Empirical Modelling: A Tool for Experiential Learning?

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Abstract

The many theories of learning which are debated by psychologists and educators alike, each offer distinct advantages to the development of knowledge and meaning within an academic environment. One such theory is that of experiential learning, which for those in the development of knowledge, is well recognised and respected. The intention of this paper is to demonstrate the use of Empirical Modelling as a teaching aid to assist with experiential learning. Attention will be paid to its ability to model states of the world and changes between these states, predominately through the construction and analysis of a model of a classic computer science problem, the Tower of Hanoi.

1 Introduction

The modern day education system in the UK incorporates a rather limited number of the many available teaching styles, with the majority of classroom teaching still formed from the instructional approach. In order to convey the large amount of information which is specified by the national curriculum, schools see the instructional method as an ideal approach. Unfortunately although this approach offers a useful means to communicate facts and figures, the development of core transferrable skills such as problem solving, is left relatively untouched.

Over the past decade, the introduction of Information and Communications technology (ICT) across schools has made had a profound effect on how information is distributed to students. With students all possessing different levels of learning ability, ICT is seen as a medium to support the communication of the curriculum, supported by suggestions that it can make the difference between learning objectives being met or not (Iles, 2008).

This paper will be developed through five distinct sections, developing the connection between experiential learning and Empirical Modelling (EM). The first section will discuss the problem which this paper will model, the Tower of Hanoi. Following from the analysis of the problem, the next section will discuss the development of the various approaches to learning, highlighting the essential principles which underpin the current stance on the subject.

The discussion will then focus upon the current artefacts which are available for use as educational tools. This analysis will include a contemplation of the similarities between EM and these artefacts. The modelling study forms the fourth section of this paper and will incorporate details of the construction of the model in addition to the EM principles which have been incorporated.

The conclusion of the paper which forms the fifth and final section of the evaluation will discuss the potential for EM to be utilised as a framework for assisting experiential learning. Consideration of the example model will be central to this conclusion, assisting with the explanation of how EM facilitates experiential learning. The overall evaluation forms an interesting discussion of experiential learning, and its contribution to the development of knowledge and understanding. However discussion of the practicalities and challenges of incorporating EM as a teaching aid will form a key part of the debate.

2 The Tower of Hanoi

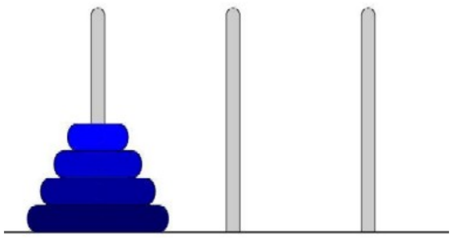

Figure 1: The Tower of Hanoi

The Tower of Hanoi is a classical computer science problem which has traditionally been used for teaching the concept of recursion. Created by the French Mathematician Édouard Lucas in 1883, the problem involves moving a stack of disks arranged in decreasing size from base to top as shown in Figure 1, from one pole to another, subject to a stringent set of rules (Stockmeyer, 1998):

1. The disks will always be stacked in some combination across the pegs, in decreasing order of diameter from the base to the top.
2. The top disk may be lifted from any of the stacks of disks, and placed onto another pole, provided either:
   a. The pole is empty
   b. The disc at the top of the destination stack has a larger diameter.

2.1 Solving the Problem

There are various theories in place which suggest the optimal strategy for solving the problem, with proof that the optimal solution centres on recursion.

2.1.1 Recursion

Recursion is defined as a procedure which is defined in part by a reference to itself, using the output of the preceding step to continue the operation (IBM, 2004). In terms of the Tower of Hanoi, this problem can be solved by utilising a recursive algorithm to move the stack of discs from the source pole to the destination.

To move a tower of N discs from pole s to pole d, utilising the remaining pole r as a temporary storage location:

1. If N > 1, move the N-1 smaller disks from pole s to pole r.
2. If N = 1, move the final disk from pole s to pole d.
3. Move N-1 disks from pole r to pole d.

2.1.2 Optimal Solution

The proof of the recursive solution can be shown through mathematical induction. However this proof will not be shown here due its limited relevance to the discussion. The proof of the optimal solution affords the ability to construct a generalised recurrence relation which can then be solved to give the minimal number of moves to solve the problem with n discs:

$$2^n - 1 \; for \; n \geq 0$$

Equation 1: Minimal Moves

As a problem which has a definitive optimal solution in addition to explaining a core concept, this problem affords the construction of an informative educational model. It is important to highlight that the construction of such a model to enable the learning of the concept of recursion is not the only learning outcome which can be drawn from this problem. Key transferrable skills can also be developed from working through the problem, most notable being that of critical problem solving highlighting the benefit of learning by way of a model over simply learning the concept itself.

