Datalogging: a unique affordance unrealized?
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Abstract
Datalogging has the potential to facilitate and extend opportunities for inquiry-based science by providing data and different modalities of representation with minimum effort. The real-time data display provides an immediate link between an experiment and its graphical representation, enabling students to visualize the course of the experiment. It also frees experimentation from time constraints as data can be collected over days, and relieves students from tabulating data and drawing graphs by hand, allowing them to concentrate on the interpretation of data. This paper describes some aspects of a national survey of 593 science teachers on the use of datalogging in Singapore secondary schools (Grades 7-10) and junior colleges (Grades 11-12), interviews of three Science Heads of Department, and classroom observations of datalogging activities. The results suggest that the unique affordances of datalogging are not being fully realised in science learning because teachers generally lack the vision for how dataloggers can be used to enhance the student learning experience in inquiry-based science.

Introduction
Datalogging methods involve the use of electronic sensors and interfaces to measure and record changes in variables during experiments, variables such as temperature and pH. Data are automatically collected and can be displayed in the form of tables and graphs on a computer screen. This overcomes the time lag between the experiments and the graphs which students would plot manually, and can increase the likelihood of students relating the graphical or diagrammatical representation of relationships to the activity itself (Barton, 1997a; Osborne & Hennessy, 2003); Linn and Hsi (2000) found that when students graphed their own data, they seldom watched the experiment, made many mistakes and lost track of the point of the experiment. A key pedagogical technique used with datalogging, the Predict – Observe – Explain, is also enhanced through the viewing of the representation of the phenomenon on the screen soon after making a prediction (Osborne & Hennessy, 2003).

The most recent datalogging software supports sophisticated analysis and transformation of data and graphs. Thus, datalogging can increase students’ participation in the investigation by reducing the “laboriousness of work” (Osborne & Hennessy, 2003, p. 27); it frees students from taking complex measurements, tabulating data, drawing graphs by hand, and executing complex calculations. The benefits of datalogging depend on the quality of students’ thinking about the experiment, for example, asking questions about the experimental design and data, making links with other information, making comparisons and predictions, and looking for trends. It is of little use if the students watch the screen passively and uncritically while the data are being tabulated and graphs plotted, and without actually understanding what is being represented (Newton, 1997; Osborne & Hennessy, 2003; Roger & Wild, 1996). Thus, it is important to “encourage pupils to remain active while the machine is collecting data, using the ‘time bonus’ purposefully to think critically about and discuss the experiment in more depth” (Osborne & Hennessy, 2003, p. 31).

Datalogging also expands the range of questions that can be investigated and the data that can be collected in school contexts by allowing measurements of transient phenomena, as well as monitoring data collection over several hours, days or even weeks (Osborne & Hennessy, 2003; Singer et al., 2000). In sum, it extends learners’ powers of observations and improves the quality of measurement (Rogers & Wild, 1996).
Dataloggers were introduced in Singapore schools under the first Information Technology (IT) Masterplan (1997-2002). Secondary schools and junior colleges were given six sets of dataloggers for each laboratory that the school had. Training on the use of dataloggers was mainly provided by the equipment vendors, with the Educational Technology Division, Ministry of Education, Singapore, providing several follow-up workshops. A study of the implementation, efficacy and use of dataloggers in science lessons or project work was initiated in December 2003. This paper describes some of the results obtained from an online survey of science teachers in all secondary schools (Grades 7-10) and junior colleges (Grades 11-12) and interviews with three Science Heads of Department. It includes how dataloggers were used in schools and the opportunities for students to engage in inquiry-based science.

