Empirical Modelling, Constructivism and Understanding NIM

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Abstract

Whilst the attractions of the constructivist outlook on learning are well established, the majority of those who develop educational software are seemingly resistant to movement away from the instructionist view of learning that underpins many formal education systems. It is thus the intention of this work to broadly evaluate the alignment of construal construction with the overarching principles of this constructivist view of learning. In realising this intention, this work discusses both the instructionist and constructivist points of view, with particular reference to selected interpretations of constructivism. Following this extended discussion, the relationship between Empirical Modelling and constructivism is broadly considered, with explicit consideration of how the construction of construal is aligned with the constructivist outlook. The issues raised during this consideration are then concretised and illustrated through references to the NIM modelling study. Finally, this work will conclude with the suggestion that, in line with current research, construal construction is indeed a particularly relevant activity in the context of constructivism.

1 Introduction

In recent years there has been a discernable shift in psychological and pedagogical thinking which has motivated some significant reconsideration of widely accepted approaches to teaching. In general this shift has seen eminent theorists move away from an instructionist view of learning and towards an outlook which can be interpreted as broadly constructivist. Crucially, this shift in outlook has a number of serious consequences for those concerned with computer assisted learning. In particular, the consequences of this shift for those developing educational software and computer based learning platforms are particularly pronounced. However, these significant implications are still to be addressed by the majority of those developing commercial educational software. In many ways this resistance to shift towards a broadly constructivist approach to educational software may be motivated by the nature of the traditional instructionist approach making the development of this form of educational software both convenient and publically desirable. Indeed, in the past it has been suggested that the abundance of educational software with this orientation had led to the public perception that instructionist software was the only form of computer assisted learning (Blease, 1986).

It is widely acknowledged that game playing, whether it be computer based or otherwise, is a highly motivating undertaking. In the past this acknowledgement has led to significant interest in the potential for the integration of educational content into game playing experiences. However, in spite this fervent interest, a significant proportion of all the computer assisted educational game playing experiences produced are instructionist in orientation. Given this general orientation, it perhaps no suprise that, little attention has been given to the potential of learning through the creation of games, an activity which is seemingly well aligned with the broad constructivist outlook. Interestinlgy whilst a number of notable exceptions to this assertion exist, including the Alice project, these exceptions typically focus specifically upon the learning of computer programming and other such related technical concepts (Alice, 2008).

In recent work Beynon and Rowe have discussed and highlighted the potential value of adopting an Empirical Modelling (EM) perspective with reference to it alignment with the objectives of constructivist interpretations (Beynon & Roe, 2004). It is thus the intention of this work to build upon these recent proposals by broadly evaluating the alignment of EM construal construction with the overarching principles of constructivist learning. In particular, this work will illustrate this evaluation by demonstrating how the process of constructing a relatively simple EM construal can facilitate the understanding of game playing

strategies. In realising this intention, this work will engage in general discussion of the instructionist and constructivist theories of learning, before proceeding to review two particularly relevant constructivist perspectives. In overcoming the difficulties that are associated with of this initially broad approach, a framework proposed by Moshman for the general categorisation of the various interpretations of constructivism is utilised (Moshman, 1982). Following this, the merits of EM construal construction are explored in the context of the constructionist outlook, with particular reference being made to the two previously discussed endogenous interpretations. To support and illustrate this high-level discussion, the issues raised will then be related to the NIM modelling study. Finally, this work will culminate with the assertion that whilst EM construal construction is well aligned with the broad constructivist outlook, it is particularly suited and relevant with respect to endogenous interpretations. Further, it will also be suggested that this assertion is supported by the NIM modelling study, which demonstrates that the building of a relatively simple EM construal can facilitate sufficient understanding to allow for the identification of alternative game playing strategy.

