Modelling with dependency as an educational aid – Understanding our solar system using Empirical Modelling

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Abstract

Many dependencies exist within the planets of our solar system, orbits, length of days, temperature and chemical composition to name a few, this paper examines the ability of an Empirical Model to provide a unique learning experience demonstrating how these concepts are related. This paper's theme is modelling with dependency-drawn from Beynon's 2007 paper. Previous research has shown that technology-enhanced learning has had limited uptake and influence, this paper will focus on Empirical Modelling as a technological environment for learning. Initially identifying problems with existing computer based educational programs, and instead proposing that Empirical Modelling construals can be used as a more targeted educational aid. This paper will also identify issues such as methods of learning, before demonstrating how Empirical Modelling can be used to achieve such requirements. The paper elaborates how dependencies within the solar system model can be modelled so that a human interpreter can make connections between the observables within. This paper concludes with the findings from the experimental solar system model with respect to a modeller's learning experience.

Keywords

Educational Technology, Learning, Dependency, Agency, Observation, Construal, Empirical, Computing

1 Introduction

Beynon (2007) proposed educational technology needed a unique new approach based on Observation, Dependency and Agency[i]. EDEN (Evaluator for Definitive Notations) was the language developed with the intention of supporting this new method of learning based on dependencies. Educational establishments in the UK are driven using a national curriculum, which specifies what students must be taught but leaves the choice of teaching methods up to the teacher[ii]. Despite this the length of the UK curriculum is around 500 pages, 'one of the biggest curricula in the world' yet the UK's international positions in core subjects such as maths and science keep slipping each year[iii]. It is the belief of the author that constructivist thinking could be used to improve such falling educational performance, through unique Empirical Modelling concepts taught at Warwick University. The Education Secretary claims the "straightjacket" of such a restrictive curriculum will be removed and give teachers will be given the power to "innovate and inspire", specifically through the use of digital technology. Schools could be leading the way in technological usage rather than playing catch up a few years later[iv]. Though such vanilla usage of digital technology may not be the answer, it assumes that students learn from being taught a concept rather than being able to draw their own conclusions from observations. (Meltzoff, 1999; Byrne & Russon, 1998) identified that observational learning has a crucial role in the learning process, specifically for children learning about adults around them. Similarly Torriero et al, (2007) wrote a paper discussing from a neuroscience perspective that shows learning by observation and learning by doing utilise almost the same neural pathways, an important finding that reinforces the potential utility of observational learning[v].

Initial findings on the effectiveness of interactive whiteboards showed that they have limited affect on student's learning[vi]. In contrast more recent studies counter this and claim that interactive whiteboards do in fact improve student's learning[vii]. Herein this paper will focus upon the potential of Empirical Modelling as an educational tool. The model developed to demonstrate these principles allows a modeller to gain understanding from a non traditional viewpoint, they will be subjected to observables in the form of celestial objects, the agents that make changes to observables and dependencies which arise between observables. Such an experimental method of teaching allows a modeller to work out for themselves the connections between observables and thus to work out the dependencies which are taking place.

2 Learning Styles

Traditional learning styles can be broken down into several groups as identified by Honey and Mumford (1982). Firstly the 'activists' who learn by doing, the 'theorists' who learn by synthesising facts into theory, 'pragmatists' who need to see the use of a theory in the real world and 'reflectors' who learn by observation and thinking about what happened[viii]. These learning styles were the most widely used in a study performed by market research company, (MORI 1999), which assessed the most preferred learning approaches in the UK local Government sector. If such learning styles could be utilised throughout educational establishments Empirical Modelling could be suited to the 'reflectors'. Experimentation and observation within the EDEN environment would hopefully result in the modeller learning about real world dependencies.

More recently however, such learning styles have been found to not have any real impact on learning. It was found that despite all previous research in the area, students were rarely tested against each learning style and even where this did take place, groups of students subjected to particular learning styles did not perform better than those subjected to the same learning style. The Association for Psychological Science (2009) thus concluded-

"there is no adequate evidence base to justify incorporating learning styles assessments into general educational practice. Thus, limited education resources would better be devoted to adopting other educational practices that have strong evidence base, of which there are an increasing number"[ix]

Thus Empirical Modelling is proposed as such an alternative educational practice, making use of principles of Observation, Dependency and Agency. Whereby a modeller can learn from observing the model, identifying dependencies by analysing how a result is achieved.

3 Current Digital Education

Digital technologies are available in modern classrooms, from projectors to numerous computational software suites and microscopes to cameras. Traditional software is generally used to achieve pre-specified results and does not allow the modeller to construe the calculations used to obtain results. It is this lack of understanding that Empirical Modelling and Constructivist thinking aims to enlighten.

Research by Futurelab, (2009) reinforces the benefits of technology in supporting inclusive educational practices, citing better 'conceptual understanding' through the use of technology. Visual technologies were identified as being particularly effective[x], thus these are compared to Empirical Modelling as a technology for learning.