The online survey questionnaire
The questions in the online survey were designed to collect information from Science Heads of the Department (HODs) and science teachers on their use of dataloggers in science teaching. Two pilot studies involving open-ended questions were conducted, involving a total of 22 teachers from five secondary schools and 11 teachers in professional development graduate programs at the National Institute of Education, Singapore. After the items were finalized, the survey was posted on the website for general access. The questions focused on:

1. whether the Science HODs and teachers had used dataloggers in their lessons,
2. if they had used dataloggers, the subjects and topics in which they used dataloggers,
3. the types of tasks involving dataloggers,
4. the teacher’s role in datalogging activities,
5. the pupil’s role in datalogging activities,
6. how pupils were prepared to use dataloggers,
7. whether pupils were able to interpret data,
8. whether inquiry-based activities were conducted, and if so, how were the inquiry-based activities conducted,
9. the support structures required for datalogging activities, and
10. the difficulties they faced in conducting datalogging activities.

Examples of the items in the online questionnaire are given in the Appendix. The options in the multiple-choice items of the questionnaire were derived from the data collected in the two pilot studies. A majority of the items allowed the respondent to select more than one choice, for example, to capture the various ways the teacher used dataloggers in class. Most items also had an ‘others’ option which allowed the teacher to provide any response which was not included in the options given. The free-response questions allowed the teacher to elaborate on more specific situations and issues, for example, the difficulties faced by students using dataloggers, and how the teacher helped them to overcome any difficulties.

In July 2004, letters and emails were sent to the Principals and Science HODs of all secondary school and junior college in Singapore, explaining the objectives and nature of the research project, with a request that six teachers, including the HOD, complete the survey. A total of 175 HODs and 875 science teachers from 175 schools were invited to participate in the online survey. After five weeks, when the online survey was closed, a total of 114 responses from HODs (65.1% of the target) and 479 responses from science teachers were received.
teachers (54.7% of the target) were received. The overall response rate to the online survey was 56.5%.

**Survey results**
The survey responses showed that 394 respondents (66.4%) had used dataloggers in the past two years (at the time of the survey), 91 (15.3%) last used them more than two years ago, and 108 (18.2%) had not used dataloggers at all. The 394 respondents were thus classified as users of dataloggers, past-users (91), and non-users (108). The users included significantly higher percentages of the two most experienced groups of teachers, those with 16 to 20 years (75.4%) and over 20 years (75.7%) of teaching, than the least experienced teachers, those with less than 5 years of teaching (57.5%). This unexpected finding conflicted with common assumptions about technology use, in that younger teachers were expected to be more adept and more exposed to information technology (Figure 1).

![Figure 1. Percentage of the different user types in each years of teaching category](image)

Time to deploy and setup, equipment access issues, perceived lack of relevance to the syllabus and scarcity of computers discouraged the non-users from using dataloggers. Similar reasons were supplied by past users; the main reasons given for ceasing to use dataloggers were the lack of time (47.3%) to prepare, set up and carry out datalogging activities, and the pressing need to complete the planned work schedule. Past users also had difficulties with equipment-related issues (35.1%) such as the shortage of computer workstations in the laboratory, the setting up of datalogging activities, and the troubleshooting of faulty equipment. In addition, some found incorporating datalogging into the curriculum daunting (16.5%), giving reasons such as the lack of relevant datalogging activities in the syllabus, especially in the School-based Practical Assessment (SPA) which was specifically designed to support the experimental skills in learning science. These issues are illustrated by the comments of two Science HODs, H1 and H2:

**H1:** I don’t see much success (in the use of dataloggers)...seriously I don’t see much success...in fact...my dataloggers are...actually white elephants...I have to find a place to store...right, and I also have a hard time encouraging my teachers to use ...because...I myself also find it so cumbersome to use...and I also find it very difficult to...you know...expect my teachers to use it...at the same time, lab techs also, they are not familiar...thus, some constraints there. (Note: ... denotes pause.)
H2: Time consuming...issuing and collecting the multilog (a brand of dataloggers)...like if you want to use it to measure the voltage, ordinary voltmeters can do the same job...and temperature...clinical thermometer or this lab thermometer can do the same job, so it’s time consuming (to use dataloggers).

