Empirical Modelling, Learning and Visual Perception

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Abstract

Reading textbooks does not always help learning of students with different learning styles. Learning involves understanding information using your own internal references, which is not always plausible by just reading textbooks, it requires placing that information into practice, exploring, interacting and experimenting with it, learning by doing. Principles of Empirical Modelling place emphasis on this approach, known as a constructivist approach, to assist learning. This approach can provide learners with a deep understanding of a concept/interest through constructing a model, observing and experimenting with it which in turn helps with the learner's life long understanding of that particular topic. There are a number of tools, which are used to apply Empirical Modelling principles in practice, providing modellers with an interactive environment where they can build artefacts called construals. Whilst building construals, the modeller lays the foundation with basic observables and dependencies, then explores and builds on top of it using their understanding of the concept and adds further complex observables and dependencies. This paper presents a discussion on how Empirical Modelling aids learning and why Empirical Modelling has not been widely spread. It also discusses how the models created in the past/present using principles of Empirical Modelling can benefit end-users with different learning styles. Lastly, it presents a comparison between the two main tools used in the application of Empirical Modelling principles, EDEN and JS-EDEN. This comparison uses the understanding that came from the development of models on visual perception and optical illusions as part of the modelling study.

Keywords
Learning, Sense-making, Visual Perception, Optical Illusions, EDEN, JS-EDEN, Observation, Dependency, Agency, Construal, Learning styles

1 Introduction

Over the years, computers have become an important part of education with the introduction of technology-enhanced learning in schools and higher-level institutions (HEFCE, 2009; JISC, 2008). Examples of such e-learning tools include online collaborative tools such as Topolor (Cristea, et al, 2013) or Piazza used at University, virtual learning environments such as the online interactive lectures provided by Further Maths Support Program (FMSP, n.d) to students enabling distance based learning. Although this movement has been beneficial for students as it allows them to learn in a different way compared to just reading books and looking at static images, it still relies on the instructivist approach of learning, which is following instructions given on a website, listening to a lecture online, or answering questions about what they already know, leaving limited exploration in a particular domain. The learning of students still sometimes lacks the use of their own experiences to understand a concept, as they do not apply the information into practice or explore the given topic by constructing something so sometimes information is forgotten over a period of time. The principles of Empirical Modelling (EM) enforce the constructivist view through the building of construals, leaving behind the instructivist view.

After briefly discussing the theme of the paper, learning, in this section, the structure of the remaining paper is as follows. Section 2 will look at EM further from the educational point of view. It will also focus on analysing the different learning styles students have and how the development of different types of construals using the tools available can help learners with different learning styles. Section 3 will look at the construals on visual perception and optical illusions developed as part of the modelling study. These models will be used as the basis for comparison between the two main tools, EDEN and JS-EDEN used in the development of construals mentioned. Section 4 will conclude the paper by and summarising the key topics and highlighting why Empirical Modelling is the most suitable method for learning.

2 Empirical Modelling and Learning

2.1 Why EM has not been widely spread for learning?

EM has many applications ranging from modelling topics in different domains such as modelling Lungs and disease in Biology (Web-EM1, 2005) to modelling real-life events and recreational interests such as modelling the American Football (Web-EM6, 2010). Although EM has many applications, everyone may not accept it as an approach to learning. This is because some people disagree with the Constructivist/experiential method of learning, suggests a study by Clark, et al (2006). This study proposes that minimally guided instruction is less likely to be effective and it may actually have a negative impact on students if the students acquire incomplete or incorrect knowledge. This might be one of the reasons why EM has not been widely accepted as an approach to learning in Computer Science.

On the other hand, supporters of EM do not suggest that EM is the only method that should be applied to learning. Instructivist and Constructivist approaches can both be applied simultaneously to learning like they have been in other disciplines such as Biology, Chemistry and Physics. In these disciplines students explore a particular topic by carrying out lab work, not knowing what the end result will be at times, as well as read textbooks. The similarity between experiments carried out by Scientists before formalising a theory and modelling with dependency, is also noted by Beynon (2007).

Even if everyone accepts the constructivist approach, will they accept EM as an alternative approach to conventional educational technology? EM gives the modeller a more personal experience when creating a model whereas conventional approaches follow an instructive method, focusing on reaching a target output, making the experience impersonal. From this explanation, it does seem like EM is a better paradigm for learning, as it allows learners to explore a topic of interest using their imagination. However, the tools used in EM are not fully developed, limiting the use of EM in learning. This might be another reason why EM has not have been widely spread and has not been accepted as an alternative approach at present.

