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The SENSE Project: A Context-Inclusive Approach to Studying Environmental Science within and Across Schools

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Abstract. This paper describes a project designed to provide children with a context-inclusive approach to collecting scientific data. The term context-inclusive refers to the collection of data which records the process of scientific data collection itself. We outline the design process carried out within two partner schools with the aim of engaging children in taking part in, and reflecting upon, the scientific process involved in collecting and analysing scientific data. We provided children with the ability to share and compare their data with children at their own and other schools. Our context-inclusive approach involved the design of tailored sensors and a bespoke interface displaying video data synchronised with environmental pollution data. Through evaluation of the data collection, analysis and sharing sessions, we describe how the context-inclusive approach impacts on children's understanding of the scientific process. We focus on children's discussion and reflection around understanding the constraints of measuring. We argue that the collection and presentation of contextual data engenders reflection on constraints, and may enable improved understanding of that process.

Keywords. Context, collaboration, eLearning, children, evaluation, sensors, pollution, visualisation

INTRODUCTION

Innovations in Grid computing (Foster et al., 2001) and e-Science will soon enable access to large collections of remote scientific data and high performance visualisations of this data, including data captured from sensor networks, for example as part of environmental science (Steed et al., 2003). The SENSE project, reported on here, builds on such approaches and technologies with the aim of demonstrating how Grid-enabled e-Science sensors might provide data resources for children to collaborate with one another within and across schools.

Several recent projects have involved children collecting data within their local environment and then being connected with other children so that they can make sense of, and compare data (see Cohen, 1997; Lawless and Coppola, 1996; Pea et al., 1997; Tinker and Berenfeld, 1994). As new interactive technologies are developed, new possibilities emerge for children to learn by doing, receive feedback and refine understanding while building new knowledge (see Kafai and Resnick, 1996). Authors have often argued that the nature of investigation is better understood by carrying out one's own inquiry (Dewey, 1910/1964; Resnick, 2000), and many educational institutions aim to help children learn through real world contexts by carrying out field trips and visits. These experiences however, are often peripheral and educational environments have become increasingly structured, allowing limited time for creative participation and autonomy in learning (Resnick et al., 2003; Price et al., 2003).

There is also a move towards using mobile technologies to support class-based experiential and active learning. The RAFT project employed the ideas of mobile learning in remotely accessible field trips (Kravcik et al., 2004). The children on the fieldtrip used tablet PCs, a web cam and microphone to connect to peers back in the classroom who were able to offer extra information to the field group, and input their ideas to the team's goal.

In all this and related work, there is a concern that individual learners gain an understanding of real world context and this can be achieved through exploring and discussing these contexts. Where collaborative learning is concerned, children are often introduced to (aspects of) real world settings to ground their knowledge and understanding. In the SENSE project we have been acutely aware that sensor technologies should be used by teachers and children to aid real world collection and analysis of data. However, while other projects are exploring real world collection of data and the importance of collaboratories involving other children and scientists, we have particularly focused on how the distribution of such data over networks will remove such contextual factors of real-world settings as are afforded by local experience. Accordingly, we have stressed the importance of video to enable children to contextualise the data they are exploring. Children collected data within the natural environment, extending activities that teachers already carried out in class, but giving them additional resources to enhance the relevance of context and engage children further in the process of science such as exposure to time/location methodology.

The contribution of this paper is to inform how the video data collected operates to give contextual cues and therefore understand how best to design remote collaborative technologies. We proceed by describing the sensor technologies and applications we have developed, and then discuss our evaluation of our context-inclusive approach taken from analysis of video recordings of the school data collection, analysis and sharing sessions.

DESIGN ACTIVITIES

Environmental Science in School

The children's domain of scientific work was environmental science, and more specifically pollution monitoring, specifically focusing on carbon monoxide (CO). In order to introduce the domain and use of sensors we developed a programme of activities that spanned one school year. Working closely with the teachers and children at two schools, one in Nottingham and one in Brighton, the aim was to encourage children to think about the process of 'doing science'. The activities were designed to familiarise children with capturing, manipulating and reflecting on their own air quality data, and with using a tailored interface to share data across schools. The children in Nottingham were aged 10-11 years, and in Brighton aged 13-14 years. They generally worked in small groups of 4, accompanied by an adult facilitator when data collecting.

Technologies

In order to conduct these school sessions, we developed a range of technologies that enabled children to input, manipulate and visualise their collected data in a variety of ways. Whilst we are yet to directly integrate with Grid technologies to distribute data across schools, we simulated such an approach by hiding the technical process of data transfer between participating schools.

