The Next Steps of Empirical Modelling in Education

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Abstract

This paper presents to the reader an in-depth analysis of current EM research. Evidence for the use of this research in education is presented and ideas discussed. Consideration has been given to other emerging technologies and research in the field of education. A model of a practical classroom demonstration is presented and discussed. This led onto the topics of further practical work in EM involving development and deployment before making concluding statements.

1 Introduction

Empirical Modelling (EM) is an unconventional modelling technique with its unique set of principles and strengths developed at the University of Warwick. The principle behind EM is essentially to utilise definitions and dependencies between the definitions to allow the modeller to construe the subsequent outcomes of the model. These unique properties for modelling give EM an advantage when applied in certain practical environments. The focus of this paper is to look at EM in the context of education.

1.1 EM and Education in the Past

Research by the Empirical Modelling group at the University of Warwick has shown EM's suitable application in the field of education. There are several advantages and drawbacks to the use of EM in its present form to be used in education as will be discussed later. However, essentially it has been well established that it is viable to look at the utilisation of EM in this field for an improvement in learner experience and so this paper proceeds on this basis.

Previous work that looks at the application of EM in education generally does so by developing a model using EM principles to demonstrate its applicability in teaching the user about the topic. For example, in the Fourth Warwick Empirical Modelling Bulletin (WEB-EM-4) [1] models were developed that would allow the user, in this case a student at school, understand trigonometry or the gas laws. They demonstrate the capabilities of EM tools in education and discuss the impact of EM in the field to a varied extent.

1.2 Aims and Overview

This paper aims to look at EM as a research area and the different aspects of education to provide a high level analysis of the state of convergence between these two fields. This analysis will start by first obtaining evidence to justify further work that utilises EM in the field of education. Then ideas with regards to emerging research in education are introduced along with an understanding of their impact on EM (and vice-versa). Finally, there will be a need to look at the practical side of the process and the related development and deployment techniques that can be used in taking the next step of convergence between the two fields concerned.

2 Computing Technologies and EM in Education

Two landmark papers in the discussion of EM in education by Dr Beynon of the University of Warwick must be referred to as a starting point [2][3]. The emergence of information technology has impacted many fields therefore it only makes sense education adopt and utilise the same. To some extent, this has benefited the field by improving both teaching and learning processes. For example, communication frameworks like Blackboard [4] improve the effectiveness of communication between teachers and students as well as improving the delivery of educational content. Other software suites can improve education by providing visualisations of concepts or tools for use by students. However, much of the software development activities surrounding education simply treat the field as another case of meeting user requirements in the tradi-

tional sense of business needs – as this is where the software vendors originate.

2.1 The Shortfalls of Conventional Techniques

Often, there is little consideration given to approaching the problem from the educational perspective. As outlined by papers [2][3] this leads to several issues that have meant conventional software has not made as much of an impact in the field of education as some might have expected. To begin with, a traditional (pre-IT revolution) school or university (in most cases) is not able to facilitate the use of terminals or laptops, or indeed have the expertise to invest in suitable software for extensive use by pupils. Many schools still rely on IT personnel that originate from a business background to purchase workstations or software for the school. This leads to constraints in the availability of suitable IT tools to assist the teaching and learning in these institutions.

By extension to this thought process, it can also be realised that most software applications developed in the conventional way are optimised for the technical environment they run on, not the real-world social psychological environment they are required in. This can explain, to some extent, the slow uptake by educational institutions. Adding to the lack of suitability of such software to the educational process is the vast gap between the conception and application of the developed applications. Software developed in such a fashion "is conceived or customised by the teacher; designed, implemented and maintained by the developer; used by the learner," [3] often leading to major shortfalls in successfully accomplishing its purpose.

Additionally, due to the rigid nature of conventional software (often written in a procedural programming language), there is a distinct lack of flexibility in what can be taught, communicated or interpreted from the provided application. Once past the development phase, there is very limited scope for variation in the delivery of content or manipulation of the tools available from conventional software. This means that teachers are unable to do much without specialist technical knowledge, hence severely limiting their abilities in the classroom.