Using dataloggers solely to measure temperature and voltage, as H2 had mentioned, is indeed a waste of time and effort as it is much easier to use a normal thermometer or voltmeter. Of note is the requirement to not only have the datalogger but also to have available an associated computer. This combination of two pieces of equipment imposes additional challenges for the teacher over single unit measurement devices.

Use of dataloggers
The most common use of dataloggers was in demonstrations and experiments. Experiments were the set student activities which were included in each school’s scheme of work. The percentage of all users (users and past users) who indicated that they used dataloggers for demonstration was 59.4%, and for worksheet-based experiments, 56.3%. Dataloggers were used to a lesser extent in fieldwork or project work (19.0%), enrichment activities (19.6%) and for co-curricular activities (5.6%). Respondents were asked to give examples of how they had used dataloggers (see Appendix item D3). In particular, they were asked to describe the outline of the activity, and the roles of pupils and teacher in the activity. From Table 1, the majority of the examples (71.9%) were worksheet-based experiments where students followed instructions like a recipe from the worksheet to set up the experiment, collect data and interpret the results. Student investigations (14.7%) where the students had to plan their experiments themselves were a much less used pedagogical strategy, and teacher demonstrations (13.4%) represented the remainder of the uses. It can be seen that the pedagogical affordances of scientific enquiry and independence to focus on the science rather than the procedure was largely not taken by the teachers. Examples or the range of uses that were described in item D3 are illustrated in Table 2.

<table>
<thead>
<tr>
<th>Use of dataloggers</th>
<th>No. of examples given (n=402)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demonstration</td>
<td>54</td>
<td>13.4</td>
</tr>
<tr>
<td>Experiment</td>
<td>289</td>
<td>71.9</td>
</tr>
<tr>
<td>Investigation</td>
<td>59</td>
<td>14.7</td>
</tr>
</tbody>
</table>

Potential unrealised?
There are ‘dangers’ of using dataloggers in worksheet-based experiments; several research studies exploring practical work in science have shown that, in general, students do not understand what they are doing in the experiments and are unable to link what they have learnt in class to their practical work (Berry et al., 1999; Duit & Treagust, 1995; Gunstone, 1991; Hart et al., 2000; Hodson, 1992; Sere, 2002; Tan et al., 2001; Tasker & Freyberg, 1985). Using dataloggers in normal worksheet-based experiments where students follow instructions and collect data may not result in increased student learning if the students do not understand what purposes the apparatus serve, how to use the given apparatus, or even what to observe and measure when conducting the experiment (Sere, 2002). The time saved from not having to manually tabulate and plot data may not result in learning gains if
students uncritically watch data being displayed and indulge in unproductive (non task related) talk (Roger & Wild, 1996). As it takes additional time before the lesson to set up the datalogger and notebook computers, and then to dismantle and account for the equipment on completion, the perceived advantage of the approach must be seen by the teacher to be of sufficient value to support the time investment. As mentioned earlier, it is a waste of time and effort to use dataloggers in experiments where it is sufficient and more convenient to use normal measuring equipment.

