Investigating Plant Growth and Development Using the DigitalSeed

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ABSTRACT

Here we present the 'DigitalSeed' toy for making investigations around these concepts of plant growth and development. Plant growth and development are fundamental concepts in learning biology, yet there is a recorded lack of motivation of young people to grapple with these concepts because of the contextualisation of plant biology. We aim therefore to make the concepts more accessible to children through hands-on digital interaction; this is part of an on-going project investigating improved ways of science learning involving digital media.

KEYWORDS: *DigitalSeed, Digital learning, Plant biology, Toy*

INTRODUCTION

This work presents the way in which technology can be used to simulate a biological system that takes account of the cognitive processes that are involved. Technologists might think to introduce simulations in an attempt to replace the real biological system itself, however, we recognise that technology should not attempt to do this. The challenge is therefore to at least equal the depth and breadth of learning that takes place when children have quality one-to-one instruction with respect to plant growth and development.

However, experimenting with plants in general, and in particular with the life cycle of plants, is problematic in formal schooling. Children hold constrained views of what plants are and how they function (Bell, 1981; Darley, 1990; Kinchin, 1999); factors concerning learning about animals rather than learning about plants (Wandersee, 1986; Schneekloth, 1989; Simmons, 1994; Hickling and Gelman, 1995; Tunnicliffe and Reiss, 2000; Tunnicliffe, 2001).

Life cycles produce further cognitive challenges since they require the learner to have acquired the schema of seriation or time sequencing. Traditionally, learners' interaction of life cycles has been to examine the sequence of events in the lives of animals (as opposed to plants) such as butterflies and frogs, focussing on the complex concept of metamorphosis. Young children typically do not know that certain foods bought in supermarkets are the result of plant development. Indeed, one of us (TMCC) has probed primary student teachers on their knowledge of where berry fruit originates and found misconceptions to be much in evidence. Thus the practical knowledge of the teacher, particularly at primary level will depend on what experience (s)he had in their initial pre-service education or the 'real' world. Finally, the growth and reproduction of plants is a non-interactive phenomenon in the temporal domain, in other words, it can only go forward; one cannot go back and check an earlier stage. If the next class is one week later, it may be the case that the plants have grown and developed beyond the desired point in the life cycle.

Elsewhere, we have reported the results of our initial workshops with young children (aged 4-5 years old) (Cherubini *et al.,* 2008) and here we develop interplay of the science conceptual knowledge and the technology. This is an evolving process and as we turn to older children in this on-going project, new concepts and schemata will be addressed.

METHOD

The DigitalSeed is an electronic device was built that represented symbolic images of (i) real objects (plants, seeds, *etc*.) and (ii) processes (growth, pollination, *etc*.) with animated characters.

The DigitalSeed arose from the idea that technology could help children to play with the key ideas of plant growth and development. Thus we started from the problem of the temporal direction of the growth of a real plant and how to overcome it. Obviously moving into a virtual world altogether (*i.e.,* using a computer simulation or virtual reality) would be the easiest solution but in this case we would have had to dispense with the tangible features of a real plant and the subsequent richness of the learning environment that this produces. Finally, we moved our design into a space between these two extremes. Without pretending to have all the features of a real plant, we selected those tangible aspects that we were able to, preserve in the virtual world. We decided to maintain the following variables:

- water content of plant (as opposed to humidity)
- temperature
- light

A fundamental part of the learning environment is the interplay between these variables. In the phases of the growth of the plant it is not just one factor that is dominant and responsible for growth but rather it is the interaction that is responsible for that. Humidity, temperature and light exposure are fundamentals factors for life: they have to be present at the same time and in the right proportions.

The real interface

In the real domain, we wanted a robust interface, with adequate dimensions, waterproof and shock resistant. We decided to use an iPaq "pocket pc" as the elaboration unit and as the display for the virtual world. Compaq's iPaq is a personal digital assistant (PDA) that is relatively easy to use and yet powerful enough to carry out in-depth processing of sensor data. Handheld computers or 'palmtops' have had, of course, a role to play in digital learning in science in terms of datalogging and general computing – here, though, we use the iPaq as a means to learn more about plant growth and development.

We used environmental sensors as a bridge between the real world and the virtual world, to acquire quantitative differences around the iPaq. This acquisition process was realised through an interface board with a printed integrated circuit (PIC). Five pairs of light and temperature sensors were installed, one for each face of the cube with the exclusion of the base. We decided to use a flow sensor instead of a humidity sensor because we need to appreciate differential readings rather than an absolute value and above all because the commercial humidity sensor cannot be used in direct contact with water which is exactly which is what we intended the children to experience. (see Figure 1).

