# Chapter 1

# Conclusions

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This chapter will summarise the main arguments of this work, trying to highlight how the design solutions supports the arguments and how the evaluation support my hypotheses. Therefore is important to say that because of the time constraint of this project and for incurred technical problems, was not possible to complete the software interface as I designed, so a complete longitudinal evaluation of the Biosphera interface was not completed. For these reasons, I prefer this work to be evaluated as a design exercise instead of a complete and mature experimental work; the premises set in this thesis may be considered as a starting point for a intensive evaluation of the design solution I am proposing here and in addition as premises for future design in this particular field.

## 1.1 Summary of the main arguments contained in this thesis

The table 1.1 reports the main arguments of this thesis. Three key points emerged from my study that I consider very important whilst developing microworlds for Life science Exploration: reducing the Time Lapse between action and reaction (a); enhancing the variable's visualisation can help in understanding the current status of

the system (b); placing the variables of a Multivariate system in a defined and dynamic framework can help the learner in grasping the relationship among the variables (c); giving the possibility of proofing the validity of the simulation model can help to overcome black box assumption (d).

(a) From the DigitalSeed workshop I realised how much the delay in a system can influence the understanding an observer can have during the exploration of the same system [Gash and Cherubini(2002)]. A person, a child interacting with a plant experience this delay all the time, and because of this different time scale s/he can make hypotheses and develop conclusions not conform to reality, although in most of the cases this interaction resolves without any interesting conclusions or consideration which is why I started to be interested in this problem.

(b) A plant's pot in a bedroom is a multivariate system. Lots of variables can contribute to a model we can use to describe what's going on to the plant. Understanding the connections among these variables is not trivial. The more complexity we add, the less understanding we achieve; the more easy we look for, the more complexity we discover. My personal strategy is to imagine the variables in a synestetic and multi-modal interface able to give the user a "feeling" of the connections. I tried to incorporate a glimpse of this idea in the circle design attempt (see section **??**). The relation among the variables was translated in a metaphor of springs stretching between the circles. Unfortunately, this interface was still too complicated, with lots of visual elements that could eventually distract the user, so I moved to the tiles design which does not present the same synestetic principle but which suggest the user to think about the variables *in time*, building the set of environmental conditions along the timeline. This may help the user in thinking more dinamically about the relation between the variables.

(c) When a scientist observe a new phenomenon, s/he tries to sketch a model that can describe it, defining a certain number of variable that can represent the main feature of this phenomenon and finally defining the relationships among the variables. For this last point is essential to use a very defined setting, or strategy, using which, the observer, can make strong conclusions about the nature of these connections. One

of these strategy may consist in keeping one of the variables constant and observe the effect of this perturbation on the others. Sometimes this technique cannot be applied because it is not possible to keep a variable still all the time, so a different framework has to be used. My argument is that using a dynamic framework is possible to adapt any particular situation to the contingence of the moment, giving the user the possibility to experiment several strategies and making comparisons between them.

(d) SimCity, or SimLife [1] are great tools for learning "rules" based scenarios. Reality can be quite different and far from simulations. My approach consists in helping the users of my microworld in review critically the results of what they have obtained in the simulation using a direct comparison with reality.

## 1.2 Design synthesis

The arguments reported in the previous section reflect on precise design choices in the final prototype: (a) a simulated reality can highlight and speed up the processes which involve the plant; (b) merging the timeline with the variable's placement help the user to think about the variables in a dynamic way; (c) the possibility to save the current status of the Biosphera into a "story" files, help the user to compare two or more environmental setting with their relative outcomes; (d) a physical plant which grows with the same conditions of the virtual plant works for a visual comparison and proofing method of the simulation algorithm.

(a) In the final prototype of the DigitalSeed and of the Biosphera, I used a simulation in the software interface. In the Biosphera, this form of visualisation is driven by a growth algorithm, the WIMOVAC described in section **??**, which very finely describe how the plant is going to grow in a certain environmental situation. Because this representation is driven by the computer, and is free from physical constraints, it is possible to enhance the speed of the represented processes and highlight central aspect which are normally hidden and slow in reality. This is particularly useful when you want to maintain interactivity and sustain interest from the observer which is

[1] Both are games by Maxim: see http://www.maxim.com .