Table 2. Responses given to item D3

<table>
<thead>
<tr>
<th>Use</th>
<th>Topic</th>
<th>Outline of task</th>
<th>Pupils' role</th>
<th>Teacher's role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expt</td>
<td>Sound</td>
<td>Pupils were required to conduct an experiment to determine the speed of sound in air.</td>
<td>Set up apparatus according to procedures in workbook, conduct experiment, record observation, perform calculations and then draw conclusion.</td>
<td>Provide guidance and advice.</td>
</tr>
<tr>
<td>Expt</td>
<td>Investigating the melting and cooling of stearic acid</td>
<td>Pupils have to carry out instruction given in practical worksheet and use the datalogger to register the changes in temperature of stearic acid as it is warmed to its melting point and allowed to cool back to room temperature.</td>
<td>Pupils have to connect up the datalogger and calibrate the logger with instructions given. They then measure the temperatures of changes with time. Sketch the graph of the data obtained.</td>
<td>Prepares the worksheet on the practical. Give instructions for pupils to carry out the calibration of the datalogger. Supervises the pupils during the experiment.</td>
</tr>
<tr>
<td>Expt</td>
<td>Enzyme kinetics</td>
<td>Monitor the amount of products formed as a measure of the rate of enzyme reaction.</td>
<td>Carry out procedure i.e., grind leaves, extract enzyme, carry out experiment i.e., monitor rate of reaction, setting up of experiment.</td>
<td>Plan procedure, knowledge dissemination, assist in experiment.</td>
</tr>
<tr>
<td>Demo</td>
<td>Nuclear Physics</td>
<td>The loggers were used to demonstrate spontaneous decay of radioactive particles from a given source.</td>
<td>Spectator - nature of experiment disallows student participation at secondary school level.</td>
<td>Prepare and check radioactive specimens for leakage. Set up the Geiger-Muller tube, multilog data logger and notebook attachments. Prepare notes and Excel spreadsheets for graphing purposes.</td>
</tr>
<tr>
<td>Student invest</td>
<td>Lower secondary science project Work</td>
<td>Pupils were required to monitor the pH value of a number of water samples related to research on optimal conditions of algae growth.</td>
<td>Plan the experimental setup and carrying out the experiment.</td>
<td>Provide necessary advice on experimental setup and suggestions on apparatus they could make use of.</td>
</tr>
</tbody>
</table>

Full exploitation of datalogging not only requires knowledge of the workings of the sensors and the facilities available in software, but also vision of how the tool or method might be used for scientific inquiry (Rogers & Wild, 1996). For example, dataloggers can
be put to productive use in demonstrations or experiments where the aim is to provide students with an experience of the phenomena that they are studying (Woolnough & Allsop, 1985). For students to experience an exothermic reaction, a beaker containing the reactants can be circulated among the students to allow them to feel the heat produced by the reaction – a macroscopic representation of the reaction. At the same time, a temperature sensor can be placed in another beaker containing the same reagents to allow students to see, in real time, a graph of the changes in temperature with time to enable them to experience the symbolic/graphical representation of an exothermic reaction. These experiences add to the personal data bank of the students which can help them in “acquiring theoretical understanding of the underlying concepts later” (Woolnough & Allsop, 1985, p. 46). Similarly, students can see and experience the real-time graphical representation of a bouncing ball using a motion sensor, an experiment that is difficult to conduct without a datalogger as the changes occur over a very short time frame and they are very difficult to measure using normal measuring equipment. The most recent dataloggers have associated software which enables students to see the displacement-time, velocity-time and acceleration-time graphs one at a time or simultaneously, to calculate values, and to compare the differences at any point in time. By exploiting such real-time data display, the data transformation capabilities of dataloggers and their ability to record changes in short time frames, dataloggers can be feasibly used in practical work with students experiencing scientific phenomena.

Dataloggers can also be used profitably in inquiry-based science or investigations. Investigations are important as a practical work pedagogical strategy as they help students to “develop competence, in working like a real problem-solving scientist” (Woolnough & Allsop, 1985, p. 51). Steward (1988) believes that if students are allowed to design their own experiments, “then the laboratory protocol becomes more important than the laboratory report” (p. 269) and more time is spent on planning and organizing the experiment than on ascertaining whether the results are as expected. Again the real-time data display, and data analysis and transformation capabilities of dataloggers lend themselves well to such student led investigations. In addition, the range of questions that can be investigated and amount of data that can be collected expand as dataloggers support measurements of transient phenomena, as well as longer term monitoring of variables (Osborne & Hennessy, 2003; Singer et al., 2000). However, dataloggers are only enabling tools, so they do not guarantee student’s success and learning in investigations.

