EM for Learning - A Modeller's Experience

1035660

Abstract

Research in Empirical Modelling (EM) promises major benefits in the domain of providing educational software. This paper contributes to the research by introducing a model for educational purposes and discussing the modelling experience relating to the claimed benefits of EM. Previous research results are confirmed, but issues that could hinder the spread of EM for learning are spotted as well. In order to promote EM as the best approach for learning, more comprehensive case studies than the one in this paper will be necessary.

1 Learning with EM

Experience with Empirical Modelling (EM) has soon revealed a huge potential for applications in learning. Beynon (1997) discovered that the process of learning aligns well with the process of modelling a construal. Firstly, both begin with an interaction with certain elements of the system to be explored and the experience of change as a consequence of these interactions. Secondly, as a system is explored further and understood sufficiently, it can be represented in terms of formal specifications. For instance, when a primary school pupil gets to know basic mathematical operators for the first time, the obvious way of understanding them is to recall how elements of the real life could represent numbers in equations. The ongoing process of interaction builds experience, which will later allow the pupil to fully understand the formal mathematical notation.

Roe (2003) also concludes that EM is better suited for building models and providing educational software than traditional programming. This is due to the reason outlined above, but also to the fact that the perspectives of teachers, pupils and software developers move together. Teachers and developers may have different expectations concerning learning software, and pupils as well as teachers may encounter situations in which more adaptability is desirable than conventional programs are able to offer. EM allows pupils to comprise all three roles at the same time, although this cannot be a general solution, because the majority of them lacks the necessary basic programming skills and may not achieve the learning outcomes of a curriculum with their own model. However, a teacher could build models to educate the students, but that would necessitate teachers with programming skills. Even if none of these would be an option, the adaptivity of EM models enables students and teachers to collaborate more closely with developers, and thus simplifies the tailoring of educational software to changing contexts and different types of learning. With a case study, Beynon and Harfield (2005) demonstrate how an EM construal is able to represent students', teachers' and developers' exploratory activities at the same time. Roe (2003) points out that in order to be able to generate the claimed advantages, the empirically modelled learning environment should allow the user to experiment with any input he likes, be contextually realistic as well as adaptable and extendable.

Besides these EM approaches to educational software, traditional programming has been exploited to enable constructionism in learning environments. Beynon and Roe (2004) criticise the still insufficient distinction between "'learning about computer programming' and 'learning about a domain independent of computer programming'" (Beynon and Roe (2004, p.1)) in such solutions and promote the use of EM as the better alternative.

2 An EM learning example

The modelling study about currency exchange rates (Currency Model) is thought of as a case to test and discuss the claims of Beynon, Roe and Harfield about EM for learning. But before this will be done in Section 3, this Section presents the motivation and an overview of the Currency Model.

Motivation

The exchange rates of currencies are of importance for every international company in the world. Therefore, a key learning point for business students is to understand how they are constructed and by which factors they are influenced. In addition to the finance literature, an interactive model may be well-suited to give students an intuition of the mechanics of exchange rates. This is because the learning process in the student's mind usually starts with experiencing the changes of observables of a certain part of the currency theory, before it is even possible to understand the theory and its dependencies as a whole.

State-as-experienced

The experience in EM arises from observation, experiment and interaction with the model. (cf. King (2007)) By taking into consideration the different personal experiences of the respective modeller, each modeller's view could be described differently. So in the Currency Model, someone familiar with basic principles of finance such as interest rates and inflation will have a different construal in his mind than someone else. However, the latter group of persons will still be able to understand the currency theories, as the model provides an explanation of the implications of a changed observable.

Observables in the Currency Model

The model incorporates 7 observables. The *interest rates* of countries A and B typically describe the interest that can be earned with riskless lending, for instance by acquiring government bonds or putting cash on a savings account. A drop in purchasing power is reflected in positive *expected inflation rates* of A and B. For example, if the expected inflation rate was 1%, 100$ would buy 100 chocolate bars for 1$ each today, but only 99 chocolate bars in the future. The *spot rate* from A to B shows how much of the currency of A needs to be paid today in exchange for the currency of B. The *forward rate* from A to B is the price of exchange of currency of A into B that is fixed today for a point of time in the future. The *expected spot rate* is the spot rate from A to B at a future point of time, so it cannot be known now, but the forward rate underestimates the expected spot rate as often as it overestimates it, so both are the same on average.