2.2 What EM Has to Offer

Having discussed the shortfalls of conventional software, it is now appropriate to look at how the unconventional EM approach can provide capabilities that can put EM tools ahead. First and foremost, the EM approach encourages the use of tools to build a model through programming. The fundamental ability to build a model from an elementary level upwards provides the level of flexibility that cannot be made available through traditional software. Along with this, another major advantage of EM from a social psychological perspective is the capability given to the modeller to form his/her own construal. Simply put, a construal is "an interpretation of the meaning of something."[5]

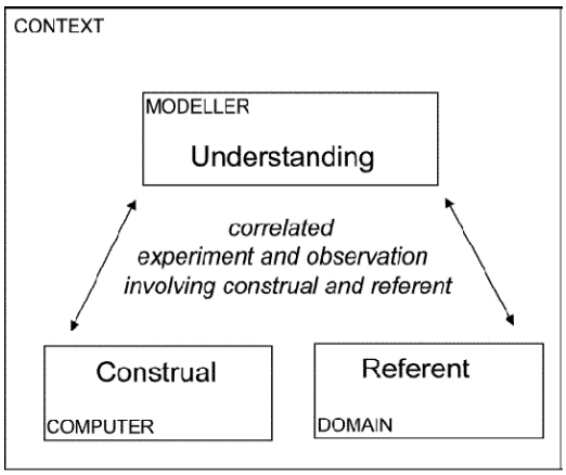

Figure 1: Construal in Empirical Modelling [3]

The use of language to communicate can often limit the teaching and learning processes in education. [2] A straight-forward example of this is, for example, is when a pupil is able to use an EM tool to produce an artefact how he or she construes it. They might be unable to communicate it sufficiently well through spoken or written language, but with the aid of EM technologies the teacher is able to gain an understanding of the learner's perspective. In fact a teacher can be a part of a chain of interactions in the model building and interpretation activities due to the concept of agency - enhancing their role as a teacher rather than limiting them in any way. Immediately it is obvious that this is a significant improvement in the day-to-day processes surrounding education (on a theoretical level). Already the stated strengths of EM advance on the capabilities of conventional applications.

There are further properties of EM that can be classed as advantageous in an educational environment as it is supported by relevant literature. The nature of model-building activities in EM encourages creativity and open interpretation. This as well as the opportunity to learn through self-discovery greatly enhances a learner's ability to retain important concepts in their mind. Reflecting on experience-based knowledge enhance the modeller's capacity to learn from experience. [6]

3 The Future of Technology in Education

Recent research in the field of education has resulting in some promising new ideas for the application of technology in the field. The emergence of impact analysis, adaptable systems and 'learning design' can help with understanding how technologies such as EM can be utilised most effectively in education.

3.1 Analysing the Impact of Technology on Education

Studies into the causes of adoption of technology into education have revealed some interesting facts that are worth noting. Firstly, the flexibility in terms of time and location that technology brings with it in most aspects of life also make it beneficial in education for similar reasons. This kind of flexibility is sought by individuals in order to better organise education into their lifestyle. Formalisation and industrialisation of curriculum is also a driving force behind adoption of new technological frameworks. [7][8]

New work in the field of education has also left educators feeling insecure about their skills and understanding of new forms of teaching, prompting a growth in academic development initiatives – this resulted in an increased openness to the acceptance of new technologies. With the emergence of new roles such as 'learning technologist' and a change in attitude towards the role of a teacher, it seems the problems mentioned earlier regarding conventional approaches to IT are being realised by those in the education field. [7] What this means for EM is that now, more than ever, educators are opening up to new technologies and with these facts in mind, it is possible to analyse the impact of developments in EM in an educational framework.

