SCIENCE, SENSORS AND GRAPHS IN PRIMARY SCHOOLS

Ed van den Berg, Frank Schweickert and Rosea van den Berg

ABSTRACT
Within the framework of the European POLLEN project, we developed a series of activities with sensors and graphs for Dutch primary schools – i.e. for children 10 to 12 years of age. Lessons were piloted with 282 children and their teachers at four primary schools in the inner city of Amsterdam. The simplified interface €Sense in combination with the software Coach Lite allows for measuring and graphing temperature, light, and sound. The activities use minimal text, and focus on the exploration of the sensors as a tool for free investigations. The paper reports on what the children learned and on criteria and boundary conditions for making ICT enriched activities work in primary schools.

KEYWORDS
Science, sensors, ICT enriched lessons, primary schools, digital microscope, graphs

INTRODUCTION

There have been many studies on data logging in secondary school, but few in primary schools. McFarlane et al (1995) reported positive experiences with children of age 7 and 8 in UK where use of sensors in primary schools is probably most widespread. Other positive experiences have been reported in well controlled studies by Nicolaou et al (2007) in Cyprus and Zucker et al (2007) in the USA. Children can handle data logging equipment and learn with it.

In the Netherlands the AMSTEL Institute has been involved for well over 20 years in developing and expanding a platform for micro-computer-based laboratory. The *Coach* platform enables measurement with a large collection of sensors, data analysis and representation, video measurement, modelling, and robotics. Data collection outside is possible as well using a data logger. *Coach* won the European Academic software award in 2002. *Coach* is present in almost all Dutch secondary schools and has users in many other countries as well. Most users are at the upper secondary level (grades 10 – 12), but Coach is also used at junior secondary level and in universities. Six years ago, we tried some activities in elementary school. The activities were designed such that most options in the software were hidden, thus creating a simplified environment. Children conducted measurements in a learning corner, for example working with a computer in a corner of the classroom or in the hall. We would teach one pair of children how to conduct measurements and produce graphs. Then each child would be paired with another child and usually within 20 minutes the new children learn from their peers and would be able to conduct measurements and produce graphs by themselves. They would then teach others, and so forth. The children rotate through the learning corner until eventually the whole class had carried out the activities. We reported on this amongst others at GIREP 2006 and in Berg and Ellermeijer (2006).

Figure 1: €Sense with plugged-in external temperature sensor and USB-connector. Also on the frontpanel: the sound sensor and the light sensor. (photography: © Andrea Denotti, denotti.com)

Since 2007, there is €Sense, a little pink box with a sound sensor, a light sensor, a temperature sensor (Figure 1) and a buzzer. €Sense has been designed specifically for use in the elementary school and is plug-and-play. Just plug it into a USB port and the software starts up. All the pupil has to do is to choose an activity and then go! Well, that is what we think. How does it work in the classroom?

We designed a series of activities (Schweick et al, 2008) and tried them out in schools with the following questions:

- How does €Sense work in the classroom? Can children use it as easily as we think they should?
- How does €Sense work when some 25 children are doing sensor activities at the same time rather than only two of them in a learning corner? Can teachers manage this without extra assistance?
- What do children learn from the activities? In particular, what did they learn about connecting graphs with physical phenomena?
- How can teachers be prepared for teaching effectively with the sensor and data analysis package?

TEACHERS AND SCHOOLS

Somehow it was difficult to find schools for try-out. Children have a very low threshold for computer activities, but elementary teachers have a high threshold for science and technology (S&T) and even higher for S&T with computers. After false starts at schools where the key teacher got sick and another got into an accident, we linked with 4 schools through an existing ICT project which promoted computer use in teaching but lacked content. Because of this way of entering the school, our sensor project was initially considered as sort of a road show, an event where teachers could sit back and visitors would do the teaching. In a second round, this was corrected by clear agreements with the teachers and by withdrawing ourselves gradually during the lessons.

In 2007-2008, we had access to four schools and about 280 children from grades 4 – 6 (ages 10 – 12). The schools were located in the inner city district of Amsterdam Old-West with many migrant children In the Autumn of 2007, the activities were carried out with 142 children of two schools while in the Spring of 2008 activities were carried out with about 140 children at two other schools. In Autumn, somehow schools expected a special event run by our institute where their teachers could take a passive role. In the Spring, we required teachers to take an active role and in many of the lessons only one of us would assist. At one of the two Spring schools all grade 4 – 6 pupils participated while at the other school participation was optional and a choice alongside other electives. In the interview study we decided to focus on the school where all pupils of participating classes had taken part in the activities.