Dependency in the Currency Model

The currency theory is based on 4 partial theories that depend on each other. Each of these dependencies has been given a name. The Interest Rate Parity relates the difference in interest rates of currency A and currency B to the difference in forward and spot rate from A into B, whereas the Expectations Theory relates the expected change in spot rate to the difference between forward and spot rate. The Purchasing Power Parity describes the connection between the expected change in spot rate to the expected difference in inflation rates of A and B, and the relation between the latter and the difference in interest rates is called International Fisher Effect. Figure 1 summarises these dependencies.

Clearly, seven observables have to be taken into consideration when building the model. A change of one observable impacts several others because all theories are connected. The EM model enables students to get familiar with the theories by observation of the implications of particular changes in the values of observables.

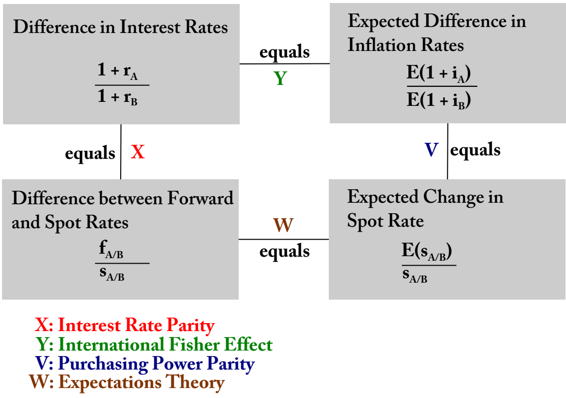

Figure 1: Relationships between Currency Theories, (ref. to Brealey, Myers, and Allen (2008, p. 758))

The following example illustrates how a change in one observable will affect at least one observable in each of the four differentials.

> Analysts claim that the inflation rate of country A is expected to change. The forecast for the inflation rate of country B does not change. As a consequence, the inflation rate differential changes. Firstly, the International Fisher Effect proposes that the value of the inflation rate differential and the interest rate differential should approach each other. This is because the change of expected inflation rate of country A creates an arbitrage opportunity, which is then exploited by investors and forces the interest rate differential to change. So the value which the interest rate differential will approach is known, but there is uncertainty about the degree of change of both interest rates of country A and country B. Secondly, the Purchasing Power Parity suggests that the expected inflation rate differential should equal the quotient of expected spot rate and current spot rate. The current spot rate refers to this moment in time as it can be observed in the Foreign Exchange (FX) market. It is predicted to approach the expected spot rate at a certain point of time in the future. As a consequence the expected spot rate changes, and with it the value of the quotient of expected spot rate and current spot rate. Finally, both Interest Rate Parity and Expectations Theory could explain why the forward rate between the currencies of country A and B needs to alter as well.

After loading the model in tkeden, the user is provided with a Scout interface showing the values of the observables and allowing him/her to update them and watch the consequences. Additionally, an explanation is shown for each variable when it is updated to foster the learning process. Figure 2 presents the model in a Scout window of tkeden 1.76.

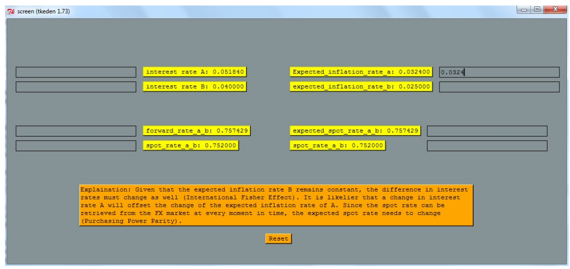

Figure 2: Currency Model in tkeden

Possible Extensions

The Expectations Theory as incorporated into the model sets the forward rate and expected spot rate equal. Brealey, Myers, and Allen (2008) point out that this is true on average, because the forward rate underestimates the expected spot rate as often as it overestimates it. But to make the model more realistic, this could be modelled with a random function. Doing this, on the other hand, would not make it easier to get an intuition about the underlying theory. The expected inflation rates of the two countries are forecasts. An extension of the model could include different forecasts and error margins.