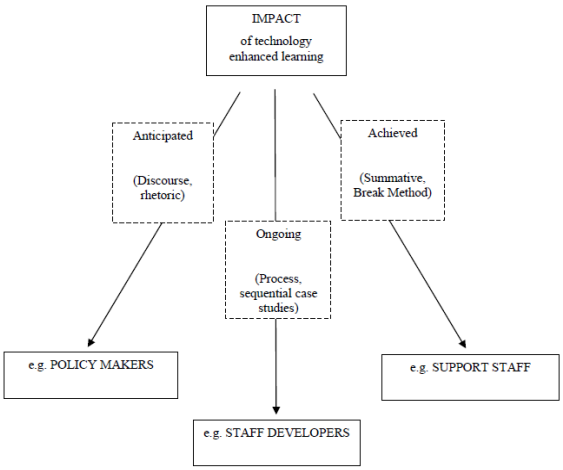

Figure 2: Overview of Potential Pathways upon Impact of Technology/New Research [7]

3.2 The Use of Learning Design

'Learning design' is a conceptual-level description of the teaching and learning processes – it is a specification of "under which conditions, which activities have to be performed by learners and teachers to enable learners to attain the desired learning objectives." [8] In order to avoid the typical technological problem of providing education based on available resources or technologies, a new approach to applying EM principles in education would be to start by adopting the principles of learning design theory so that activities are guided by pedagogy.

The IMS Learning Design Specification aims to "enable many kinds of educational designs to be created, using a consistent notation, which can be implemented uniformly in multiple courses or learning programs." [9] Executable by computers, they consist of an information model, a best-practise and implementation guide as well as an XML binding. [8]

With consideration to these factors, EM is actually well suited to the requirements of pedagogical-based approaches. Learning and teaching activities tend to be more beneficial when the focus is on collaborative activities rather than consumption of content. [8] An innovative EM-based technological solution to problem solving, for example, is far more effective in an educational context than an objective-based e-book.

3.3 The Emergence of Adaptive Educational Hypermedia Systems (AEHS)

Significant progress has been made in the past few years on the subject of adaptive hypermedia systems. These systems are especially suitable for use in education as the requirements can vary vastly between learners, and these systems possess the capabilities to execute adaptation strategies when delivering educational content.

Adaptation strategies can vary everything from the medium of the content being delivered, to the frequency, the format, the ordering/sequence and even choose the right topics for the learner. The reason for their suitability and success in the field of education is because a learner typically does not know much about the domain to make their own decisions on how the content should be approached. Automatic adaptation using inferred rules, domain content and a user model. [10]

With the concept of agency within EM, there is already room for implementation of adaptability to some extent. For example, where the learner is the super-agent, several agents can be set up to monitor progress and form a user model or infer certain basic rules about how the content can be adapted. [2] However, in the context of EM, complications arise easily. EM involves a high level of interaction rather than just delivery of content for consumption. As such, adaptation strategies built for EM tools would require a different form of architecture. However, a framework that can formalise how adaptation strategies can be taken as input by EM tools will greatly benefit the convergence of these two fields in providing innovative capabilities in the field of education. As an example, complex models can often overwhelm a learner when it comes to experiential interaction and discovery – but with an adaptation strategy in place, the complexity of the model can be actively presented to the user depending on deductions made about the user through the use of a user model and an adaptive strategy.

4 Empirical Modelling in Understanding Quantum Mechanics

So far, many theoretical aspects of applying EM to education have been discussed. In the past, several projects have also shown various ways in which they apply EM to teach a concept. One of the most unconventional, counter-intuitive and difficult concepts to grasp when looking at education in high schools, is that of the concept of quantum mechanics at A level physics. This is a particularly challenging line of thought as it is the first time physics curriculum makes a major shift away from classical physics laws.

The way teachers introduce students to the concept is usually through a practical demonstration famously known as the “Feynman Two-Slit Experiment” named after quantum physicist Richard Feynman. The objective of the demonstration is to show students the idea of wave-particle duality with light.