2 Instructionist Learning

In general the instructionist approach to learning is grounded in an objectivist stance, which can be considered to assert that reality is entirely independent from those that perceive it, thus implying that learners may interpret this reality to acquire objective knowledge. Hence the instructionist approach to learning places emphasis upon the provision and transmission of knowledge which is passively acquired by the learner. In practice this approach to learning relies heavily upon a seemingly unidirectional transfer of knowledge, whereby a teacher will attempt to articulate their own inherently personal understanding to any number of learners.

Instructionist teaching methods are particularly convenient and applicable in the context of formal education systems and have formed a cornerstone of such national systems since their inception. In this context instructionist methods provide a means of explicitly prescribing what is to be learned, as well as lending themselves to written examination and peer comparison, all of which are frequently thought to be essential mechanisms for the management of national education systems. Typically instructionist methods are considered most relevant in the context of the formal teaching of mathematics and areas of the sciences, where abstract concepts are considered to form an essential basis for understanding.

In motivating the previously discussed shift in psychological and pedagogical thinking the shortcomings and misgivings of the instructionist approach to learning played an important role. As the knowledge being transmitted to a passive learner is highly personal to the individual articulating it, it may be that case that the knowledge itself will not be sufficiently meaningful to facilitate the development of genuine learner understanding. Thus in many was the instructionist approach could accused of, potentially, encouraging the development of rote knowledge, with little fundamental understanding which could be applied in other contexts.

Further to these limitations, when considering educational software, with particular emphasis upon educational game based software, a number of the aforementioned consequences of the instructionist approach for those concerned with computer assisted learning become clear. Perhaps most critically, developers adopting an instructionist approach can be seen to use their technical skills to articulate their own understanding and prescribe a narrow set of interactions which learners may perform. Having already highlighted the limitations of attempting to articulate highly personal knowledge to a passive learner and prescribe learning objectives, the many problems associated with this narrow development approach are immediately evident.

3 Constructivist Learning

The origins of constructivism find themselves in the diverse works of Kant, Dewey and Piaget, the latter of which formalised theories in cognitive and affective development which, despite considerable criticism, will continue to impact upon countless fields of research. As an outlook on learning, the constructivist viewpoint does not singularly endorse any pedagogy above any other, instead it is principally concerned with the learning process itself, offering a mean of explaining how understanding is occurs in the mind of the learner. As such, the constructivist outlook asserts that learning is an active process in which learners construct internal knowledge structures which are principally based upon their own inherently subjective interpretations and experience. Thus the knowledge and understanding of any individual can in some sense be considered to be both

intrinsically and permanently linked to the various experiences and subjective interpretations of that individual. To supplement this description, Jonassen provides concise points which illustrate the previous discussion of constructivism.

> *"[Constructivism]...claims that reality is constructed by the knower based upon mental activity. Humans are perceivers and interpreters who construct their own reality through engaging in those mental activities." (Jonassen, 1991).*

> *"What the mind produces are mental models that explain to the knower what he or she has perceived" (Jonassen, 1991).*

From the previous discussion and the above quotations it is possible to deduce two important characteristics of the constructionist outlook that are relevant to this work and perhaps even the EM perspective in general. That is, as the theory focuses upon the process of learning, no assumptions are made regarding the previous knowledge of the learner. Further to this, as learners construct thier own individual internal knowledge representations based upon the interpretation of experience, the notion of defining what is to be learned does not allign well with the constructivist outllook.

At the heart of Piaget's work in developing the theories which would eventually lead to the various modern interpretations of constructivism are the concepts of 'schemata', 'accommodation' and 'assimilation'. Broadly speaking, Piaget suggested that actions are organised into distinct patterns of behaviour known as schemata. Further, the process of assimilation refers to new perceptions being integrated into existing schemata or the development of new schemata to organise unfamiliar perceptual experiences. In contrast, the process of accommodation refers to perceptions which are inconsistent with current expectations forcing the modification of existing schemata, is thus the accommodation process is often considered as learning through the experience of failure (Wadsworth, 1996).