On the whole, EM does have benefits and it does overcome any drawbacks of conventional educational technology. However with its current tools, it may be difficult to make EM widespread in Universities but it can still be used for personal use to understand a concept in a specific domain. Students with an interest in computer-based modelling, studying any course can learn to create EM models and explore a topic.

2.2 Learning Styles

In the past, students and lecturers have created many EM models, each model focusing on a particular interest. It can be argued that each student has a preferred learning style so their learning style may have influenced what they created and how their model was visualised. Although creation of models involves active learning, the models can be created in such a way that they satisfy the requirements of an end user. The end user can have any learning style.

There are many learning styles; the ones looked at in this paper are visual, aural, read-write and kinesthetic (Drago and Wagner). Visual learners prefer images and demonstrations whilst read-write learners prefer to take notes in lectures and read difficult material. In contrast, aural learners prefer listening to instructions and enjoy talking about problems. Lastly, kinesthetic learners prefer learning by doing and do not like watching or listening.

Kinesthetic learners are the people who are most suited to EM model building exercise, as they prefer hands on job. These learners also like interacting and experimenting with models so it is possible that to some extent most learners who use the models are likely to be kinesthetic learners. An example of the type of model a kinesthetic learner is likely to prefer is linear programming and optimisation model created by Fang (2012). This type of model allows the learner to change the constraints and see what solution the learner gets; at present it's only a prototype. In contrast to kinesthetic learners, aural learners prefer listening to instructions. Although there has not been a model created in the past that suits this type of learner but it is possible to create it in the future with the help of JS-EDEN. A demo has already been created by Hudnott (2013), which allows audio files to be played in JS-EDEN environment.

Visual learners prefer demonstrations. Just like kinesthetic learners, visual learners are also likely to prefer most of the past models created by students. This is because most of the models have visualisations in different forms and have less/no text. A model demonstrating the lifecycle of malaria parasite is likely to be an effective model for visual learners. (Beynon and Beynon, 2011). This model is an animation with less interaction, which is what visual learners prefer. On the other hand, read-write learners may not prefer this model as they prefer reading and writing, the types of models most suitable for them are models created using the presentation environments in EDEN and JS-EDEN. The benefit of using the EDEN presentation environment (EMPE) is that users can edit the slides on the go and save them straight away, it does not require looking at the code behind the model and the benefit of using JS-EDEN presentation environment (JSPE) is that it allows explanations to be typed up on the slides like EMPE does. An example of a model suitable for read-write learners might be the model developed as part of the modelling study using JSPE, it has text as well as visualisations.

2.3 EM Concepts

Understanding of EM concepts is necessary to be able to create models. The key concepts are observables, dependency and agency; these are explained below, as these words will be used later in the modelling study section. These concepts are flexible in terms of what can be created; they do not limit the learner in any way.

2.3.1 Observable

An observable is something we see, it can change from one state to another. For example, a door is an observable, it can change state by opening or closing.

2.3.2 Dependency

A dependency is a link between observables; changing one observable will change another observable if there is a relationship between them. For instance, a person wanting to enter a room will require the door to open to let the person in and close it once the person is inside the room. There is a dependency between the door and the person where both door and person are observables. A change in what the person does will change whether the door is open or close.

2.3.3 Agency

An agent is something or someone that can make a change to something else; in this case it will change the state of an observable or observables. For example, a person (agent) pressing a button, allowing an animation to start, will change the state of the observables.

3 Modelling study

The modelling study involved creating two construals, one in EDEN and another one in JS-EDEN. A model of some traditional optical illusions was created in EDEN and a model of the reasons why these optical illusions exist is created in JS-EDEN with the help of the JSPE.

3.1 Motivation

The motivation for creating these models is that the modeller wanted to learn more about visual perception and optical illusions and try to link the information together. When researching information on this topic, the modeller noticed mostly static images and text was used to convey this topic to learners, which is not suited for the various learning styles. Also, sometimes not all the information was in one place making it difficult for any learner to learn about it before doing a lot of research and gathering the right information. This was another reason why it was a good idea to create a model that tries to integrate all the information and lays it in one place; JS-EDEN model tries to do this as illustrated by the two screenshots, Figure 1 and Figure 2.