| Argument | Description | Design solution | Testing |
|---|---|---|---|
| **Time lapse** | The delay between an action to and a reaction from a plant can obstacle a person in grasping the underlying causal relation in a system (section **??**) | Using virtual reality is possible to speed up the process without a loss in connection with reality (section **??**) | The workshop for the DigitalSeed proved that speeding up the process of growth can have a positive effect in connecting Key ideas |
| **Visualising the variables** | The visual display of quantitative information can determine the understanding of physical phenomena and the relation between the variables (section **??**) | Several graphic solutions have been implemented to help the users during the exploration of the variables. The final prototype privileged the easy of the iconised variables along the timeline (section **??**) | Some workshops with kids helped to consider colours maps as good design elements to represent the interaction of the variables |
| **Variable's causality** | A dynamic framework can help the user to set the variables in different situations and then comparing the outcome (section **??**) | Running the simulation and saving the results into different "plant stories" can support such comparison (section **??**) | This features of the Biosphera has not been tested longitudinally |
| **Transparent simulation** | Accessing the model underneath the simulation can help the user to explore the microworld (section **??**) | An actual plant is kept close to the simulation as counterproof method and in addition the algorithm's constituents are accessible through a pane into the software (section **??**) | This features of the Biosphera has not been tested longitudinally |

Table 1.1: Summary of the arguments

not always trained to methodic observation and calm.

(b) From the workshops with kids described in the previous chapter I realised that children often think about light, temperature and humidity as constant entities. It is difficult for them to describe them as variables which have fluctuation in time and therefore affecting the plant growth because of this fluctuations. I argued in the third chapter that this is due to their tendency to centralise the control of the system, in accord with the definition of Mitch Resnick [M.Resnick(1994)]. For this reason, I tried to make the connection between time and environmental conditions more evident. I designed a timeline made of "blocks" of the binary icon the three variables (light, heat and humidity that could assume only two values: ON or OFF; see section **??**). Using this timeline, the user can build the environmental program moving the attention on defining the variables *in time*: meaning as entities with fluctuations.

(c) One of the most important principles of the Biosphera design is to activate and support a visual comparison between expected and current outcomes of the running experiment. This may happen entirely in the virtual side or entirely in the physical side or between the physical and the virtual side. This ability of the system responds directly to the need of having a dynamic framework in which the observed variables can be placed, some changes produced and the connected perturbations observed. This feature is also implemented in the "load/save" functionality of the software interface, where two environmental conditions set are saved for direct comparison (see figure **??**).

(d) The physical concurs to the comparison function explained at point (c). In addition, This physical part has also the mean of "debugging" the system. the Biosphera software is based on a growth algorithm, and like every model, is close to reality with a certain degree of approximation. Sometimes may happen that the model differ substantially from the outcome of the experiment. For this reason the user may experience the "black box" effect, where is impossible to understand the reasons of this difference. In this context the physical side act as a counter-proof system to the simulation. Every time the user want to discover the accuracy of the model, the physical side can be used (see section **??**. In addition, a function which

I have designed but not yet implemented, helps the user to visualise the constituent factors of the growth algorithm (see figure 1-1). Using this pane, the user can adjust the influence of each factors concurring to the growth outcome of the simulation and eventually take into account "hidden" factors not considered into the main equations (see (b) on figure 1-1).

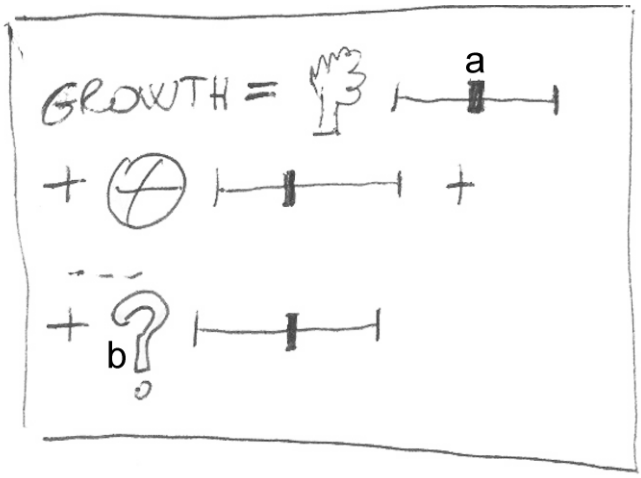


Figure 1-1: The growth pane: (a) a slidebar for "tweaking"; (b) an entries for hidden causes

## 1.3 Results evaluation

Points (c) and (d) of the design have not been tested intensively and longitudinally. However some workshops with kids have been carried out to asses the usability and the ergonomics of the Biosphera design, and some of the findings of the workshops analysed on chapter 5 supports the design solutions proposed in this work: (a) children using the DigitalSeed device start connecting the idea os seed–growth–plant; (b) using the timeline of the Biosphera software interface, children start thinking about variables *in time*; (c) children using Biosphera engaged in "growth races", restructuring their point of view on the plant biology; (d) the dome of the Biosphera interface presented aesthetic functionality and a point of reference for the young users.