The small teams of school children were given an array of sensors to measure their local environment: a CO sensor; an anemometer for wind speed; and a video recorder to record the scientific activity in context (Figure 1). In addition, a local map was used to plan measurements locations, and any changes to the plan. The CO sensor equipment was designed for use in environmental scientific research (Steed et al., 2003), and adapted following design sessions in school with the children. CO readings were recorded and displayed by a PDA attached to the CO sensor. The children in Brighton kept the CO sensor and a PDA together on a board, whilst children in Nottingham made the CO sensor multi-coloured and attached it to the end of a stick.

Figure 1. Sensors used to collect environmental data: anemometer, CO sensor with PDA, video recording

Data Analysis Tool

The data analysis challenge for the children was then to manage the different types of data they had and to develop an understanding of what each data type told them individually about their local environment and what the combination of data types offered them in their task of air pollution analysis. For this detailed analysis and reflection task we created a data visualisation tool for use in the classroom. Our tool displayed a graph of the CO data, along with time-synchronised video data recorded by the children (Figure 2). Annotations of interesting and surprising points recorded by the children were then added to the graph, e.g. when a large vehicle passing did not appear to increase the CO reading. Annotations were displayed as a red point on the graph.

ANALYSING AND SHARING

Our analysis focuses on the children's understanding of the scientific process, particularly how understanding the constraints of CO measurement is impacted by the provision of contextual data alongside measurement data. We examine how children explored measurements whilst considering methodological issues in data collection. We focus on critical incidences around factors such as delayed readings, effect of the wind on the readings, and recall on incidences of particular import. We divide our analysis into the particular stages of the process from data collection, through analysis and finally through reflection on data provided by the other school.

Data Collection

Hypothesising about expected CO readings began in the classroom during route planning activities. The nature of obtaining immediate readings whilst out collecting data meant that these hypotheses could be discussed, and location decisions altered during the data recording session to develop more in-depth hypotheses about how CO behaves, and the properties of the sensing devices in use. In one example, a group of children saw a lorry coming out of their school and waited to measure exhaust fumes as it passed. No change was recorded by the sensor, with the reaction "that's rubbish!" elicited from one in the group. Using knowledge about the equipment, the group decided to alter the position of their sensor at a roadside location and place it on the pavement, closer to traffic exhaust fumes. They further hypothesised that their position by a pedestrian crossing would reveal higher readings because "at the traffic lights cars stop then they start again so they must… chuck a lot more carbon monoxide out." A lower reading than expected was gained here and the children reflected on the equipment they were using, and also whether wind may be responsible for that reading.

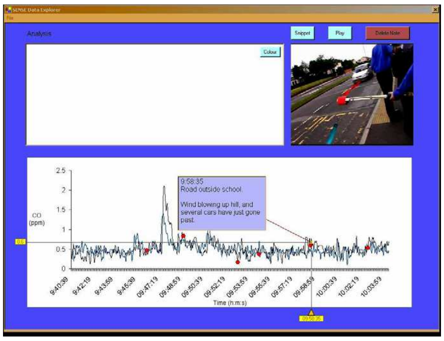

Figure 2. Data Analysis Tool Interface with CO graph, annotations and video context

Data Analysis

On the following day, the children used the data analysis tool to inspect their data. The group mentioned above developed their own ideas about how their equipment worked. At the time of the lorry incident it was not apparent that their monitor had detected an increase in CO. One girl noted, "The lorry didn't do much [to our CO reading]… we would have thought there would be more pollution, it's a big vehicle and we were standing right behind it".

Reviewing the video data, another child then noticed, "It suddenly goes up in a minute… What happened at 10:09? The next bit where we stopped it goes up really high". Another responded, "It might be we haven't actually got the carbon monoxide yet, it's sort of floated… and then it started reading". They then chose to annotate their graph with their hypothesis about the equipment, "We expected more of a change in carbon monoxide [by lorry] it took longer than we expected about 30 secs or maybe a minute to go up slightly".

The sensor used in Nottingham was attached to the end of a long stick. This enabled children to experiment with holding it in different positions in relation to the traffic. The wind ribbon was also attached to this stick underneath the sensor. The children recorded the wind direction in relation to the hole on the sensor where the air enters. These two factors led children to experiment with trying to 'catch' pollution, by turning the sensor to either face the wind, or to face the direction they believed the car exhaust would be coming. These brief instances highlight the children's awareness of how the design of the sensing technology could influence the results.

The facility to view synchronised video and CO data was used both as a memory aid for what was done, and as a way for absent children to participate in the later reflection stages even though they had not witnessed data collection first-hand. Our intention for data annotations was that they would enable others to access the reflected thoughts of the children who captured the data, whilst providing further opportunity to add in their interpretation of the data or hypotheses. Comments that were inserted included location-relevant information, wind observations, notes about malfunctioning equipment, reasons for location choice and reasons for different sensor positions and orientations.