4.1 Setting Up The Two-Slit Experiment

The main components of the experiment is (1) a single light source, (2) a ‘backboard’ that the light source is pointed at, and (3) a board between the light source and the backboard with two thin slits relatively close to each other.

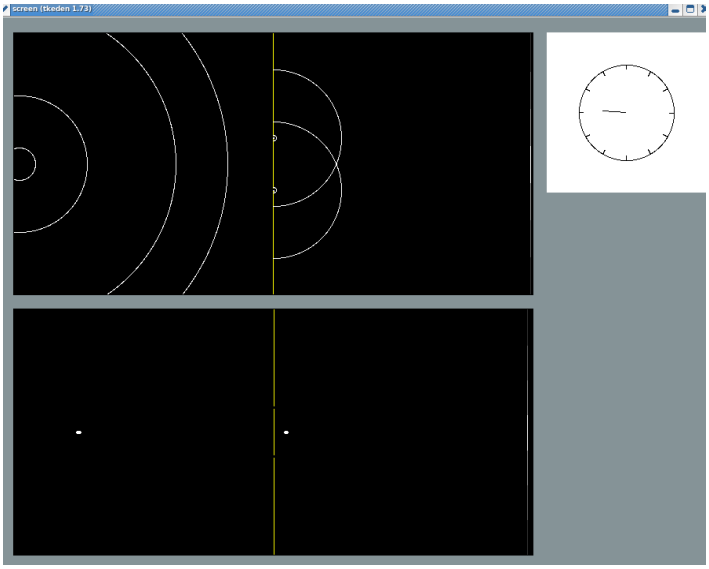

Figure 3: TK Eden Model of the Wave-Particle Duality of Light

As the light shines through the slits, certain light and dark patterns form on the backboard from the light that reaches it. These patterns can then be explained as a result of light behaving as a wave or as a particle. The teaching objective is to get students to understand that although conceptually the two behaviours are different, the result is the same – hence the theory states that light is both a wave and a particle at the same time.

4.2 Building the TK Eden Model

As an exercise in the practical application of EM principles in education, as well as an experiment to demonstrate the experiential nature of EM as was discussed earlier – and indeed to show its applicability in even the most unconventional areas of education – this experiment was modelled in TK Eden.

The resultant model is capable of showing light as a wave as well as a particle on a conceptual level. There is a wave agent (top window) that shows waves from a light source conceptually, the effects of the slit on these waves, as well as the resulting pattern.

Another agent (bottom window) shows light as a particle – again, conceptually – to have a concurrent comparison of the dual behaviour exhibited by light under these circumstances. Some of the key learning in this experiment comes from an interactive and self-discovering mind-set. As such, the model is left to open interpretation rather than constricting the learner with a limited set of variables to adjust. A student may, for example, check how the position of light in both agents is being updated (using the clocks). This will lead them onto realising that the time dimension that governs the movement of light waves is also one that affects the "probability clock" (shown in the model) that conceptually displays the "probability level" of a particle of light being present at any particular point at a given time. The model also displays how the patterns on a backboard can be depicted using a set of lines.

4.3 Exploring the Model

The model opens up the opportunity for students to build on top of what is available. For example, they could model their own interpretation of the backboard which would in turn cause them to think carefully about the patterns that do form in reality and why they might appear in the particular way they do. This will re-enforce learning once again.

One particular aspect that can be considered a shortfall of the presented model is how light as a particle is conceived. The model shows the particle travel in a straight line with shifting probabilities shown on the clock. What the model is trying to show is that even though there is a barrier between the backboard and the light source, light patterns can form right in the middle of the backboard. What this means is that the cumulative probability of light particles is causing at least some of them to reach the middle. Students might find better ways to show this, perhaps with the particle being perceived in more places, through a slit, and so on. This will cause them to think about the probability principles and construe the particle in their own way. In modelling this, they will also be showing the teacher an understanding of the concept from their perspective without having to go through the barrier of written or verbal communication – which can make it hard to communicate understanding as mentioned earlier.