From the survey, there is little evidence of the students engaging in inquiry-based science though there are many experiments involving the use of dataloggers. The students were reported to "do" worksheet-driven experiments involving dataloggers that tended to be of the verification type in which they seek the "right" answer. Hence they lack the skills to conduct investigations and need to be taught “the purpose and skills of inquiry as well as how to carry out a set of tasks for scientific purposes” (Flick, 2000). This was borne out by additional observations by two of the authors, of a group of 18 Grade 7 students participating in 17 weekly, hour-long, inquiry-based datalogging sessions. The learning activities in the sessions included heat conduction and radiation experiments, using light sensors to create a burglar alarm, as well as to determine the period of a pendulum and a rotating fan. The students had difficulties with the dataloggers as well as the investigations; they had little idea of the purpose and method of sensor equalization, how to design the experiments, how to interpret data, how to use data as evidence for their inferences, and how to control variables and minimize experimental errors. Overall, they could not relate theory to their investigations.

While inquiry-based science is encouraged in syllabus documents and is taught in their pre-service science pedagogy modules, secondary science teachers in Singapore generally
do not place much emphasis on it. The main reason is that the national science practical examinations at Grades 10 and 12, until recently, do not include any inquiry component; only from 2005 is an inquiry component included in the Grade 12 practical assessment, and from 2007 for the Grade 10 practical assessment. Thus, the teachers may not be competent in conducting inquiry-based science lessons, and need to learn to scaffold the inquiry process by helping students “learn to gather information, evaluate evidence, select methods for investigation, weigh alternatives, and recognize when they need more information” (Linn & Hsi, 2000, p. 46). They need to be able to play the key role in selecting, modeling, instructing and cueing the use of skills necessary for inquiry, to use “questions, prompts, task selection and structured classroom interactions as cognitive supports for recall of appropriate knowledge and skills in a timely fashion to maintain the continuity of investigative work” (Flick, 2000, p. 109). Teachers were provided training by the equipment vendors when dataloggers were distributed to schools but the training was largely focussed on technical how-to-use-it skills. The Educational Technology Division, Ministry of Education, Singapore, provided several follow-up workshops and activities to help teachers integrate the use of dataloggers into the curriculum and in inquiry-based science, but these were generally one-off training and newer teachers might not have the opportunity to attend such training. Thus, there is a pressing need for modules on how to use dataloggers effectively in science, as well as inquiry-based science pedagogy in in-service teacher education.

Overall, the results of this study suggest that the unique affordances of datalogging are not being fully realised in science lessons because teachers are generally uncertain how to use dataloggers to enhance the learning of their students, and lack the skills and experience in facilitating inquiry-based science. Thus, it is not the datalogger technology that is the real focus of concern, but the vision of how the datalogger can be appropriately used, and the myriad of ways of how teachers can be supported in their use of dataloggers in their classes and in conducting inquiry-based science.

References


Murphy, C. (2003) *Literature review in primary science and ICT. A Report for NESTA Futurelab* (No. 5) (Bristol, NESTA Futurelab).


Appendix: Examples of items in the online survey
(Note in the online version, the open-ended items included space for respondents to type in their comments)

Types of usage
1. Which is/are the subject(s) you used dataloggers with? (You may tick one or more responses)

   - Physics/Science(Physics)/LSS(Physics)
   - Chemistry/Science(Chemistry)/LSS(Chemistry)
   - Biology/Science(Biology)/LSS(Biology)

2. What did you use dataloggers for? (You may tick one or more responses)

   - Demonstrations
   - Set experiments from workbook/worksheets
   - Student initiated investigations
   - Fieldwork/Project work
   - Enrichment programmes
   - Co-curricular activities (e.g. science club, competitions)
   - Others (please elaborate)

How are dataloggers used?
Types of tasks
D3. In the table below, based on the science subject(s) you indicated in question 1:
Name the topics/project titles for which you used dataloggers and describe how you/your pupils used dataloggers in these lessons.

Example:

<table>
<thead>
<tr>
<th>Subject/Topic</th>
<th>Outline of task</th>
<th>Pupils' role</th>
<th>Teacher's role</th>
</tr>
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</table>

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