In the school where the activity was optional, some kids came gate crashing after they had heard some stories from classmates. Initially they looked ready to disturb. However, once they started they were serious and next time they opted to join again.

ACTIVITIES

There were 5 lessons with the following topics:

- Temperature
- Light
- Sound and microscope (one half of the pupils doing sound, the other half digital microscopy)
- Microscope and sound (switched)
- Activity proposed by the teachers

Each activity started with an experience of the senses such as children feeling cold and hot water simultaneously with their left and their right hand and then experiencing how their hands feel differently when put together in the cold water immediately after. So there are problems in using human hands as thermometers. Then children used the sensor and competed in trying to achieve the highest temperature. While doing this, they saw three different representations of the temperature on the screen: a column with height proportional to temperature (like a traditional thermometer), the temperature written in numbers, and a graph of temperature versus time (Figure 2). Action and graph came at the same time. After having employed the warmth of their hands and clothes, the children eventually discovered rubbing the sensor in order to achieve higher temperatures by means of friction (usually 50 – 60 °C). In another activity the children were asked to make the cooling of the sensor as slow as possible. They invented all kinds of insulation such as covering or packaging the sensor with various materials like clothing, paper, and styrofoam.

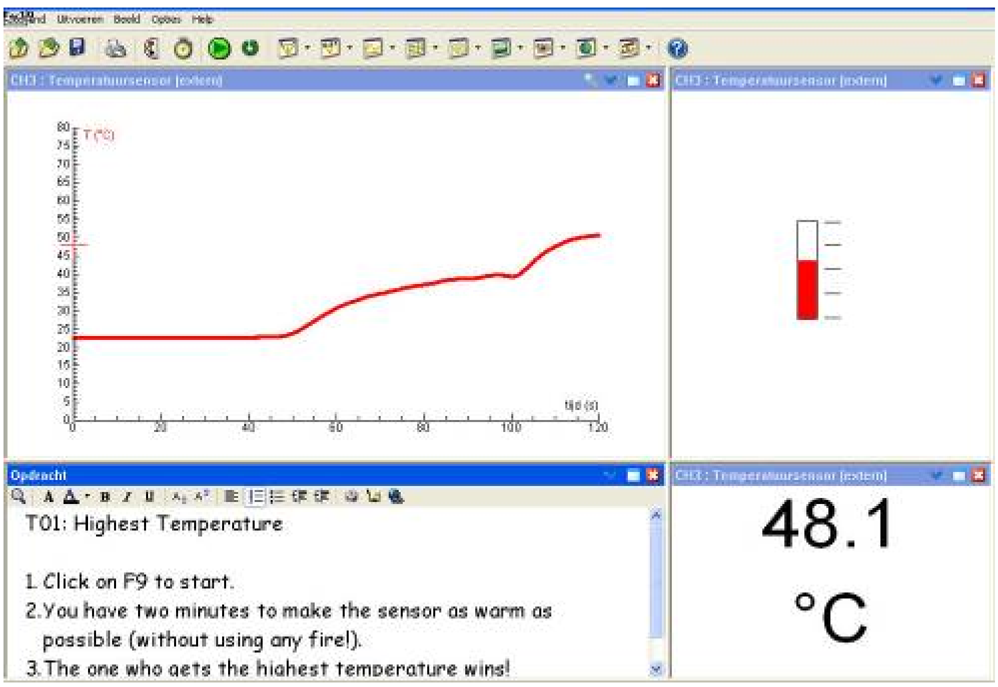

Figure 2: For 40 seconds the sensor measured room temperature. Then we started heating it by rubbing the sensor with a piece of cloth between the fingers. After 100 seconds we found a more effective way of rubbing and temperature went up further.

The idea of competition recurred in several measurement activities like *who can achieve the highest temperature* or *the slowest cooling*, *who can whistle loudest* with the sound sensor. In the latter children have to organize a fair test: The competitors have to be at equal distance from the sound sensor.

Another element that comes back in several activities is that the children are asked to reproduce a given graph with their sensor. They have to move the sensor in such a way that it will produce a similar graph to the one given, for example, a graph with two peaks, one wide and one narrow.