As previously discussed interactive whiteboards have debatable impact on learning, with the underlying assumption that traditional learning styles apply in the digital educational domain. Not only are interactive whiteboards expensive, their usage requires teacher training which draws teachers away from teaching in order to produce enhanced experiences for students (Beynon W. M., 1997). Instead, Empirical Models could be used across the curriculum, as modellers are part of the learning experience the teachers need not require such extensive and perhaps distracting training. Empirical Modelling has a unique potential to teach via dependencies, much like those found in a spreadsheet, thus the modeller is able to take control and discover dependencies within a subject, such as the solar system.

Slideshow presentations are regularly used throughout education, though these are found to be distracting when non essential information is conveyed, (Bartsch, R. & Cobern, K. 2003). Empirical Modelling is able to offer a Presentation Environment to display useful content without such distracting sound effects and imagery. At the same time this environment is uniquely able to offer Empirical Models for interpretation by the viewers.

With the advent of the Internet, online education has become an increasingly popular form of learning, the first online university started in 1993[xi]. Since then many thousands have sprung into existence offering a plethora of courses. Yet questions remain about the true effectiveness of learning online, as such other contemporary and more promising educational technologies like dynamic web based systems are increasing in popularity. Cristea et al, (2009) explain the advantages of personalisation in e-learning to 'provide the best learning experience' to both individuals and groups[xii]. Empirical modelling has this personalised experience inbuilt, the interpretation of the model and the Agency associations made are entirely subjective to the modeller. Empirical modelling thus has a great potential for Lifelong learning as Beynon & Harfield (2007) identified[xiii].

4 Empirical Modelling and Education

The case for Empirical Modelling as a visual educational tool is also reinforced by Tiberius, (2009) who performed a study on medical students to evaluate how well they learned by observation.

The team's results indicate the students favoured learning by observation as a 'valuable' experience citing the students enjoyed the 'highly interactive participation'[xiv].

Empirical Modelling has the potential to provide not only a new dependency based approach to learning but also a previously established visual and practical approach too. Such a combination should improve the whole learning experience for both teachers (who would not have to detract their focus from teaching to attend courses), and students who would have a novel and exciting way of learning through observation and dependencies. The dependencies encountered through Empirical Modelling aim to provide a personalised and meaningful interpretation to modellers, through which they can learn the underlying concepts.

5 The solar system model

Our solar system is comprised of the sun and many astronomical objects, the eight well known planets amongst other dwarf planets and asteroid belts. Each of these celestial objects has a different physical composition and therefore varying properties. In terms of Empirical Modelling the solar system has many observables which are explained in the lessons below.

5.1 Lesson: Distance from the sun and the effect on the period of rotation.

The length of a planet's year, varies in relation to the square-root of the average orbital radius around our sun cubed. This is derived from Kepler's third law as seen in **Figure 1**, below.

$p^2 \alpha a^3$ *simplifies to* $p = \sqrt{a^3}$

Figure 1: Kepler's third law and simplification for an orbit around a central body (our sun)

The average orbital radius, otherwise called the semi-major axis, is measured in astronomical units (the average distance from the Earth to the Sun).
A modeller can move a planet away from the sun and observe that the rotation around the sun is slower and vice versa with moving a planet closer, thus learning from Agency.

5.2 Lesson: Size of the sun and therefore distance from the sun effects the period of rotation

The model allows the changing of the sun's size with the dependency on the orbiting planets, resulting in the period of rotation reducing significantly the closer they are to the sun. Due to the increased gravitational forces (One concludes this through principles of Agency). The opposite case is also an observable in the model, the smaller the sun becomes the slower the orbiting planets rotate. The model also allows the planets to be swallowed by the sun – reinforcing that the planets are not repelled from the sun.

5.3 Lesson: The chemical composition of a planet affects its observable colour

The chemical compositions of planets are usually taught as a set of facts. This model allows a modeller to generate new compositions and observe as the dependency of colour changes with the different compositions. This serves two purposes, the planets are not just their respective colours by chance and a modeller is able to use Agency to construe connections between compositions and resulting colours.

5.4 Lesson: The size of an Astronomical unit has an effect on the period of rotation of planets

The size of an astronomical unit is the distance between the Earth and the Sun. The model allows this distance to be changed to see the resulting effects on periods of rotation around the sun. A larger value (in km) for each Astronomical unit decreases the period of rotation and vice versa.

5.5 Lesson: The solar system is multidimensional and small in comparison to the universe

The modeller is able to change their viewing position around the solar system, there are no constraints on the zoomed out distance to give a real sense of scale of our solar system against the size of the entire Universe. Similarly the modeller is able to travel through the centre of the Sun to reinforce the real 3D nature of the 2D model. Reset functionality is provided to return the observer to the default viewing position.

5.6 Lesson: Factual Information

For comparative educational purposes facts about the solar system and the currently selected planet are available in the model. Facts are displayed below a close up of the selected planet in a manner similar to a summary provided in a textbook. The facts and formulae used within the solar system model were from a number of sources indicated within the code, as well as Bakich, (2000) for in depth planetary information[xv]. All planetary sizes and distances between them are accurate and to scale.