Furthermore, the concept of agency could be used to simulate effects of some typical economic events. So for example, the impacts on currencies of a rise in unemployment rates of one country could be of interest for a student. The event agent would manipulate some observables in a way the changes could have appeared in the economy. Of course, this would result in notably higher complexity of the model and the modelling activity, but may nonetheless only be a very simplified view on economic relationships.

3 Experiences with the Currency Model

In this section, the advantages and issues encountered during the creation and use of the model will be related to the claims of Section 1.

3.1 Advantages

In principle, the functionality of the Currency Model could also be generated with a conventional programming language such as Java. But the EM solution provided several advantages. Before starting to model, there was no need for a clear specification. It was only necessary to begin with the creation of a construal, and with it an idea of how a model could assist this process in the mind of the modeller. So how could a student be assisted when trying to understand the theory behind currencies? The implementation process itself underpinned that EM is more a tool in the real sense of the word than many traditional programming languages. Allowing redefinitions as the model is running, tkeden opened up the possibility to align the process of construing the referent and implementing a model. The conventional way to produce a program would have been to mature the thoughts about the referent, and produce code that the modeller thinks of being correct and complete. Unless this code is free of mistakes, the process of debugging may take a significant amount of additional time. Although EM models may also contain errors, the emerging process of EM inhibits that many of them exist longer than a few seconds, i.e. until a (re-)definition is tried in tkeden. On top of that, tkeden in connection with Scout allows a much easier creation of a graphical user interface than many other traditional programming languages. This advantage is a contributor to the modelling experience.

In traditional programming, it is usually necessary to restrict the data types the user is allowed to input. Otherwise functions may be invoked with wrong arguments, causing the program to crash. In EM, the input data does not have to be preconceived, since tkeden is able to cope with all of them without crashing. The waiver of variable declarations goes along with this concept. As a consequence, the modeller of the Currency Model was not mandated to catch exceptions, and anyone using the model is free to try any input.

EM creates a symbiotic relationship between developing and using, because thinking of referents in terms of dependencies makes understanding easier, and this is not only the case in the Currency Model. In fact, every program comprises dependencies, as every problem in the real world does. Making these dependencies the most important part of the modelling process leads to a higher level of understanding. As a consequence of this and the advantages claimed above, it is easier for the original as well as later modellers to adapt the model. Students as well as teachers may find this useful when realising their personal construals of the currency theories by adding features for instance. Or in case of a developer doing the modelling for them, he/she would have an easier job.

3.2 Issues

Although the use of EM means many advantages, the tkeden environment does not fully exploit them. First and foremost, there is no single notation for modelling. But instead, special notations such as Scout and Donald have to be employed. Cadence, the EM research prototype of the Computer Science Department at the University of Warwick, aims to tackle this problem. Cadence also deals better with the concept of dependency. When a student wants to create a Currency Model to assist the learning activity, EM is the better choice compared to traditional programming. Nonetheless the advantages claimed in terms of a better adaptability may only be relevant if somebody is willing to use EM, a method not yet really wide-spread, for further modelling. Especially students from non-technical domains may lack the motivation, but not necessarily the ability, to use a tool like tkeden to customize and extend the Currency Model. In this case, there would be again a clear distinction between developer and user like in traditional programming, and this would render one advantage of using EM void. More importantly, it may just be the activity of extending rather than only using the Currency Model that leads students to think about the underlying theories intensely enough to understand them and to be able to apply them.

4 Conclusion

This paper has summarized the research conducted concerning the learning with EM. The Currency Model has been introduced to illustrate how EM could be applied in learning and to provide a starting point for the discussion of the claims made in the research papers. The experiences with modelling confirm that EM is a superior approach for providing learning environments compared to traditional programming. But issues with the EM developing environment and the necessity for the modeller to be equipped with programming experience may impede the spread of EM in learning. Future research could try to show the benefits of EM in a bigger field study in an educational institution. A success would as well attract more attention to EM in general.

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