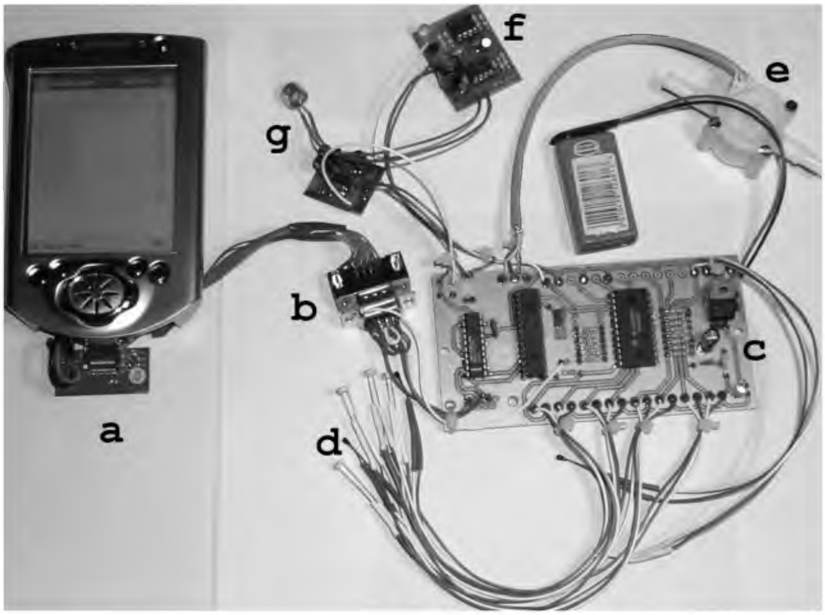

Figure 1. *Sensors interfacing with the iPaq. (a) iPaq pocket pc and the cradle, (b) serial connection with the sensor board, (c) interfacing board, (d) temperature and light sensors (a pair for each side of the box excluding the bottom, (e) flow sensor to detect 'watering', (f) clap sensor, (g) three-axes accelerometer (We incorporated a clap sensor and an accelerometer for further interactions improvements of the interface)*

We packaged this equipment within an ABS box (see Figure 2). We used two funnels, one on the top of the box, the other on the bottom to direct the water flow and to activate the flow sensor, these were fixed in position using 'silicone' bond. A window (the same dimensions as the PDA's screen) is provided to display the story of the seed. Because the temperature sensors and light sensors are all around the cube, it is possible to detect also changes in the direction of the light and the provenance of a principal heat source.

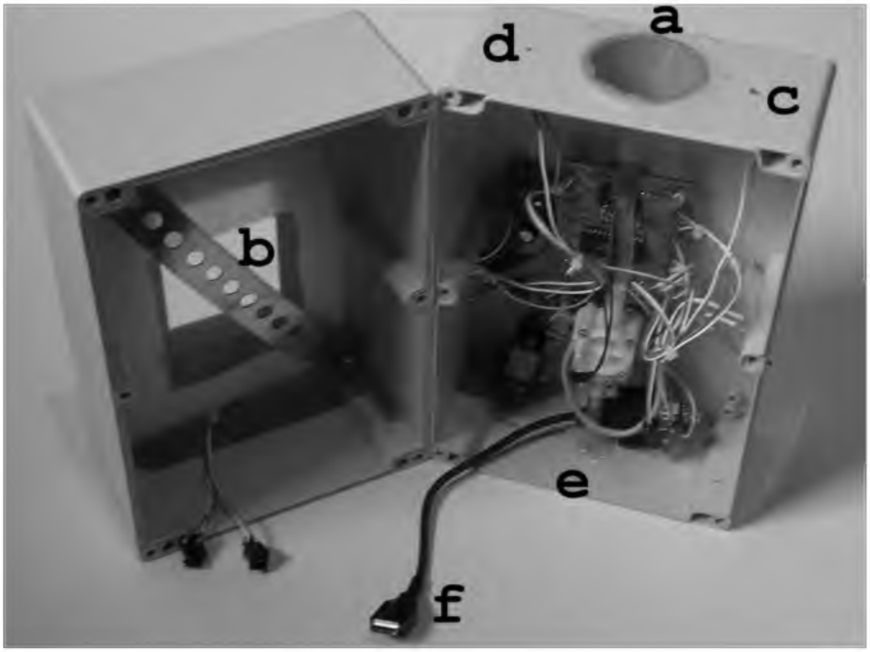

Figure 2. *Representation of the external interface. (a) Funnel or water drainage (b) Window for the iPaq display with holders, (c) light sensor, (d) temperature sensor, (e) exit of the water, (f) iPaq's cradle connector*