3.1 Interpretations of Constructivism

Despite the criticisms of Piaget's work, his contribution to the conception of the numerous interpretation of constructivism is undeniable. However, the broad nature of constructivism, alongside the heterogeneity and controversy surrounding prominent interpretations, ensures that any evaluation of its relationship with EM is decidedly difficult. In recent work Beynon and Harfield employed the framework proposed by Latour to account for these difficulties and allow an effective evaluation to be conducted (Beynon & Harfield, 2007). Rather than adopting a similar framework for the consideration of the constructivism outlook in the context of EM, the broad framework proposed by Moshman, which has previously been applied by Dalgarno in considering the implications of modern constructivism for computer assisted learning, was selected (Dalgarno, 2001). Further to this, and quite apart from the aforementioned endorsement, the adopted framework will also facilitate a flexible general discussion of the relationship between constructivism and EM.

The Moshman framework identifies three broad and non-distinct categories of constructivist interpretations, namely endogenous, exogenous and dialectical (Moshman, 1982). In terms of orientation, the endogenous classification is principally concerned with interpretations which place emphasis upon learner exploration and discovery. Contrastingly, the exogenous and dialectical classifications focus upon the role of direct instruction and interaction between learners respectively.

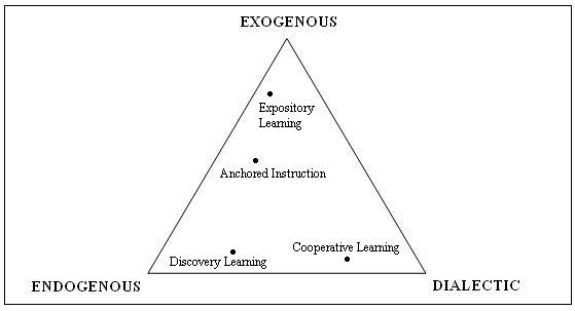

Figure 1 - Visual Interpretation of Moshman's Framework (Armarego, Fowler, & Roy, 2001)

Interestingly, whilst it is not the aim of EM tools and principles to align with any single interpretation of constructivism, it has previously been highlighted that EM is well suited to learner-directed activities which place emphasis upon personal experience and exploration (Beynon & Harfield, 2007). Given this orientation and the intention to subsequently address the relationship between EM and constructivism, it is useful to consider two prominent interpretations of constructivism that can broadly be categorised as endogenous in nature.

3.2 Constructionism

The theory of constructionism can generally be attributed to Papert, who became familiar with the ideas and theories of Piaget after working alongside him for several years. Papert openly criticised the majority of established educational software and coined the 'instructionist' and 'constructionist' terms in expressing these concerns for the future of computer based education (Papert, The Children's Machine, 1993).

The constructionist theory of learning asserts that conceptual development is enhanced when the learner is actively engaged in construction in a much more physical sense. To clarify what is meant by this description, Papert and Harel offer their own theory of constructionism.

> *"[Constructionism]...shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe." (Papert & Harel, Situating Constructionism, 1991).*

Perhaps Papert's foremost achievement in the field of constructionist learning was the creation of the LOGO programming language, which allows learners to explore mathematical concepts through the definition of geometric structures. However, in spite of the relative success of the LOGO programming language in supporting constructionism, many theorists and practitioners criticised LOGO for not sufficiently facilitating domain learning, a criticism which has also been directed towards instructionist educational software (S.Talbott, 1995).

3.3 Experiential Learning

The interpretation of constructivism known as experiential learning is intimately related to constructionism and has also been interpreted in a number of subtly different ways. Broadly speaking, experiential learning can be seen as 'learning from experience', though this description perhaps neglects to acknowledge the intricacies of this complex set of interpretations.

In spite of the vast number of proposed models relating to experiential learning, the Kolb four stage model of experiential learning is perhaps the most prominent and widely acknowledged (Kolb, 1984). In Kolb's model, learners proceed through a cycle of four stages which are known as concrete experience, reflective observation, abstract conceptualisation and active experimentation.