The main inspiration for the JS-EDEN model was trying to create something, which suited all learning styles. Earlier on in the creation process, it was realised that it will be difficult to create a model without much explanation. First of all, it would mean that it does not suit read-write learning style and secondly users may not understand what each observable stands for. Keeping in mind that there will be text, new observables and dependencies can be introduced as the model develops, JSPE was used instead. This choice made it easier to keep track of lots of observables and dependencies by using the slide number. The JS-EDEN model can be seen as a few small models put together in one model and linked to each other theoretically or via dependencies.

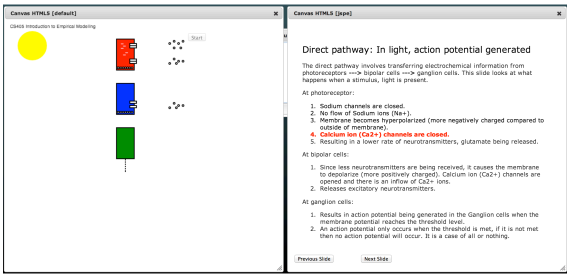

Figure 1: JS-EDEN model - Animation

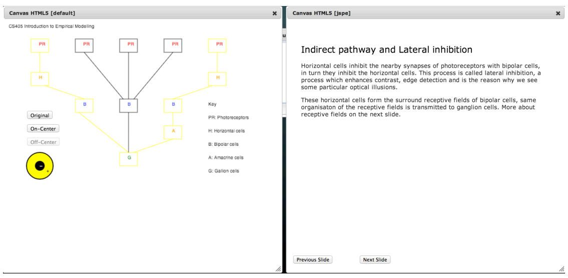

Figure 2: JS-EDEN model - Receptive fields

On the other hand, EDEN model shown in Figure 3 was developed for visual or kinesthetic learners, with less text and only visualisation of optical illusions, which the learners can interact with.

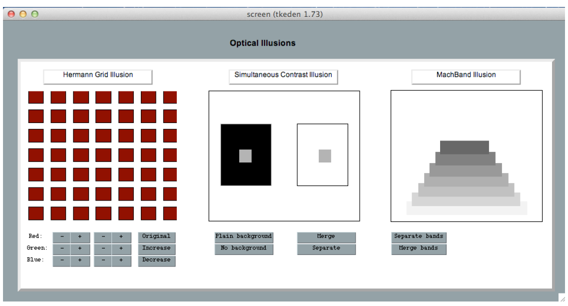

Figure 3: EDEN model

3.2 JS-EDEN

The JS-EDEN model was created using the EDEN notation and used limited JavaScript. JavaScript was avoided to make comparison between EDEN and JS-EDEN model fairer.

3.2.1 Observables, Dependencies and Agency

Most of the observables defined in the JS-EDEN model are dependent on other observables. The animation part of the model relies on these values:

```
recepX = 50; recepY = 40;
recepW = 40; recepH = 30;
receptor1 is Rectangle(recepX, recepY, recepW, recepH,
"white");
```

Changing the value of recepX or recepY or recepW or recepH will change the animation part of the model, it will either move it by x-coordinate or y-coordinate or change the width or height of the observables respectively. Another dependency in the model is when the gap in the Hermann Grid optical illusion is increased or decreased, it results in circles appearing or disappearing depending on how big the gap is between the squares. The circles represent the illusion we see, the grey dots.

To make any of the observables change state, a human (agent) in this instance will have to initiate change by clicking the start button in the animation, or clicking the buttons to increase or decrease the gaps or executing code to change the color of an observable.

3.3 EDEN

The EDEN model was created using the EDEN, DONALD and SCOUT notations. DONALD notation was used for creating 2D observables, SCOUT notation was used to create windows in which the observables defined in DONALD were to be displayed and finally EDEN was used to defining procedures, which will allow the buttons to work and carry out a particular change in an observable when clicked.

3.3.1 Observables, Dependencies and Agency

Observables are dependent on one another as they are defined using one another. The code below shows that changing the coordinates of grid observable will result in a change in another observable g1b. This code is for the squares of Hermann Grid.

```
viewport view1
openshape grid
        within grid{
                rectangle g1a
                g1a = rectangle({10,10}, {110,110})
        }
int gapx, gapy
gapx = 150
gapy = 0
shape g1b
g1b = trans(grid,gapx,gapy)
```

To interact with the illusions and change observables, the user can click on buttons, seeing if colour has an affect on Hermann grid or whether the squares of the simultaneous contrast are the same or not. Every button click changes an observable's state.