The virtual interface

The virtual interface takes the form of a 'simulation', and of course, simulations have been employed in science education for many years. Richards and his co-workers explored the use of simulations that were informed by a constructivist epistemology of learning back in 1992 (Richards *et al.,* 1992). Baxter (1995) used computer simulations to assess hands-on learning in the 6th grade concerning electric circuits. Indeed, the commercial programmes, 'Crocodile Clips' (www.crocodile-clips.com), is very popular in schools and colleges, and it is the one area that has had the greatest attention concerning learning through simulations. Further, we note that many simulations deal with upper secondary and third level topics in science and tend to concentrate in the physical sciences. One exception was the development of 'Lateblight 3.1' (Fry *et al.,* 1990 and reviewed in Arneson and Ticknor, 1999) – this is a computer simulation that attmepts to model plant fungal disease, which in turn lead to the renewed interest in the Irish Potato Famine as a historico-scientific phenomenon (Fry and Goodwin, 1997). Lee *et al.,* (2002) used Lateblight 3.1 to teach science process skills to preservice teachers with great effect.

The virtual interface was constructed (see Figure 3) using the Microsoft Software Developer's Kit for handhelds, mainly in 'Embedded Visual Basic'. In the program, the story of a seed prior to germination to the production of a new seed was displayed in separate frames. We divided this growth in relevant stages and we match each stage with an animation and with a different software state. The resolution used was of 240×268 pixels. Each image was prepared as a bitmap with contours in magenta. In this way was possible to process each image as a layer and arrange them one on top of the other for the animation process. To advance between stages the seed need the right input from the user in terms of the "correct environmental conditions" monitored through the sensors.

Figure 3. *The software interface layout*

The interaction between virtual and real

Initially, we had wanted a complete cycle but in a definite and reasonable amount of time in order to maintain interactivity. It was decided to assign 15 minutes the complete cycle and to work with a definite number of stages of development (n=10) in which the user could interact with the growth. The software was modelled to respond to the environmental condition in three different states: present in the right quantities, not enough present, too much present. So, between each stage/state the sensors were checked to decide whether to proceed to the following state or to proceed to a meta-state in which the plant it is not healthy (see Figure 4). This provides a reasonably challeging environment for the learner to appreciate. Not only do the learners have to appreciate the forward temporal direction of the life-cycle, but also the alternative possible outcomes, given a particular balance of variables. It is this feature that provides the richness of learning that can take place. A secondary aim therefore is to enhance the Piagetian schema of time sequencing – a specific form of seriation. We note that the CASE project included this schema as a target for their intervention at 4-5 year old age group.

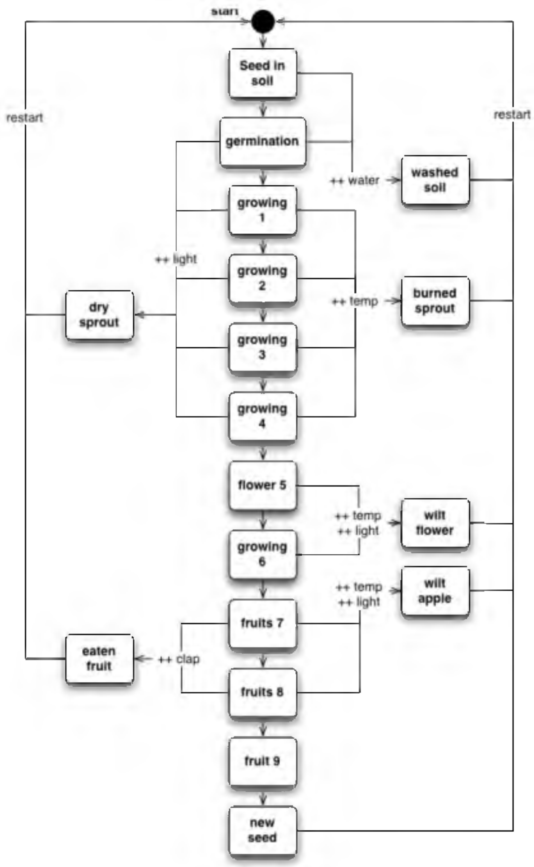

Figure 4. *Software state chart. To proceed through the main flow of interaction the child should provide the right amount of water, and light and temperature exposure of the box. Over- or under-providing the right conditions brings the simulation to one of the unhealthy states on the sides. Prolonged mistreatment of the box kills the simulated plant and the cycle is restarted*

During the life of the plant, we also include some other animations to enrich the environment and to introduce some other concepts as corollaries. What we wanted to show was the direct relation between a certain environmental component and the effect on the growth of the plant through the schema of balancing of variables. If the value of this variable was not enough the software moved to a meta-state that expressed poor health of the plant. In the same way, if the value of the variable was too great, the represented plant exhibited the unhealthy state (see Figure 5).