In an additional set of activities the children used a digital microscope to produce images on the computer screen. They could paste such pictures into a report into a word processing application, but they could also use image processing to turn the microscopic image into a work of art. Children looked at objects like salt grains, sugar grains, human and animal hair, a drop of water from a canal, and other objects. During one session, a living louse suddenly appeared crawling under the microscope. The physicist facilitator did not recognize this at first, but the teacher did. Vivid memories appeared six weeks later in the interviews.

SET-UP

The schools did not have computer labs, but the district had a travelling computer lab with ten desktops/laptops which were set up in the early morning and dismantled and moved to another school in the afternoon. Children worked mostly in pairs and some in a group of three. During the activities the teachers were assisted by one of the authors.

Figure 3: The living louse.

€SENSE IN THE CLASSROOM

The activities in the classroom went relatively smooth. The lessons did require a teacher and a developer to both be active but then it was possible to do a lot more than just fixing problems with computer and equipment. We were able to ask children questions about their understanding of the concepts involved, about experimental methods such as fair tests, and about their interpretation of the results. Sometimes it was necessary to stop the activities and let students observe the teacher do the measurement carefully as a model in order to get more accurate quantitative results.

During the first round in fall 2007, the children would type in their answers into the Coach activity on the computer screen. This way, however, it was hard to oversee whether previous screens had been worked through seriously and correctly. Therefore, in the second round in spring 2008, pupils were required to write their answers on paper copies of the worksheets. That way we could look back and ask questions about one or two screens back and connect answers to previous activities with the current one.

EVALUATION

Eight children were interviewed about four weeks after activities ended, four children from grade 7 and four from grade 8. The teachers were asked to select one pupil above average, two average, and one below average. Yet we have some reasons to suspect that those presented to us were actually in the top 60% and that the bottom 40% was not represented.

The children were first asked to remember what they had done in the various activities, and which activity they liked most. Then they were asked to conduct measurements with sound, temperature, and light. They were asked to read graphs and to interpret a given graph. They were also asked to reproduce a given graph with their sensor. See Appendix A for a list of interview questions.

Memory:

All children could mention and describe the activities even though some had been conducted two months before the interview. Some recalls were surprisingly detailed. One remembered that in the sound activity, they were allowed to go and get music instruments, that the volume of sound was too much for the sensor, and that they solved it by going farther away from the sensor. Some children remembered the units like decibel and lux which were not emphasized much. The children who had seen a louse in their digital microscopy remembered details of the body and that one could look through it and – with some imagination – see something like blood flowing inside the body.

John*: We had somebody in the class who had a louse and it was very much enlarged on the screen.*
Interviewer: Which *parts of the louse you could see?*
John*: Like an insect, light brown, you could see through and saw the blood stream. Very small hairy legs.*

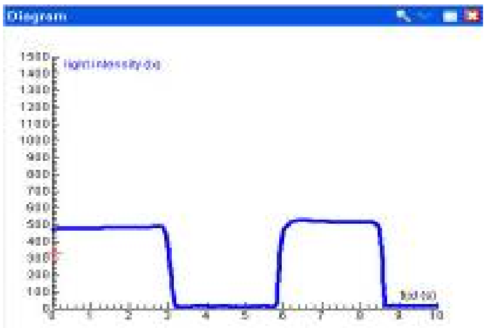

Figure 4: Light-dark-light-dark. How long did the first period of darkness last?

The *most popular activity* was the digital microscope (4 children), but also temperature (1) and light (1) were mentioned.

Reading graphs:

All children could read values on the vertical and horizontal axis of the graphs. Children were asked for the duration of a time interval, *how long has it been dark in figure 4*. That was a difficult question and three out of eight had trouble answering. One of those three first read the wrong units but then discovered the inconsistency between reading the graph.

Interpreting graphs:

All children could correctly explain the major changes in a given graph in terms of how the sensor was manipulated in order to produce the graph. They could point '*here it was light and the sensor was facing a lamp or the window', 'then perhaps you covered the light sensor or moved it under the table'*, etc. Similarly correct explanations were given for a sound graph.