5.7 Traditional Teachings and the Constructivist approach

Traditional methods of teaching the solar system involve acronyms (MVEMJSUNP) to remember the planet names and their respective order from the sun. As well as the principles of day and night, facts such as the composition and temperature of the sun and that all the planets revolve around the sun. The key stage four national curriculum specifies teaching that 'the solar system is part of the universe, which has changed since its origin and continues to show long-term changes'[xvi].

The model has an analogue flavour, allowing the modeller to observe many dependencies in action without being constrained to predefined functionality. The solar system model created also has a digital flavour, a purely educational side which teaches using the traditional method of providing hardcoded facts. This combination of analogue and digital flavours allows a direct comparison of which is the most effective learning tool in the EDEN environment. **Figure 2,** below, shows the solar system model in action, the left hand side demonstrates a close up view of the selected planet and provides relevant facts. The right hand side offers the modeller different variables to alter and observe the dependencies in action.

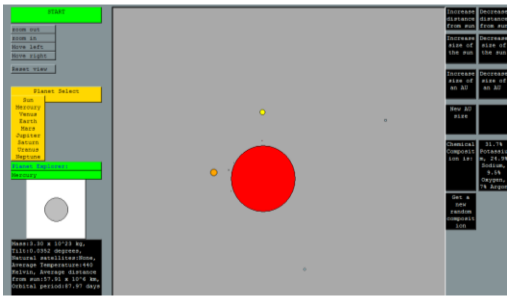

Figure 2: The solar system construal

Furthermore the solar system model has no constraints like a standard program, the viewer is able to travel through the solar system and observe from the other side – an interesting and somewhat surprising feature. Empirical Modelling can provide such unexpected advantages, stretching one's imagination through the use of dependencies. **Figure 3**, below, demonstrates the dependency of chemical composition on planetary colour and the period of rotation varying with the distance from the sun.

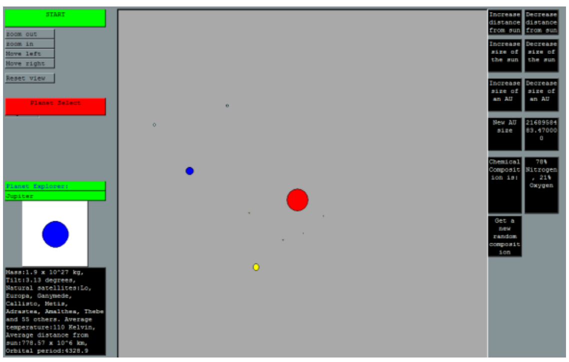

Figure 3: Jupiter (with a different chemical composition) moved away from the smaller sun

Whereas a "normal" program may allow the movement of the sun, Empirical Modelling allows all planets to be moved at the same time as the sun. All without any extra code due to the inbuilt dependencies of the model. These important differences draw the line between Constructivism and traditional computing where specific interpretations are loaded at the beginning of a program and these cannot be revised during execution. On the contrary constructivist thinking allows the modeller to experience new interpretations throughout experimentation with a construal.

As well as EDEN, Scout (Definitive notation for Screen layout) was used for modeller interaction, such as to set or change observable values via a GUI. Donald (Definitive Notation for Line Drawing) was also used for 2D graphics such as the orbital paths and the shapes for celestial objects.

6 Evaluation and further work

It must be said that Empirical Modelling may not be the silver bullet in educational technology, yet it could be used in combination with other traditional techniques to reinforce learning. Such diversity should benefits students across many different learning styles. Or, if The Association for Psychological Science (2009) is correct that student's performance is unaffected by the learning style they are taught with. Empirical Modelling provides at the very least a variation to their teaching routine. The importance of which should not be underestimated, such unusual and innovative methods are likely to encourage memory via the Von Restorff effect[xvii].

From personal experience a construal provides a more useful medium of learning about the solar system than traditional fact based methods used in schools. The Constructivist approach allows freedom to make one's own connections through Agency whilst observing the dependencies. Though, this may of course be due to the author's preferred learning style.

6.1 A teacher's view

From a teacher's view of the curriculum the model could be extended to show other galaxies as well as our own Solar System. The concepts of expansion or contraction could also be conveyed if all celestial bodies were given a velocity from a marked central point of the big bang. Students could observe the effects of increasing or decreasing this velocity and using Agency conclude on the overall fate of the universe over time (the elastic band theory or continuous expansion theory).

The solar system model could also be extended to include Newton's theories of gravitational forces. Labelling two planets with their respective gravitational forces would allow a modeller to move them further apart and see as the resulting gravitational force decreases proportionally to the square of their distances apart. Such experimentation would also have the potential to teach the concept of proportionality equations and to introduce the gravitational constant G (6.67300×10^{-11} m^3 kg^{-1} s^{-2}) to one's attention.

Most importantly however, teachers would not require extensive and detracting training as with other digital technologies. The next step would be to implement the model in a classroom environment and gain teacher and student feedback on the effectiveness. Undoubtedly useful improvements to the model could be suggested by trained educators (not such as the author of this paper), perhaps there are clearer ways of conveying the inherent dependencies.

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