3 Approaches to Learning

Of the various established learning styles in existence, it is perhaps disappointing to see such a reliance on the instructional approach. With so few techniques utilised to their full potential, especially experiential learning, one begins to ponder the reason for this dominance. This presents an ideal opportunity to investigate the theories of both instructional and experiential learning, contrasting their approaches to account for the dominance of the former theory in modern day teaching.

3.1 Instructional Learning

There are many definitions of the instructional approach to learning with the first suggesting that "students will proceed at their own rate through a prescribed set of materials to reach a predetermined set of objectives". This contrasts with second definition which insinuates that "students will be free to select their own means of achieving their own objectives" (Dick & Carey, 1996), although both approaches are centred on the objectives which will be achieved as a result.

A common distinction which is generally demonstrated through this approach is the division of the curriculum into themes. The idea of themes is to give a meaning and sense to the learning process, with each theme containing similar topics which can be used in conjunction to achieve some ultimate goal. This approach is often used with subjects such as Mathematics and fundamental areas of Computer Science to integrate various topics which are being taught alongside the full extent of human experience (Handal & Bobis, 2003).

The division of a curriculum into themes is the first step in designing a communication structure to enable the achievement of the various learning objectives which are associated with the theme. As already mentioned, themes are constructed from a set of topics which are simply a collection of facts and information to which context has been introduced. Through the addition of context, the related facts and information can be organised into classes which are recognisable to both students and teachers alike. This structure for dividing a curriculum is exhibited in Figure 2, a representation which affirms the idea that a theme will act as the relation between the core concepts and human experience to support the learning process.

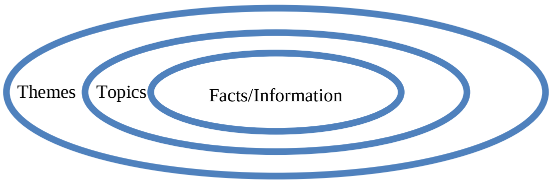

Figure 2: Structure of a Thematic Unit (Handal & Bobis, 2003)

The thematic approach which is often incorporated into instructional learning seems to be one of the key reasons why the instructional approach is often selected. The benefits of this approach both in terms of how the content is organised into themes which relate to human experience, in addition to the structure which this affords to the teacher affirm the choice by teachers of this approach. However there are several limitations which should be presented, as they are the reasons for questioning the dominance of this approach.

The main problem with this approach is the fact that the option for further investigation or in-depth discussion is limited due to the precise structure of the teaching approach. This in itself limits the learning outcomes to only the information which is presented by the teacher to the students. In the modern world, with the raft of new technological developments, surely there must be some alternatives which can afford a more interactive experience where students can develop both knowledge and transferrable skills.

3.2 Experiential Learning

The experiential learning approach offers some significant advantages over the traditional instructional approach which can be observed in so many schools. By definition, this approach is alarmingly simple, based on the idea that people will learn from experience. In further detail this approach can be expressed as “the knowledge and skills acquired through life and work experience and study” (Evans, 1994). A further definition which supports this stance offers the suggestion of this approach as “a model which begins with the experience followed by reflection, discussion, analysis and evaluation of the experience” (Boydell, 1976).

The benefits of this approach are notable, especially the suggestions for the personal development of students. There are claims of psychological value being drawn by students who undervalue themselves, based on confidence boosts from the realisation of the knowledge which has already been drawn in addition to the knowledge which they can continue to develop from experience. This approach also offers the opportunity for students to experience success in terms of their learning achievements, allowing them to realise the knowledge which they have taken in without realising (Evans, 1994).

There are a set of six propositions shared by a group of respected 20th century scholars including John Dewey, Kurt Lewin, Jean Piaget and others, which can help to underpin this theory and its associated benefits (Kolb & Kolb, 2005):

1. “Learning is best conceived as a process, not in terms of outcomes”, an offering which places emphasis on the creation of an effective learning environment and processes.
2. “All learning is relearning”, a proposal which suggests that the learning process should draw from students’ beliefs and knowledge to refine such knowledge.
3. “Learning requires the resolution of conflicts”, a proposition which presents the idea of reflecting to develop knowledge further.
4. “Learning is a holistic process of adaptation to the world” which affirms the integration of all parts of a total person including thinking, feeling and cognition amongst others.
5. “Learning results from synergetic transactions”, an indication of the importance of utilising knowledge alongside new experiences.
6. “Learning is the process of creating knowledge”, a statement which has already been highlighted by the definitions and discussion of this approach.