5 Further Development of EM Tools

Having discussed the reasons behind EM's suitability in education, the need for innovative technology in education and the possible frameworks for working with EM tool – as well as having seen a practical example, the aim now shifts to presenting some ideas with regards to future development of EM tools and their deployment.

5.1 EM Tools Today

Currently, there are two main EM environments – TK Eden and Cadence – used at the University of Warwick for research in the field. TK Eden is a reliable environment for implementing modelling ideas and Cadence is a more recent development that can make use of 3D art in models. There is also a web-enabled version of the Eden interpreter. All of these tools have been used to varied extents to teach principles of EM to students at the University of Warwick.

5.2 Ideas for Further Development

Having discussed the potential for the uptake of EM tools in the world of education, an idea for practical deployment of EM tools in schools and universities is user-centric development of existing or new EM tools. Regular use of EM tools in day-to-day teaching activities at institutions might be an ideal situation for those wishing to bring about widespread use of EM principles. However, there are difficulties such as available hardware, suitability of existing software and means of mass deployment.

A more realistic start would be to increase the use of EM in terms of frequency and number of students. In order to pursue such an agenda the two main aspects to focus on are development and deployment.

In terms of development, EM tools are always being developed at the University of Warwick. However, further work in the field can include outlining a framework for practical development of EM software. Such software could be developed as an open

source project by collaborators. A community-driven approach often encourages contribution. For example, the most popular web Content Management Systems (CMS) are free to use and open source. There is also a variety of free and purchasable plug-ins available for most packages. A Learning Management System (LMS) that encompasses the use of EM could be a suggestion for further work, with the possibility of extensions to manage some of the ideas mentioned earlier in the paper – such as Learning Design or an interpreter for adaptation strategies.

The role of a 'learning technologist' was presented early in this paper. Perhaps an increased organisation of EM tools catering to specific topics, lessons or subjects would increase the suitability of EM technologies for education. Another aspect to consider is that while EM is relatively simple to program in, building complex models might be asking too much when it comes to teaching staff. New software development initiatives should look to tackle this issue by, for example, building an enhanced GUI.

Web-based deployment of software has shown the highest levels of success in recent times. Such software is easier to update and most time-effective than most other implementations. While Web-EM does exist, there are certain limitations for its use over a large scale. Perhaps with the development of HTML5 there is scope for further work in utilising the new technology in implementing a new web-enabled EM tool.

6 Concluding Statements

In the analysis of ideas and research presented in this paper, there has been strong evidence for the continued and possibly increased use of EM tools in education. However, there have been cases where an EM project in education has not provided desired results in the part (see for example: "An educational system for modelling mechanics problems" [1]). Such weaknesses must be analysed in full detail before committing significant resources to undertake further work, however, in the undertaking of the model presented in this paper no such problems were encountered. As such, further work based on the ideas presented in this paper is encouraged.

In pursuing an agenda such as the rapid deployment of new technologies in education, it is easy to overlook the moral and ethical implications. Although the cause of improving education is morally sound, in altering the life style, or the role of students and teachers with new technology it is important to give consideration to aspects such as the social psychological effect of having to cope with change. For example, does a teacher really want technology to take over much of the tasks that were previously undertaken by them?

In conclusion, evidence has been presented for the appropriate use of new technologies in education. EM principles and tools were analysed and other emerging technologies discussed. Frameworks for the appropriate use of technologies in education were also presented and then the practicalities of EM in small and large scale modelling/deployment were discussed.

Acknowledgements

I'd like to thank Dr Meurig Beynon and Dr Steve Russ for their continued support in my understanding of EM concepts and for help with technical issues encountered with using EM tools.

I'd also like to thank Charlie Do for his help in testing the model presented in this paper.

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