachers in their use of dataloggers, especially for the multiple roles they have to assume as they transit from being an instructor to a facilitator of science inquiry.

References