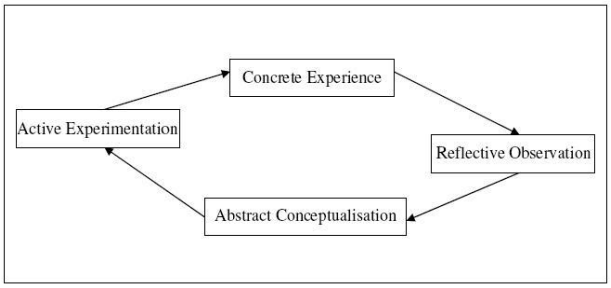

Figure 2 – The Kolb Model of Experiential Learning

The cycle commences with some concrete experience, which will subsequently prompt the learner to undertake personal reflection upon the experience. Following this stage of private reflection the learner will attempt abstractly conceptualise their interpretations and reflections upon the experience. In doing this they will seeks to make sense of the experience through the formulation of abstract explanations and general rules. Crucially, the ideas and concepts formulated during this stage then incite further active experimentation, which in turn will lead to further concrete experience, thus resulting in ongoing conceptual development.

Despite its widespread acknowledgement and prominence, the Kolb model has been subject to much criticism. For example, the model has been criticised for failing to take account of individual learning styles and the practicalities of formal education. However, in recent years the Experiential Framework for Learning (EFL) has been shown to describe different domain learning activities in a manner which is consistent with the assumptions and stages of the Kolb model (Rowe, 2003).

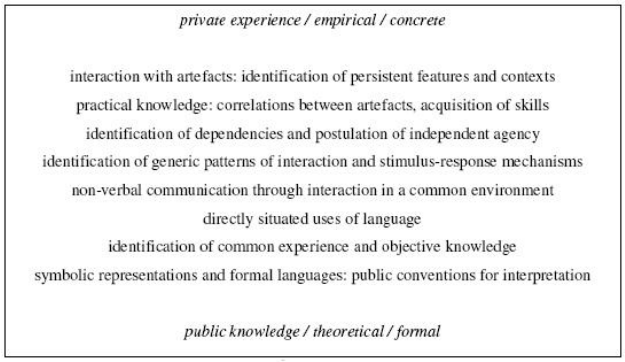

Figure 3 - The Experiential Framework for Learning (EFL)

As can be seen from Figure 3, learning activities defined within the EFL are placed on a scale which in some sense expresses their nature in terms of their concreteness in relation to other learning activities. Perhaps most crucially, learners move freely between the learning activities defined within the EFL, thus overcoming many of the issues raised regarding the Kolb model. Further to this, whilst the EFL is well aligned with a the constructivist agenda due to its emphasis upon experience, the activities associated with the abstract end of the EFL are relevant to the instructionist perspective, thus contributing to the general purpose nature of the EFL.

4 EM & Constructivism

Having broadly considered the instructionist and constructivist outlooks on learning, the immediate focus of this work now turns to consider the relationship between EM and constructivism. In particular, this consideration intends to broadly assess how well the EM philosophy and the process of the construal construction align with the overarching principles of constructivism.

4.1 Philosophical Orientation

In considering the relationship between the EM and the constructivist outlook it is helpful to appreciate the philosophical sympathies of EM, which find their roots in the Radical Empiricism of James (James, 1912). Specifically, Beynon relates EM to James' attitude by highlighting the emphasis which RE places upon the notion of "pure experience" and the suggestion that the nature of knowing can be expressed entirely in terms of experience and interpretation. Further to this, Beynon stresses that this view of experience should be considered more than just discrete sensory perceptions, suggesting that it must also incorporate relationships that are conjunctive in nature. Given this philosophical orientation, clear parallels with the constructivist outlook on learning may be drawn. In particular, the previously discussed emphasis upon the personal learning activities involved in the construction of individual representations and understanding is well aligned with the orientation of EM. In addition, the central role of experience in the constructivist outlook is consistent with that of EM, particularly in light of the previously discussed experiential learning interpretation of constructivism.