3.4 Comparison between EDEN and JS-EDEN models

EDEN model involves using various different notations, each notation having a different syntax. To create a model using the different notations can be a time consuming process as it involves remembering the syntax, especially if the modeller has not had much practice in using them. Also, it can sometimes be confusing for a beginner if two notations have different ways of approaching the same thing, for example, DONALD and SCOUT notations use opposite y coordinate system to each other. Once the modeller becomes familiar with the syntax it becomes quite easy to create models and the modeller can roughly keep the different notations in different files to keep the code organised. Also, the error messages are quite informative so it is easy to debug.

In comparison to EDEN, JS-EDEN models only use one notation, do not require learning different syntax and are extendable by using JavaScript so it may be seen as a better tool for computer based modelling, as it requires less effort. However, it is not that simple, JS-EDEN comes with its own problems. One of the problems with JS-EDEN is that it is a relatively new tool, which is used to apply EM principles in practice so it is not very stable compared to EDEN, which has been around for longer. Eden is more stable but even then EDEN still has bugs. A bug found in EDEN was to do with opening two SCOUT windows as part of a model after closing them once, when the user tries to open the windows again, the main SCOUT window opens but the additional window does not open, leaving an output in the input window saying the additional window already exists. To open both windows, it requires the user to quit EDEN and restart it.

As it can be seen from the comparison, both tools have advantages and disadvantages so one tool is not better than the other and discovering bugs should not put us off from using EDEN or JS-EDEN as they will probably be fixed over time as the tools become more developed. Also, another reason to continue to use these tools is that the EM concepts are new, interesting and can help aid learning in the future.

3.5 Further Work

The improvements and further work mentioned here were added to the plan incrementally as the model developed but due to the amount of research involved it was not possible to carry them out quickly. All the work mentioned is likely to take less time if the information is provided quickly and is correct.

3.5.1 JS-EDEN model

In JS-EDEN model, processing of visual information in the brain was not demonstrated. This is something that can be done in the future to give users a complete picture of how visual information is processed. Another aspect that can be modelled is Hubel and Wiesel experiment involving the cat's visual cortex and other experiments conducted by Hubel and Wiesel, which contributed to understanding the processing of visual information in the brain. It is difficult to make something users can experiment with when that topic already has a formalised theory but experiments mentioned could be modelled to find out the thought process of the Scientists.

Furthermore, other interesting optical illusions can be modelled, which allow the user to experiment and interact with them. Lastly, an improvement can be made to the current model by modelling the eye with dependency. The eye was created using EDEN notation for illustration purposes only with not much dependency. It is only used on one slide at the beginning.

3.5.2 EDEN model

In EDEN model, only three optical illusions were modelled with dependency. One improvement that can be made to this model is actually displaying the illusions using squares/circles, in a similar way to the Hermann Grid illusion modelled in JS-EDEN.

Further work that can take place with this model is converting everything done in JS-EDEN model to EDEN and ensuring everything links together perfectly. The new model in EDEN should have minimal text and should be more suited for visual learners.

4 Conclusion

In conclusion, tools and techniques of EM have not been widely spread due to the tools still being in their development stage. They have limitations, which will take time to overcome. Another reason is instructivist approach is still mostly being applied to learning, instead of the constructivist approach. This is another drawback for EM as the principles of EM enforce the constructivist approach. Regardless of these drawbacks, EM can still be applied in practice for learner's personal use to help their learning. The main benefit of applying EM to learning is that learners are able to build their own references as they explore and experiment, not relying on memorising anything anymore. This will in turn help their understanding of concepts and it is unlikely that this knowledge will be forgotten in the future. It was further noted that EM models benefit all learning styles, whether it is kinesthetic, visual, read-write or aural. Although, there is not any evidence of past models, which benefit aural learners, but there is evidence of how the model can be created in the future. Finally, as a part of the modelling study, a few small models in the same area were incorporated in JS-EDEN presentation environment, the aim of doing this was to try to gather all information in one place which can be interacted with by the user. Another model was built using EDEN mainly aimed at visual learners, which led to the comparison between JS-EDEN and EDEN, with both having their own advantages and disadvantages leading to a conclusion that both should be used, one tool is not better than the other.

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