(a) 4 and 5 years old children used the DigitalSeed device for a certain amount of

time. They were interviewed before and after the experience and i registered a trend in their ways of talking about the connections of seeds and plants: before they used to think about seeds as food for the plant; after they said that plants comes from inside the seeds (see chapter 5). The same concept can be applied to the Biosphera design: speeding up the process where the plant is involved can help the children to explore the connections between actions and reaction to the plant and will avoid to lose their interest in the topic.

(b) The design of the Biosphera timeline helped the users to concentrate on the variables in a dynamic way. In fact, because the user has to displace the variables along the timeline which was related to the simulation they could refer every change in the timeline with a particular point in time of the life of the plant. Changing a variable in a point in the future was not the same of changing the same variable in the same manner in the past. the growth of the simulated plant was witness of this visual difference.

(c) Most of the users of the Biosphera ended trying to grow the plant at the maximum size and subsequently engaged with their peers in a sort of competition. In doing this they tried to learn how to save their "plant story" and how to reload it. Every time the story was reloaded they tried to change a small amount of things along the timeline in a way that the changes could be "tracked" and remembered; then the changes were classified with the increased output they produced. The choice between bad and good changes was performed by a visual comparison using a trials and errors technique.

(d) Some of the children coming out of the Biosphera experience usually wanted to keep feeding the plant, asking for a commercial version of the dome. The aesthetic design of the dome is, in fact, suitable for a room environment, as a small terrarium.

## 1.4 Future work

Although Biosphera seems to be the natural evolution of the DigitalSeed design, I envision a separate development and future for each of them. Particularly, I do not

consider the DS experience concluded. Lots has to be done to proof the impact of this technology on the longer term. Lots of features and interactivity can be added to the same design to enrich the interactivity and the functionality of this object.

### 1.4.1 Biosphera

This thesis presented a prototype learning environment for exploring the underlying concepts associated with dynamic, multivariate systems. Biosphera supports learning through an exploratory, comparative framework. The working prototype I present here promotes personally meaningful knowledge creation. A key aspect of the design is the use of physical and virtual avenues of discovery. In this way, the learner is free to interact with the system, following non-linear paths of interaction, and testing multiple possible futures in the their "plant story".

In terms of future work, lots has to be done on the development of the virtual world. As I specified in the evaluation section (1.3), a proper longitudinal study has not been carried out. For this reason is important to asses if this technology is going to provoke a change in the user's learning process in the longer term, and also is important to take into account the users' ideas and opinions to build upon my initial designs. I hope that this will lead to new designs that are useful, attuned to and supportive of children's learning needs. In the longer term, I envision a further investigation of the collaborative learning paradigm by using multiple Biospheras in diverse geographical locations. In addition, The Cognitive Equation concept described in the previous section (1.4.1) needs to be developed further.

Another interesting aspect which can be developed further is the "Time based visualisations". This is a way to present the information in time oriented manner. For example in the figure 1-2, I am describing the status of the plant with a single numerical factor called: "factor $K$", plotted in the figure named above, against time. The scale of this horizontal axis can be adjusted for different purposes. For example, if nothing happen for a certain amount of time, the scale can be adjusted to fit on screen only important events, turning this visualisation system into a diachronic table. This way of representing the information can be very powerfull and informative. Another

example is represented in figure 1-3, where the current status of the plant is visually compared with its past (a kind of "history") and with its future, predicted using the growth algorithm.

### Cognitive Equation

The Biosphera workshops decribed in chapter 5 brought me to feel the need children have for a cognitive situation in which something equals something else, to say that I found that a lack of understanding or a misconception can be resolved when the object of the inquiry is situated in a context in which a modification of this object can resolve in a visible effect on the context. This design principle is used in several microworlds although is not explicated [Ackermann and Strohecker(2000)].