Interestingly, this approach to learning can be summarised simply as shown in Figure 3. This cycle starts with an event which the student has experienced. Reflective observation of this event directs the user to abstract conceptualisation, which should be followed by experimentation with the concepts which have been developed as a result.

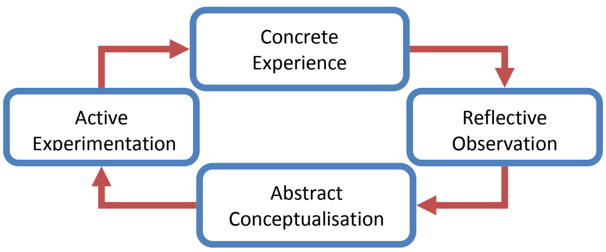

Figure 3: Kolb’s Experiential Learning Cycle (Boydell, 1976)

A further model which adds weight to the proposals for experiential learning to be adopted can be observed in Figure 4. This model offers both teachers and learners a framework to identify the attributes which are required to support this form of learning.

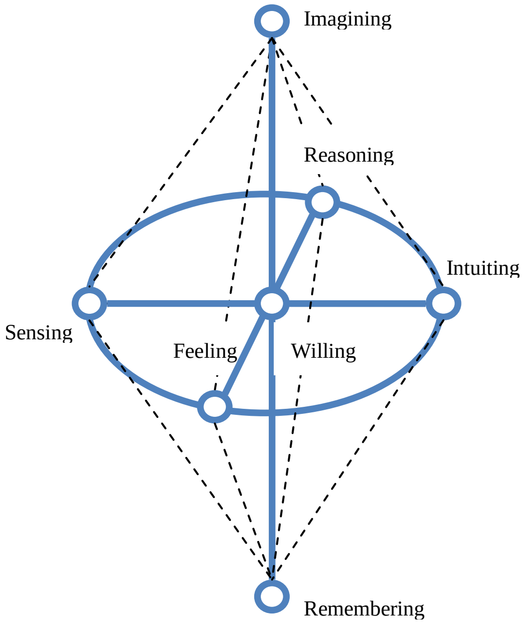

Figure 4: Model of Internal Processes (Mulligan, 1993)

The attributes highlighted by this model, are all related as shown by the various lines which connect them. For example reasoning demands a rational, purposeful framework contrasting with the need for a subjective and emotional response for feeling which is demonstrated by their polar opposition in the model (Mulligan, 1993). In the same way, sensing and intuiting are also in a state of polarity. If we move to the outer nodes within the model, representing imagining and remembering, these both depend on the attributes already mentioned to support effective learning with their positions set merely by their temporal states of past and future. Willing is central to this model as it acts as the motivation which is required by the remaining attributes to organise the learning process.

Both of these models highlight the idea that experiential learning is a process concerned with constructing knowledge. This thought is supported by numerous others, a selection of whom further extend the model shown in Figure 3 to incorporate a mapping between each and every one of the states, creating a connected graph instead of a simple cycle (Kolb & Kolb, 2008). This forms a far stronger proposition in terms of the links to the various established human information processing models.

3.3 Comparison of Approaches

These two approaches to learning are fundamentally different, with the instructional approach placing reliance upon the structure and objectives of the learning contrasting with the focus upon the learning process with experiential learning. However it is not from this difference which the benefit of one approach over the other can be exhibited. Instead the opportunity to develop transferrable skills through the experiential approach is a significant benefit over the instructional approach.

The benefits of the experiential approach seem not to have been realised by those leading the development of education, which perhaps means there are secondary reasons as to why this approach hasn't received further accolades. The following section aims to tackle the use of tools to assist with learning, discussing the current approaches in contrast with the EM advancements for educational tools. It is hoped that such a discussion will offer an insight into the relatively small uptake of this exciting approach to learning.

4 Tools for Education

The vast development of technology over the past two decades has been huge, with a large number of households now owning or having access to ICT equipment. This change has also been supported by schools with the government incorporating ICT into the strategy for schools. This has resulted in the adoption of interactive presentation techniques by teachers which include the transition from blackboards to interactive whiteboards to incorporate multimedia content into lessons.

4.1 Current Approaches

Unfortunately the modern approach to incorporating technology into learning has not been as successful as the technology suggests. The inclusion of multimedia and additional content to lessons may have left students with an improved environment in which to obtain knowledge, however the problem of the approach to teaching has not changed. There are various problems which have been highlighted with the incorporation of technology into education.