4.2 Construal Construction

The process of constructing construals which share a negotiated relationship with some referent is central to EM. These construals can be considered to be computer based learning artefacts that represent the current understanding, and hence ignorance, of the learner that constructed them. Knowing this it is reasonable to suppose that EM may be well aligned with the constructionist theory of learning, as both perspectives endorse the active construction of learning structures in a physical sense. In support of this supposed alignment with the constructionist interpretation of constructivism, the recent work by Beynon and Rowe highlights the potential of EM in a constructionist context (Beynon & Roe, 2004).

Aside from the emphasis that is placed upon the active construction of learning artefacts in line with the constructionist tradition, EM also gives priority to the virtues of learner exploration in construal construction. Further, this attribution means that whilst learners are actively constructing a construal, they can be considered to be negotiating meanings and attempting to make sense of afforded experiences and relationships that they do not yet understand. Again, the exploratory nature of the processes endorsed by EM would seem to align well with the constructivist agenda, as learners are actively engaged and almost solely responsible for directing the exploration. In fact, the nature of construal construction goes some way to unifying the roles of developer, learner and teacher, further safeguarding alignment with the constructivist ideal of realising learner directed experiences. In the context of the endogenous interpretations of constructivism discussed in this work, the exploratory nature of EM would seem particularly relevant. Specifically the construction and active experiment which are entailed in the development of a construal can lead directly to the concrete experiences and reflections which have already been identified as being crucial in conceptual development.

In addition to admitting priority to the virtues of learner exploration in the construction of construals, EM also acknowledges the significance of personal interpretation and experience in this process. Aside from the experiential issues previously raised in the context the philosophical attitude of RE, the prominence of experience and personal interpretation in EM can be perceived to manifest elsewhere when constructing construals. Specifically, the constructed construals them-

selves are always open to individual reinterpretation and extension. Indeed, in supporting this notion, Beynon and Harfield suggest that, apart from the potential association of experience, there is no reason why an EM artefact should be interpreted in any specific way (Beynon & Harfield, 2007). Once again, the subjective and potentially confusing nature of construal construction and interpretation chimes well with the aforementioned constructivist notion that individuals actively construct their own interpretation of reality, which themselves may be subject to chaos and confusion.

5 The NIM Modelling Study

To provide insight into the modelling activities which were responsible for motivating much of this work and to further illustrate the discussion of how the process of EM construal construction is broadly aligned with constructivist principles, what follows is an overview of the NIM modelling study. This overview contains an introduction to the game of NIM, a discussion of how the NIM model evolved throughout construction and the author's personal reflections upon the study.

5.1 Introduction to NIM

The game of NIM, which is thought to descend from an ancient Chinese game known as Jianshizi, is a two player game of strategy. The game begins with the creation of two or more non-empty piles of tokens. Following the creation of these piles the two players will take turns to remove one or more tokens from any one of the created piles. Typically, the winner of NIM is the player who is able to remove the final available token, though winning criteria frequently differ between variants. Interestingly, the game of NIM has feature in the work of Papert, who, in a manner not dissimilar to this work, recognised that its intricacies can present considerable challenges for learners (Papert & Solomon, NIM: A Game-Playing Program, 1970).

5.2 Understanding NIM

Although, the game of NIM has previously been solved for any specified number of piles and tokens, the associated mathematical proof is difficult to comprehend, especially if the intention is to derive an optimal playing strategy from it.

Prior to the undertaking of this modelling study, the author was aware of a single optimal strategy for the playing of NIM, which was principally based upon simple binary arithmetic. This strategy requires that the optimally playing player remove tokens from the correct pile so as to ensure that the binary sum of all pile sizes, ignoring positional overflow, is zero. This calculated sum is known as the NIM-sum and forms a mathematical basis for the aforementioned proof.