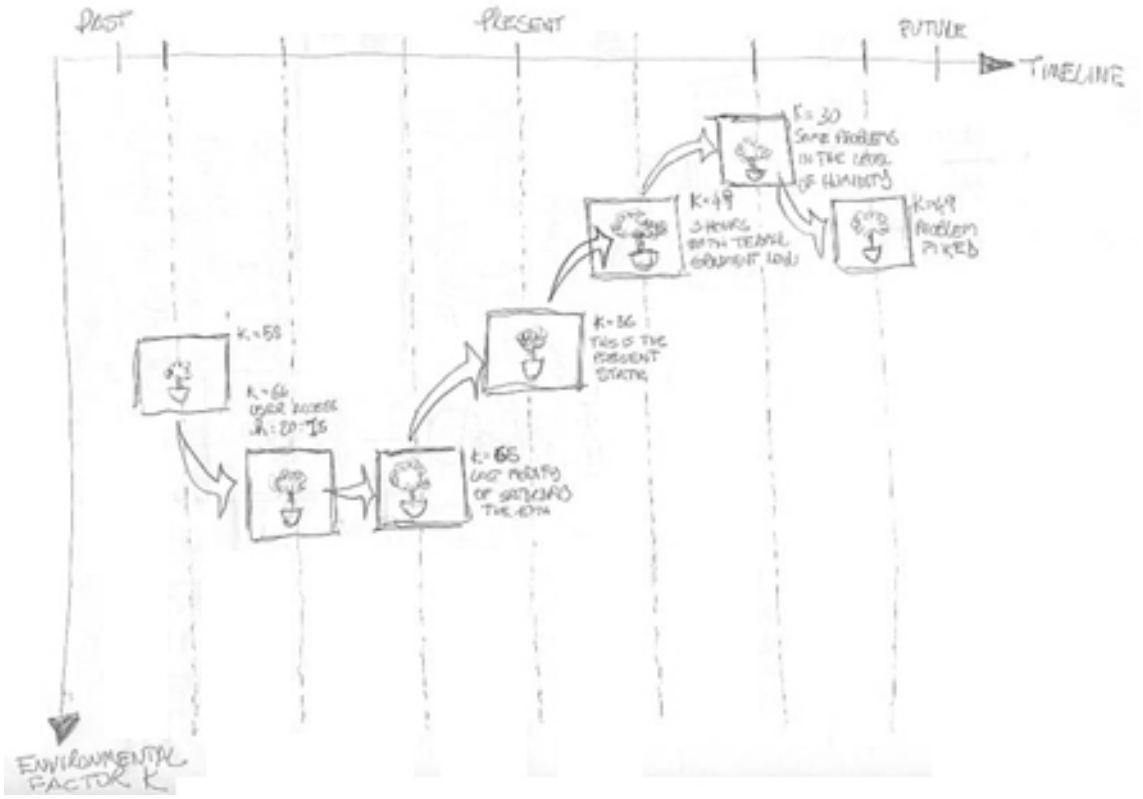


Figure 1-2: The diachronic visualisation pane

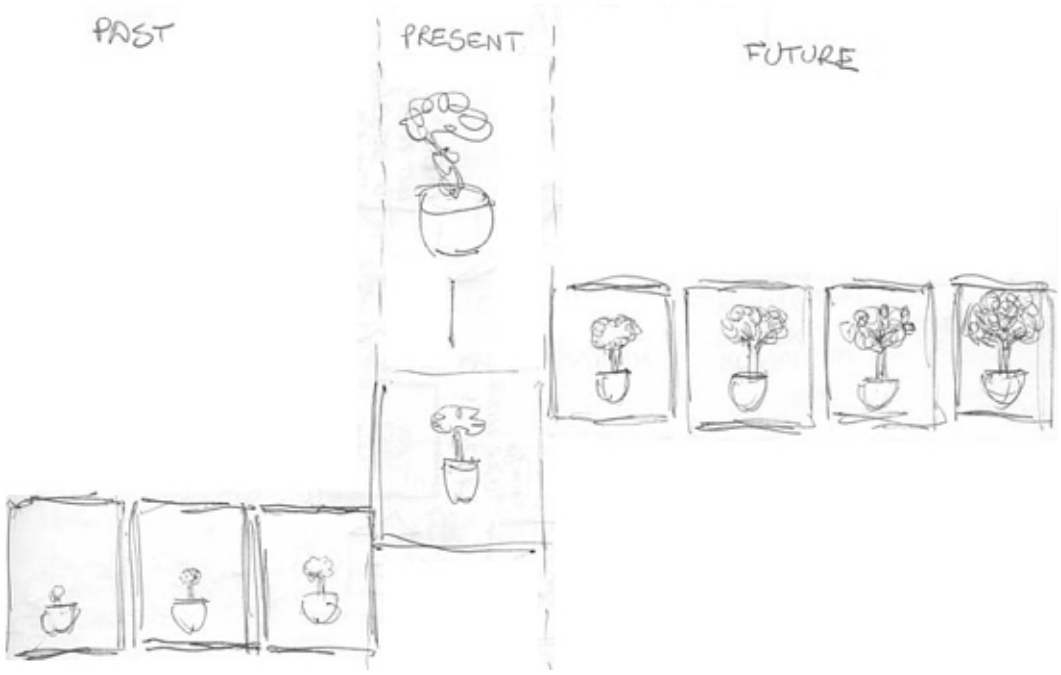


Figure 1-3: An example of time based visualisation

### 1.4.2 DigitalSeed

I regard childrens ideas not as being systematised in stages, but as differing and changing over time and culture . I am not looking for an absolute truth, but I am trying to build an environment in which children can experiment with their ideas, an environment in which it would be possible to perform operations among many states and particular objects. This interplay is informed and inspired by love for a specific idea or domain; for example, the concept of life-cycle in the DigitalSeed study. I think of knowledge as experience, and experiencing as defining ones own boundaries and curriculum (see [Peacock(2000)]).

The work reported here only begins to suggest the richness of interactivity that I am striving for. The next developments should support an indefinite number