A high level of ICT management is required due to the high rate of hardware and software turnover. This is alongside ensuring that available resources meet the needs of all those wishing to utilise them in their teaching. All teachers are looking to customise the resources which they incorporate into their teaching, which as a result of the developments in ICT has become easier in some respects. However with the demand for more sophisticated resources emanating from students and teachers alike, time is being taken away from the subject-oriented role of the teacher to develop skills in order to produce richer experiences for students (Beynon W. M., 1997).

The ICT packages which are available on the open market offer significant advantages to commercial organisations, however to educational establishments the cost of such packages cannot be offset against future revenue. On a similar note, commercial organisations can also afford to make changes to packages or develop bespoke software, which again educational establishments cannot provide. This opinion is affirmed by Beynon (2007) who states that "the accepted conceptual framework surrounding computing technology is critically ill-suited for creating environments for learning".

4.2 EM as a Learning Tool

EM is a radical new conception (Beynon M. , 2007) in terms of the development of educational tools, offering significant improvements over traditional procedural program development. There are suggestions that EM is particularly well suited to the development of educational tools based on the tight coupling between the principles of the construction of a model and the experiential learning process (Beynon M. , 2007).

Two further key attributes of the empirical modelling approach were also highlighted by Beynon (2007):

- EM addresses the concept of the computer as a physical artefact
- It involves recording the experimental contexts that inform the model

These attributes demonstrate the key elements of the empirical modelling tools which are of benefit to the development of an educational tool, affording the ability for users to interact with a model as if it were a physical artefact. Based on the traditional models such as the abacus and physical representations of the Tower of Hanoi, empirical modelling seems to offer appropriate features to develop more versatile solutions which students can interact with given little prior knowledge or experience.

4.2.1 Benefits of EM

There are various benefits which the empirical modelling approach exhibits, the first of which is the creation of a single vision which encompasses the various levels of human interaction. This is in addition to offering support for a large selection of technologies to support the creation of an interactive environment, including 3-dimensional graphics (Beynon M. , 2007).

A further benefit which is exhibited by the empirical modelling tools is the ability to place the emphasis for working with, and creating the models upon the user. The ability to create flexible "base" models can be given to teachers, allowing students to then develop and change the models to support the experiential learning previously expressed. The culture of developing a package which can then be modified by its users is significantly different to the "closed-world engineering culture" (Beynon M. , 2007) and affirms the potential of EM as a tool to produce educational models.

4.2.2 Comparison of EM to Procedural Languages

The previous sections have outlined the current approaches to educational tools in addition to discussing the merits of EM as an alternative technology to provide the tools. However there has been no comparison between the development tools which are used to create these current educational tools and those tools offered by EM.

With business applications and games there are constraints and business logic which are put in place at the outset of the development, along with a distinct set of features which the final product should exhibit. These attributes are fundamentally different to the EM approach which relies upon the ability to develop the model based on experience, changing rules and constraints as required. These options are not available through traditional procedural languages such as Java or C++, with thorough knowledge of the language and syntax required even to make minor changes.

Importantly, EM offers an abstract interface to allow even those with limited knowledge to develop the models, which is the significant advantage which it offers in this domain. By affording the ability for the teacher to create resources utilising the EM tools and for students then to experiment with or extend such tools, EM offers an approach which can support the fast changing ICT environment which the traditional development model simply could not.

5 Modelling the Problem

5.1 Aim of the Study

The aim of this modelling study was to investigate the support which EM can offer experiential learning, concentrating on the key benefits which have been raised with this approach over the traditional instructional approach to learning. The problem which was chosen is a simple model which offers controlled interactions to teach the simple concept of recursion. Despite numerous developments which each added further functionality, it wasn't until the sixth iteration of development that the model was actually functional.

5.2 *Overview of the Model*

A summary of the various efforts which formed the overall development of the model can be found below:

- Model 1: Added functionality to set and reset the basic state of the game, ignoring any functionality.
- Model 2: Constructed the various components which make up the poles using Donald, concentrating on layout.
- Model 3: Added logic to draw the basic 3 disc model of the problem.
- Model 4: Developed dependencies and base data structures to enable the changing of the difficulty of the problem and maintenance of the interface through such dependencies.
- Model 5: Added action areas to move discs, incorporating dependencies to afford only valid options to the user.
- Model 6: Included logic and dependencies to allow the user to move discs between poles, maintaining the state of the problem.
- Model 7: Added feedback mechanisms to the interface to support the learning of the optimal solution.