In the classroom we discussed reasons for high readings which did not seem to connect to any occurrence of heavy traffic. Children talked about how the wind could disperse or focus CO. One interesting feature of our use of video was that the video camera also acted as an indicator of particularly windy conditions due to the noise from the camera's microphone as wind blew across it. Children also talked about how air enters the sensor via a hole in the sensor casing. The directional nature of the hole, together with the wind, can affect the reading of CO. In this respect the design limitations of the technology enabled the children to gain a deeper understanding of CO and air movement. It also made them critical about the results they obtained, realizing that there are not always direct mappings between readings and pollution. Interpretation was needed in order to begin to make sense of what was happening, and contextual cues taken from annotations and video data were relied on in these instances.

Sharing and Reflection

To engage the school children further in understanding air pollution and promote deeper reflection on their findings, children had the opportunity to ask questions of children at the other school who had engaged in the same project. These data sharing sessions occurred between remote others who were not known before the session. Prior to communication, children from each location were given the opportunity to review the other location's video, CO and annotation data using the familiar analysis tool. Discussions centred on noticing differences in data collection methods, e.g. the two schools used different methods of collecting wind data (a ribbon versus an anemometer), how the sensor was mounted (a stick versus a board), and the different types of annotations made. Comments were made about the sensor design "theirs is on a stick"; about the scale of CO data, "they've got over 200 [parts per million CO]!"; and "What does wind towards mean, and wind across?", referring to annotations.

The feedback obtained from the participants in the session provided understanding of alternative ways to carry out a study. It opened up dialogue on aspects that children at each location had so far taken for granted:

"We held ours [CO sensor] lower to the ground and got a lower reading but they held theirs higher up and got a higher reading so if we were to do it again I would probably hold it up in the air not put it down"

Most notably, the kinds of reflection which occurred relied most prominently on the contextual data, such as annotations and video views of data collection, in understanding how the measurements were differently structured and obtained.

DISCUSSION

Gordin and Pea (1995) suggest that the ability of the human mind to quickly process and remember visual information suggests that concrete graphics and other visual representations can help people learn. We certainly believe that the video of the context in which the children took their readings aided children in understanding and reflecting upon the data they had collected. They also helped children make sense of the conditions and context in which the data sets from the other school were collected and enabled them to reflect on the method as well as the results. We believe this context-inclusive approach is significant for three reasons. Firstly, it allows individuals to reflect on method as part of data collection. Secondly it provides an aide-memoir to groups who have collected data together in interpreting results. Thirdly, it allows new participants who have engaged in similar processes to understand new perspectives on their own and others' data. It is not difficult to imagine the import of such findings for activities required by national curricula in situations where schools are networked together. Our initial studies have shown that contextual data can allow the remote participation of schools at a distance with plausible outcomes of comparison and reflection on both process and results. Such a process does not just support locally-directed learning, indeed it relies on the differences in local interpretations of scientific activities. Such interpretations are then bridged by children at remote sites through the use of contextual data.

We have identified important specific features of our approach. Firstly, the use of a common interface in presenting and analysing data is beneficial in later cross-school interpretation. Secondly, contextual data may include a number of features. In the case of SENSE, we have used time-synchronised video data and time-indexed freeform textual annotations. Finally, we highlight a range of future possibilities for furthering our approach.

Initially, we have noted possibilities for further contextual data. For example, the impact of wind on our particular scenario of pollution indicates that visualisations of wind data might prove useful. More generally, it is the case that trails on a map displaying GPS data would also provide interesting contextual cues (e.g., see Iacucci et al., 2004).

Future direction would involve designs that take into consideration the methodological issues that children were reflecting upon. For example:

- By developing software which calculates or averages time differences between reading points and annotation points, so that understanding time delays in registering readings can be considered.
- By using unanticipated features of the contextual data, such as wind noise over the video camera microphone to consider the contextual properties of each of our data sources.

In discussions, Tom (year 9) reflected "Going outside to actually measure it yourself, makes you really think about what you are doing and not just reading it out of a book cos then it doesn't mean much". As such, and following Tom, the experience retained much of the child-directed approaches to learning that research in CSCL has repeatedly shown to be an important feature of learning. Nonetheless, by encouraging children to collect what we have termed context-inclusive data, we have facilitated an integration of individual, small group and remote collaboration. The use of contextual data has supported consideration of methodology across all three whilst allowing children to collaborate across schools without the financial and time costs of field trips and long-term programmes.

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