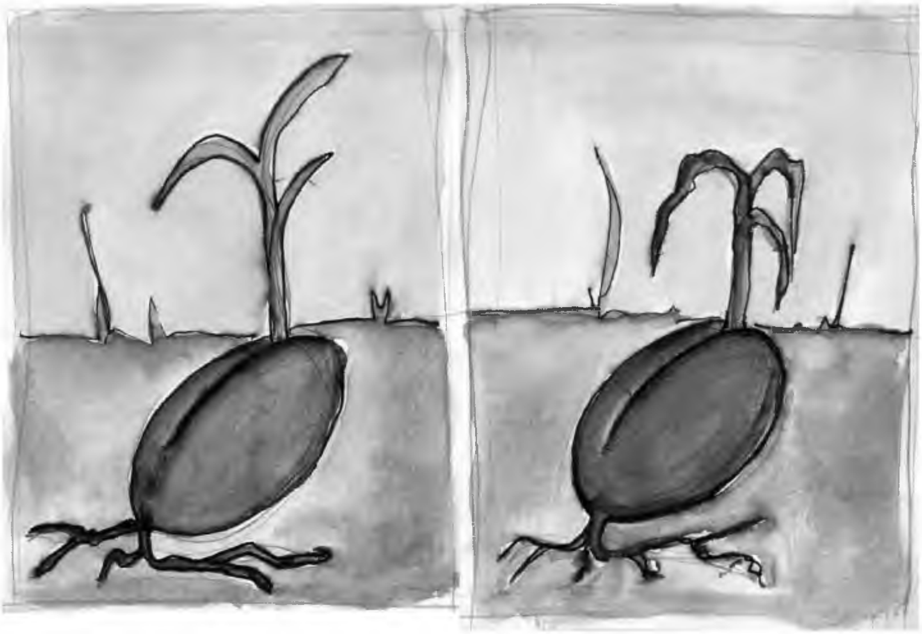

Figure 5. *On the left, the sprout healthy state.*
On the right, the sick state of the sprouted plant

The dimensions in the animation are not respected because we felt that this is not an important feature for the understanding of the growth. This direction of the animation tends to emphasise the sequence. In fact was possible to zoom to a specific part of the scene as in the final frame when we wanted to focus on the fruit and then on the internal part of the fruit, that is, the seed (see Figure 6).

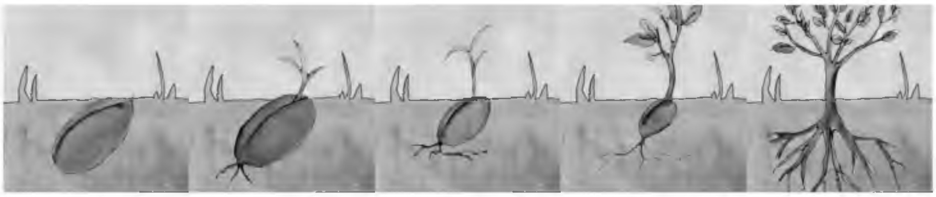

Figure 6. *Some frames of the sequence of the growth in the healthy state*

EXPECTED RESULTS AND DISCUSSION

The primary focus of this design was to give the children the sense of the continuity between the stages, pushing attention on the cycle between them: a plant 'born' from a seed and producing seeds that can 'give life' to another plant and so on. So flowers, fruits and seeds are conceived as part of this cycle, as part of the reproduction of the plant. The roots of the plants are initially hidden under the soil, but after an earlier pilot workshop (to be reported elsewhere), we decided to show them as if the child was watching a section of the terrain in which the plant is living. We 'sowed' the seed under the soil to give them the feeling of the right placement of the seed in order to find the right environmental condition for the growth. In addition, the concept of the species-specificity is addressed by this design maintaining the continuity between seeds and plant of the same kind. The environmental conditions are the variables that bring interactivity to the user/player/child.

It is expected that the DigitalSeed will be developed into a more classroom/laboratory friendly version and made freely available for teachers of biology at all levels. It is important to recall that the DigitalSeed was produced using easily available commercial resources. It is expected that the DigitalSeed (or some version of it) will make a significant impact in primary and secondary science learning as a model of the compromise between using live organisms on the one hand, and full computer simulations and graphics on the other.

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