The final state of the model is perhaps the most interesting and useful in terms of the empirical modelling aspects which have been incorporated, especially in terms of its demonstration of EM as a tool for the provision of educational tools. The final model as shown in Figure 5 is based around a set of core state variables which define the state of the problem at any given point in time. These state variables form the root of dependencies which are used to express the state of the problem in more detail.

Dependencies are a crucial aspect of empirical modelling, offering the ability to express the model in terms of such constructs to support the changing of the basis state which will then update dependants. This model expresses the layout of the interface in addition to the validity of all actions which can be performed in terms of dependencies, affording only the actions which are valid given any state of the problem. These dependencies form part of the definition of the various scout components which are added to the interface. The user can redefine these relationships which depend on the basis state to either redefine the rules of the game or to add further functionality. This concept is where EM offers this model the advantage over a procedural alternative, enabling students to redefine the relationships themselves to experiment with the model.

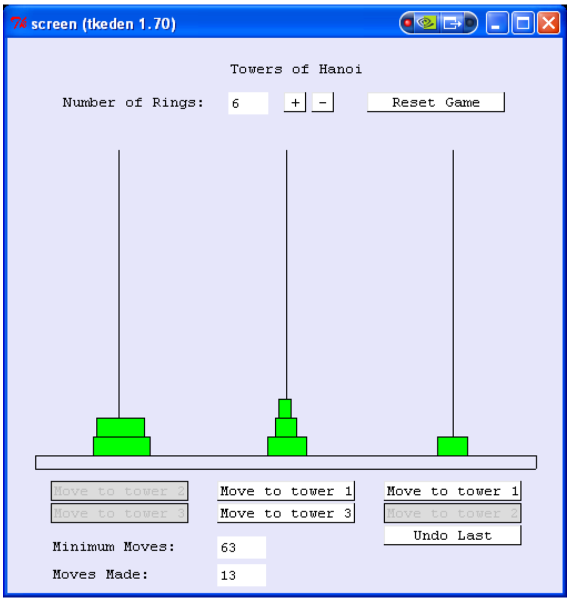

Figure 5: Tower of Hanoi Model

A further addition to the model which was added as the iterations progressed was feedback to the user based on the current state of the model. This feedback was formed by adding several attributes to the basis state of the model and expressing the relationships again using dependencies to present meaningful information for the user.

The overall result of the modelling study is a single agent system which exhibits a basis state and a set of dependencies which establish the overall model. As a solution to the lack of educational tools, this EM artefact offers a set of dependencies which can be modified by the user to support experimentation. Furthermore the interface which has been developed, simply offers assistance to the user but no instruction of the solution to the problem. By highlighting the valid moves in addition to feedback on the current state of the model, the model affords a high level of experimentation without adding any instructional components.

As already highlighted this model offers an overview of the basic functionality which the current EM tools provide. Through the establishment of the basis state and the associated dependencies, the model illustrates the potential for EM to act as a foundation for the construction of educational tools. The inclusion of elements to incorporate a feedback mechanism, add a further layer to the model, simply enhancing the user experience without instructing the user's moves to solve the problem.

6 Conclusion

This paper has discussed the various approaches to learning, suggesting that experiential learning offers significant advantages over the traditional instructional approach in terms of the additional benefits which it offers. However in order to create a successful environment in which learning can take place, consideration needs to be paid to the structure which should be put in place to afford experiential learning to support the curriculum.

The problems which have been identified relating to the problems with the traditional learning approach have been contrasted with the EM principles. This contrast identified EM as a potential technology to afford the flexibility and creativity which modern educational tools require, especially in supporting experiential learning. In summary EM is a promising development, however further marketing and development effort is required to ensure that it reaches the potential which it clearly offers to the educational sector.

Through the exploratory construction of the Tower of Hanoi model, the current EM tools were evaluated against the requirement for a dynamic, adaptive learning environment. The model also illustrates the traditional physical model of the Tower of Hanoi, allowing the user to perform only valid operations upon the model.

Future development of this model is fairly vast, including the opportunity to construct the game tree of the problem so that the user can map the problem state onto the graph. Further additions include the possibility of adding additional contextual help, such as hints when the user is moving towards key states within the problem to assist with the development of the recursive strategy. A final improvement would be the removal of the 10 disc limit which has been imposed currently. However this problem size does require 1023 moves to solve, so perhaps the former improvements would offer an improved solution!

Acknowledgements

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