Duplicating a graph with a sensor:

Children were asked to duplicate a given graph by manipulating a lamp and a light sensor, or a buzzer and a sound sensor (microphone). All children did this correctly. Usually they did it one time and then immediately repeated in a second trial to get a better version. So they were able to read the graph, figure out what to do with the sensor in order to get a graph like that themselves, and execute this properly. That shows important understanding of the link between graphs and events.

Controlling variables (fair test):

The children were asked how to set up either a comparison of the brightness of two flashlight bulbs or a comparison of the loudness of two people whistling. There was a problem with the bulbs that there were darker and brighter spots in the light of the bulb. Only one boy controlled variables immediately and automatically and did that both for light and for the sound contest.

Interviewer (I) shows two bulbs which can be switched on and off separately.
I: *What is the difference?*
Mohammed (M): *This one is much brighter than the other*.
I: *How could you compare them?*
M keeps the bulbs close to the sensor. The sensor indicates maximum for both bulbs
I: *How could you do that differently?*
M: *Do it at a greater distance*.
M then keeps the bulbs farther away but at the same distance.
I: *Why the same distance?*
M: *If you put it here (*points nearby*) than it is brighter than there (*farther away*).*

In the interviews there were no differences between children of grade 5 and grade 6.

CONCLUSIONS

We will now answer the questions:

- *How does €Sense work in the classroom? Can children use it as easily as we think they should?*
  Yes, the children very quickly learn to use the sensors and software and work with them productively.
- *How does €Sense work when some 25 children are doing sensor activities at the same time rather than only two of them in a learning corner? Can teachers manage this without extra assistance?*
  With 10 – 12 groups of children working simultaneously with computers teachers do need assistance. With more experience with computer/sensor labs the need for assistance may diminish somewhat, but at this time one assistant is essential. Therefore our future experiments will be in a learning corner setting rather than in a computer lab.
- *What do children learn from the activities? In particular, what did they learn about connecting graphs with physical phenomena?*
  Through the graph duplication activity the eight children interviewed showed clearly that they could connect graphs with events. In a given graph they could also indicate the events such as light and dark and loud and soft sounds. Some children had problems in reading time intervals and most had problems with controlling variables but that is not specific for sensors.
- *How can teachers be prepared for teaching effectively with the sensor and data analysis package?*
  Children easily work with sensors and computers. Elementary teachers have a much higher threshold for working with S&T and even more for S&T with computers. In our projects we have to push very hard to get the teachers involved. Of course they can also learn quickly how to handle the equipment and the computers but particularly in the city, they have too many other priorities and projects which compete for attention.

ACKNOWLEDGEMENTS

We would like to thank the teachers and pupils of: *De Waterkant*, *Annie M.G. Schmidt School*, *Brede School De Kinkerbuurt*, and *De Vlinderboom* and Gies Buijzerd, coordinator of ICT Creatief, a project funded by the Amsterdam district of Old-West.

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Ed van den Berg
Senior Lecturer
AMSTEL Institute
University of Amsterdam
P.O. Box 94224
1090 GE Amsterdam
Netherlands
Email: e.vandenberg@uva.nl

Frank Schweickert
AMSTEL Institute,
University of Amsterdam
P.O. Box 94224
1090 GE Amsterdam
Netherlands
Email: schweickert@science.uva.nl

Rosea van den Berg
AMSTEL Institute,
University of Amsterdam
P.O. Box 94224
1090 GE Amsterdam
Netherlands
Email: edberg51@planet.nl

APPENDIX: INTERVIEW FORM

(translated from Dutch and in condensed lay-out)

Name: ________________, Birth date: _________, Class: _____________

1. Tell me what you did with the sensors.

2. How did you like the activities? which one was most interesting?

3. What did you think you learned?

4. Measurements: children did measurements with the light, sound, and temperature sensors. The interviewer observed how fluent they could deal with sensors and software.

    a. Light with light sensor and flashlight

    b. Measuring the temperature of hot water, looking at temperature changes in evaporation, including evaporation of rubbing alcohol.

    c. Reading a given graph, horizontal and vertical axis?

    d. Interpreting a given graph, tell a story, what could have happened to produce this graph. Is there another way to get the same graph?

    e. Talking about a graph

    f. Questions about the slope of a graph.

5. Can you measure how fast you can clap your hands? How would you do that?

6. Can you reproduce a given graph using either the light (with flashlight) or sound sensor (with buzzer)?