of computational states, perhaps using a simulation paradigm, and should display carefully coordinated representations in the interface, including images, sounds and tangible input devices.

In addition lots of features can be implemented on the same design to enrich

its functionality and interactivity. For example, figure 1-4 shows a possible wireless interaction between two DS boxes. A flying bee can take pollen from one box and pollinate another box. Also, using the accelerometer inside the box we can measure the "stress applied on the virtual plant", moving the plant out of the soil for strong abuses. As last example, adding a gyro sensor to the design, we can detect the inclination of the pot of the plant, rendering a growth towards the sun which is not "perpendicular" to the ground.

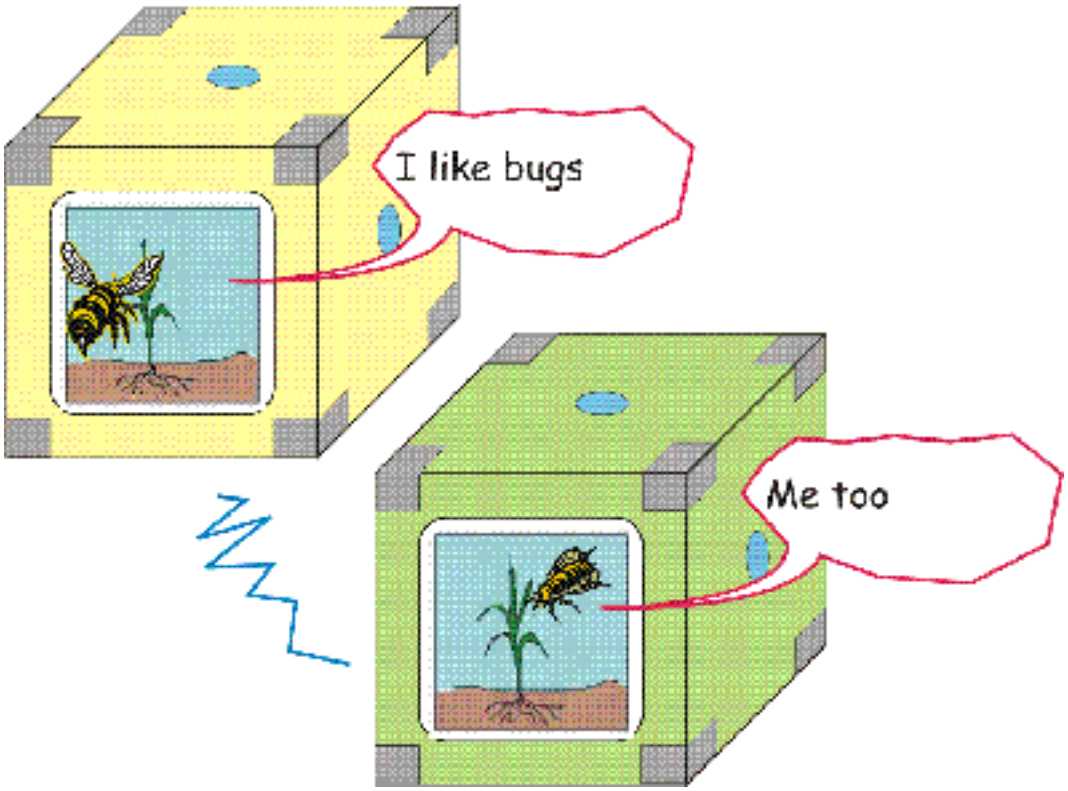


Figure 1-4: An example of wireless interaction between different DigitalSeed devices

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