Empirical Modelling and its Application in Teaching Human Biology

Abstract

This paper considers the use of Empirical Modelling as an aid in learning human biology. It is found that dependencies, one of the main concepts of Empirical Modelling have a strong correlation with relationships between organs. An EM model of the respiratory system is used throughout as a reference and a way to introduce the EM ideas. It is concluded that EM has very strong links with human biology and that its can be used as a tool to help students think about problems they encounter in the subject.

1 Introduction

It is believed that in today's classrooms and learning environment, learners construct their own knowledge according to sensory input from their experiences (Poole, 2000). These are the constructivist views of Papert which EM attempts to address when we talk about teaching. The constructivist approach of 'building' knowledge can be compared with the objectivist approach of 'transferring' information. Papert describes in (Papert 1980; Papert 1983) that providing a learner with a means (a computer) to actively build their own knowledge structure is far more beneficial than objective learning.

As well as Papert's papers, there have been many other papers and studies to show the benefits of technology and computer aided learning (Graham, 2001; Raizen, 1997; Vrasidas, 2000). This paper examines the potential merits of the approach Empirical Modelling (EM) takes in teaching students about human biology and the tools it provides the modeller to create and customise a teaching artefact. Note that in EM, the student can be the modeller or the person using the model (Roe, 2003).

To aid in assessing how applicable empirical modelling is to this problem, the tools have been used to model the respiratory system. The model is not scientifically accurate but behaves in a way that the average layman would imagine the lungs to behave.

EM is an observation-oriented state-based modelling framework (Roe, 2003) which identifies three important concepts: observables, dependency and agency. An observable is an observable value of the environment which we can assign a value to; dependencies are the relationships between these observables; and agents are concerned with updating observables according to the dependencies that they have. These concepts are examined further in the body of this paper and related to the human body.

2 Human Biology and the EM Concepts

The human body has many observables. Just looking from a high level viewpoint, we can observe the temperature, acidity, moistness, weight of the human body. Looking at the lungs, doctors can observe the surface area of the alveoli, the percentage of healthy cilia left in the trachea, oxygen intake levels and so on (Write, 2000). The more observables which are accounted for in the body, the more accurate a model of the body can be. Note that an observable requires an observer. An observer can be a student or modeller (super agent), or some agent within the model which needs to do something upon a change to an observable.

"The human body is dependent on all the organ systems in order to survive and reproduce" (Wikipedia)

"Life is dependent upon the adequate exchanges of gases in the lungs" (Kelley, 2004)

When examining the natural world, dependencies are all around us. For example, cells require energy to work. The levels of energy which reach these cells are dependent on factors such as respiration, ATP (adenosine triphosphate) and CP (creatine phosphate) stores in the body. To maintain energy to the cells, the body can perform actions to increase respiration and increase the production of ATP and CP. Hence, the level of ATP and CP are dependent on other functions in the body. Using EM, it is very easy to translate real world dependencies into a model, giving the modeller more time to think about the problem rather than thinking how to code it. Let us consider a simple example:

Overall lung health depends half on the health of the left lung and half on the health of the right lung. In EDEN, this can be written as:
overall_lung_health is 0.5*left_lung_health + 0.5*right_lung_health;

This statement ensures that the overall_lung_health is always maintained and if the left_lung_health or the right_lung_health were to change, the overall_lung_health would be updated by an agent.

To code this same behaviour in an object orientated or procedural programming language, we would need to make the requirement that left_lung_health and right_lung_health are only changed through defined functions. These functions would then need to take care of changing the desired observable and all other observables which are dependent on that. Already, this is a complicated procedure and with a large number of dependencies, this can get very complex.

Agents are what update observables according to their dependencies and can be compared to hormones and signals sent through the blood and nervous system. Without agents, the changes would not take place and our model would be static. In the same sense as if the nervous system was taken out, the human body would be lifeless.

These direct links between EM and human biology mean that the EM tools can be used as an aid in thinking about human biology and developing mental models. Assumptions and knowledge can be directly translated into a model without the need for large abstract changes to the ideas for the benefit of the programming language.