In initiating the NIM modelling study, the intention was to construct a construal which, like models such as King's Sudoku, reflected a set of supposedly well understood relationships (King, 2007). Crucially, some representation of the aforementioned simple playing strategy was to be incorporated, with the intention being that the construal could be contemplated in the context of how learners explore it in deriving any understanding. However, in the exploration that was motivated by the process of construal construction, it became apparent that it was possible to adhere to the same simple optimal strategy using less explicit methods. More specifically, the exploration led to the discovery of a simpler odd/even method, which simply involved checking the binary representation of each pile to ensure that the number of bits at a logical 1 for any given power of two was even.

Following the construction of an EM construal reflecting the author's understanding of the NIM game and the optimal strategies for playing it, research into the "discovered" playing strategy revealed that it was in fact a primitive interpretation of an previously established NIM playing strategy known as "sub-piles".

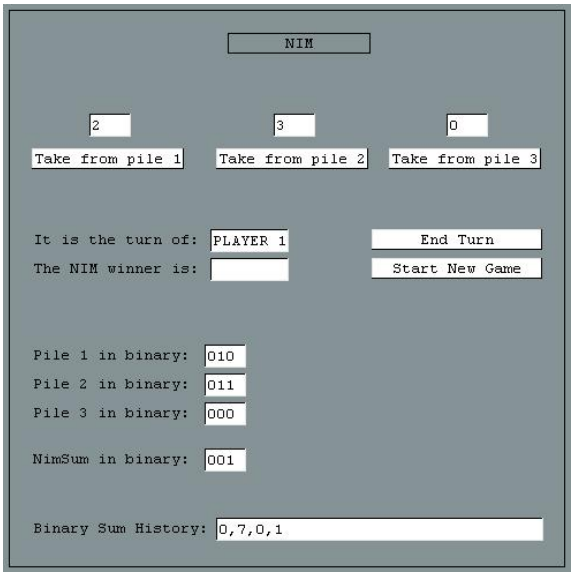

Figure 4 - The NIM Model

5.3 Reflecting on NIM

As previously stated, it was the original intention of the NIM modelling study to construct a construal which closely reflected a supposedly well understood set of observables, dependencies and observables. However the assumption that author genuinely understood these crucial elements was misplaced. Therefore, rather than serving as a model which illustrates the broad suitability of EM to the constructivist outlook, the NIM model serves to highlight how effectively the process of construal construction, which is a core activity of EM, aligns with the emphasis which the constructivist outlook places upon interpretation of experience and learner-directed exploration.

5.2 Future Work

The NIM model could be immediately extended in a number of directions. In particular, it would be interesting to incorporate colour cues into the model, perhaps using them to underline the odd/even strategy previously discussed. Also, the incorporation of a computer based player who adheres to an optimal playing strategy may enhance the model and serve as a basis for further work in experiential learning.

6 Conclusions

To conclude, this work has outlined and discussed both the instructionist and constructivist theories of learning, before proceeding to review two particularly relevant interpretations of the constructivist outlook. This work then to focused upon assessing how closely the process of EM construal construction is aligned with the broad constructivist viewpoint. Finally, the issues raised in this assessment were illustrated by the NIM modelling study, which itself served to highlight the potential of EM construal construction process for constructivist learning.

In the course of this work it had become apparent that the process of EM construal construction is well aligned with the broad and overarching principles of constructivism. Further, it would seem that construal construction is a particularly relevant activity in the context of endogenous interpretations of constructivism, perhaps because of the greater emphasis which the interpretations place upon active, self-directed exploration and physical construction. Finally, perhaps the most concrete contribution of this work is to verify that the construction of EM construals can facilitate sufficient understanding to allow for the identification of simple game playing strategies.

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