3 Learning

An important concept in the Experiential Framework for Learning (EFL) as elaborated on in (Roe, 2003) is that learning starts with private and concrete experiences and develops into public and formal knowledge. This applies to learning from real world artefacts as well as artefacts developed using a computer model.

It is clear that performing experiments on live human beings gives a student the richest learning experience. Although it may be possible to hit a hammer on a friends knee to observe their leg kick, more complex and interesting behaviour is left to videos and textbooks. For example, stimulating a part of the brain to create the illusion of a red blob in ones field of view (Robinson, 2004) is not an activity the common student is allowed to take part in. For this reason, students construct models and learn from them. E.g. scale models.

When students come to use computers for experimentation, they must rely on closed world, stereotypical applications (Beynon, 1997) which have been developed using the teacher's knowledge. As talked about in (Roe, 2003), EM is tightly connected with learning and thus bridges the gap between the developer, the educationalist and the learner. The following subsections discus how EM can be used for learning through model development, through model expansion and how EM tools can be used in the classroom.

3.1 Learning by Developing

"[EM] is about making artefacts to support human thinking" (EM Web). EM tools are designed to help the student think about the problem using existing knowledge mixed with construals (as suggested by David Gooding (Gooding, 1990)) allowing scope for creativity and 'what if' functionality. Hence, a student can learn by developing a model.

Model development is iterative and new definitions replace the old. This is similar to spreadsheet evolution where "[c]hanges to [a] spreadsheet are not to be interpreted as specifying a new spreadsheet, but as reflecting some change in our experience of its referent" (Roe, 2003). Hence, as shown in the racing model constructed by Simon Gardner in 1999 (EM Web) new definitions can at any time be introduced to either replace old ones or to add functionality to the model. This behaviour is unlike conventional programming and allows the possibility of learning through experimentation or trail-by-error. Such behaviour models how empiricists actually learn from the world (Robinson, 2004)

To see how the development of EM models fit in with learning about the human body, let us consider the model of the respiratory system. As described above in section 2, EM concepts have a direct relation to human biology. Hence, the intrigued modeller can start identifying the observables of the system and create the dependencies between them. Initially from the author's viewpoint, observables for the lungs are the left lung health, the right lung health and the overall lung health. The overall lung health is half dependent on the left lung health and half dependent on the right. In this situation, the total lung health will change according to values given to the left lung health and right lung health. An extension of this model may include a dependency which states that the left lung is dependent on the number of bronchioles and the surface area of the alveoli in the left lung. In this situation, by entering a new definition, you replace the old. It is not required of you to change any code or even stop the program running for the redefinition.

Providing these tools for the model developer will not teach them anything if they do not use other sources to find information on their subject. However, EM tools can be used to create artefacts which can help organise thought and understanding and aid in the building of mental models.

In human biology, many dependencies exist which are very difficult to visualise from simply reading about the different organs. For example, studies have shown that the use of acupuncture can significantly improve the recovery of a patient from pain or illness (Stern, 2004; Hoyosa, 2004) and needles inserted into the skin are not always at places which one would assume correspond to the area of pain. By creating a complex set of dependencies between observables, a student may find and learn from unexpected results through transitive dependencies. Alternatively, the student may find that parts of their model are not working correctly which will alert them to dependencies which they had not thought to exist. Hence, rather than teaching the student a subject, EM is helping the student understand the subject clearly and thoroughly.

3.2 Learning by Using a Model

Intelligence is recognised to be gained through a diverse range of skills and knowledge with artefact and non-verbal interactions being a powerful way of picking these up (Gardner, 1983). Currently, very advanced software exist which teach students interactively about the human body and anatomy[1] [2]. Such environments however, are limited to knowledge which has previously been encoded. There is no scope for the development of ideas. Even if the source code were available for this software, the programmer using conventional programming techniques would need to devote much of his time on integrating the new ideas and algorithms into the existing package. The EM concepts remove this complexity and allow you to easily introduce new dependencies, observables and make redefinitions.

It has been argued by Steve Talbott that however a student comes to think of a problem, they will eventually need to understand some abstract method for writing the program, taking them away from the original problem.

“The programmer may start with an interest in some aspect of the world, but the act of programming *forces* him to begin filtering that interest through a mesh of almost pure abstraction” (Talbott, 1995).

Although, a student must know how to write a script for the EM tools, we have shown above how closely related the EM concepts are to anatomy and the human body’s dependencies. Therefore, translating a dependency within the body requires very little change in ones mindset. In fact, it has been argued by Nardi that a much closer link to domain learning exists in the programming activity of spreadsheet construction compared to conventional programming (Nardi, 1993).

In realising these benefits, a student using a pre built model can grow that model according to their own experiences and requirements (F B Brooks injunction that software should be grown). Models can also be linked very easily to create the desired outcome which the student wishes.

Let us consider the model of the respiratory system once again. Assume that the overall lung health is now indirectly dependent on the contents of the air. Hence, if irritants exist in the air, then the overall lung health will be affected by this; if tar exists in the air, the lungs will be affected by this, etc. Also assume that a model of a cigarette exists. This model alters the air content, i.e. it affects the amount of tar and irritants in the air. Now, if the student wishes to find the effects of smoking on the lungs, they can simply use dependencies to make the air which is taken in by the lungs depend on the air given off by the cigarette.

Notice that at the same time that the student is learning about the human body, they are also learning social factors which may affect their views about smoking. It is most important to note that these ideas are not being forced onto the student and the student has the freedom to decide which part of the model to expand. In a limited purpose built software program, the functionality may not exist for the program to elaborate on a particular part of the subject which the student is interested in. For example, a piece of software designed to teach students about the human body may not be able to teach a student how classical music can affect your mood, thus affecting your heart beat and blood pressure.

3.3 Classroom Potential

By considering the model of the respiratory system, we can gauge the potential of EM for teaching stu-

[1] DK The ultimate human body 2.0

[2] Anatomic VisualiseR 2000

dents about the human body and beyond. Primarily, the graphical interface of the model can be used by students to learn about the lungs. Here, unlike textbooks, nothing is spelt out for the student. They must explore the model to find interesting dependencies and facts for themselves. For example, by using correctly named buttons to connect and disconnect parts of the lungs, the student can infer the names and the roles of those parts. The student can also perform activities and observe how those activities affect different parts of the lungs and what those activities do to the air we breathe. These ideas are related to teaching style and take their foundations from constructivism and empiricism.

To actually exploit the tools, a teacher may wish to customise the software using redefinitions to fit the needs of different ability students. The respiratory system model may be customised e.g. to include details of blood pressure and heart beat rates to suite the learning capacity of more advance students. A good teacher will often customise their notes and handout for a particular class and EM allows them to do the same without having in depth programming knowledge.

The EM tools also provide the ability to create definitive notations. Thus, a model may have an interface for interaction as well as a useful and intuitive notation which can be used to interact and alter the model. By providing a finite set of subject related strings which instigate different behaviour out of the model, the requirement for the student to have programming skills is reduced.

An implication of this is for teachers to set modelling tasks as homework. If a student is given the bare bones interface which performs no actions, using an intuitive notation, they can be asked to research into dependencies and make the model work. Due to EM principles, agents will then operate on existing observables which are related to the redefined observables to provide functionality on the interface.

It may even be possible to create an interface which makes these redefinitions for you, eliminating the requirement for students (or the teacher) to have programming skills. Currently, a tool has been developed which allows you to visually create and observe dependencies within a script (EM Web, DMT Tool), hence the proposition of a tool for redefinition is not infeasible.

4 Conclusions

It has been shown that EM tools and concepts are very much in line with thinking when it comes to human biology. It does not take much stretch of the imagination to find dependencies within nature and all around us. Through experience of model development, it can be seen that modelling using dependencies is a very powerful concept which frees the modeller from having to think about coding issues such as maintaining consistency between observables. For EM to help with the learning process, a students construals need to be included in their model. Simply using the interface to an EM model is no different to using an interface written in java. It is however evident that modellers using EM principles can make use of ideas which encourage learning in their models. EM's state-as-experienced orientation leads to "the construction of computer-based artefacts that have no preconceived or formally circumscribed behaviour" (Beynon, 2003)

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