DopeWars:

An Activity Theoretic Analysis of a Constructionist Microworld.

Issues in ICT in Education

End of Module Assessment – FINAL DRAFT

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Introduction

DopeWars (DW) is a freely downloadable and hugely popular trading simulation computer game. Players act out the fantasy role of a drug dealer in modern day New York City, who has 30 'days' to make as much money as possible buying and selling a large selection of illegal narcotics, whilst paying off loan sharks and avoiding capture by the police.

> "This low tech but high fun game casts you as a debt ridden drug dealer - $2000 in your pocket, but $5500 in debt to a Loan Shark. The only way to get out of this debt trap is to make money by buying the available drugs and then moving to a new location and hoping the price moves up, or is driven up by market demands.
>
> Sounds simple? It is! Except, of course, there's a certain cop called Officer Hardass on your tail, and he's not too impressed with drug dealers. You'll have to buy weapons from the store to shoot it out with Hardass and his deputies, and you'll probably need to visit the hospital to heal your wounds."
>
> (http://www.dopewars.com/dopewars/info.asp 7.2.2001)

DW uses minimal graphics, consisting of a number of input and output text-based dialogues enclosed in a small window. It is single player, but an encrypted file is produced containing the players score, which can then be uploaded to a web site, (www.dopewars.com), for display and ranking in a single international league table.

This study describes the informal introduction, by the author, of this simple game to the Merrill Lynch equity dealing room in Farringdon, London, around the middle of 1999, whilst the author was an employee there. The dealing room is one of the largest in Europe and as to be expected, is a loud, fast-paced environment, consisting of approximately 100 brokers and dealers ('front-office') and another 50 assistants ('middle-office'), as well as a handful of business analysts and software developers (of which the author was one).

This paper will set out the rationale for introducing DW into this environment to a number of select employees – colleagues of the author. The implementation will then be analysed using different frameworks and the innovation will be evaluated with respect to the original aims set out in the rationale.

Rationale

Unlike many innovations involving the introduction of technology to an educational setting, the environment into which DW was placed was already computer-rich. Not only did broker-dealers have on average 2 powerful computers and 3-4 screens, middle office staff had at least one powerful PC each, with high-bandwidth internet and network connectivity, office productivity software and full technology support. Usage, resources, computer literacy and experience, therefore, was already very high, (almost to the extent of *too much* technology becoming a problem). The middle-office setting did lack business knowledge, however, though more in the sense of business issues, rather than the properties of the financial instruments. In particular, there was widespread, though unspoken, recognition that all would benefit from both the middle-office staff as well as the technology analysts and developers improving their grasp of the fundamental strategies, goals and constraints that the brokers and dealers faced daily.

It is interesting to note here, a parallel concern of the lack of understanding on the part of the front-office of the mathematical fundamentals of the instruments they traded. Although this was not openly a problem at Merrill Lynch, there was certainly an attitude that mathematics afforded a strong competitive advantage, especially with respect to the more complex instruments, like derivatives and portfolio 'basket' trading. This concern was reflected in an implementation of a LOGO-based graphical instrument-modelling environment in an investment bank for the very purpose of improving the mathematical understanding of the dealing room professionals (Noss & Hoyles, 1996, Ch. 10).

Whilst the environment enjoyed many resource benefits, it suffered from a major drawback, which was a lack of time. Middle office and technology staff faced great difficulty in setting aside time for organised training. There were a number of reasons for this. Traders pride themselves for their intuitive grasp of trading strategies. Often, though less so now, a dealer would come from a family background of street market stall traders, and his apprenticeship would include a period as a back-office clerk, progressing to a middle-office assistant and then being offered a 'desk' – a position as a member of a team of broker-dealers. Understanding dealing strategies would therefore be seen almost as 'in-the-blood', whilst the pragmatic skills and concrete product knowledge would be acquired informally whilst progressing up the hierarchy. Also, whilst it was generally accepted that more could be done to improve the middle office awareness of business issues, it was rarely articulated explicitly, since the implication would be that middle-office staff were somehow currently inadequate or failing in their roles. Further, market professionals are notorious for their short-term view and their short attention span. For the dealers and brokers to give their assistants time off to train formally would have been a long-term gain, but a short-term loss. The middle-office assistants on their part may have had difficulty acquiring a sound understanding of market fundamentals in a lengthy, structured lecture-based setting. These reasons conspired to sensitise middle-office staff to the issue of formal training and as a result it was rarely undertaken or even considered.

Prior to the introduction of DW, the author had successfully used it as an environment within which to model, construct and test different trading strategies. This had been carried out privately and was very much an individual activity, although knowledge of the DW game was widespread, at least among technologists[1]. Although initially drawn in by the deliberately fun and subversive character of the game, the author found that it represented a simple, though not too unrealistic model of a typical capital market. Among the features represented were opportunities for arbitrage[2], multiple markets, risk & uncertainty, demand and supply fluctuations, individual buying and

[1] The entire DW program was very small, easily communicated as an email attachment and easily installed, all of which contributed to its popularity.
[2] Arbitrage is the ability to exploit price differentials between markets by buying the same product in one market and selling in another, usually immediately, to realise a profit.

selling decisions, interest on loans & deposits, and scarcity. Features of the game not present in 'real-world' markets were limited stock holding capacity, inability to short sell[3], lack of multiple market views, lack of dividend payments[4], the inability to influence markets (with buying and selling decisions) and macro-economic effects.

In the author's attempts to 'beat' the market, an important and spontaneous[5] realisation was the need to mathematically model the movements of the market. A number of simple quantitative measures were taken, which became progressively more elaborate. Among the measures were 'daily' commodity prices and quantities, historical highs and lows, moving (and various other) averages and running totals of profit and loss and attempts were made to graph this data (in Excel). This was against a professional background acquainted with basic Technical Analysis[6]. This mathematical journey, (though hardly challenging for an accomplished mathematician, which the author is not), allowed me to develop and intuitively understand various trading strategies which would then be tested, the feedback being used to inform the mathematical model, in an iterative process toward greater complexity. Increasingly, DopeWars came to resemble a Constructionist 'microworld'.

Some of the more famous examples of microworlds are the environments created (and potentially creatable) within the LOGO programming tool. LOGO is computer language developed by Seymour Papert, in 1967, specifically suitable for children. Far from being (only) a toy, it was designed as a powerful tool providing "easy entry routes for nonmathematical beginners", (Papert, 1980, p.210)

LOGO was used to create microworlds, often with the intention of helping students learn mathematical ideas. For example, students would programme an object on the screen (known as a Turtle), using simple commands to draw lines and create any number of geometrical shapes. This was known as Turtle Geometry, (Papert, 1980, Ch. 3) and the intention was not only to acquire an understanding of mathematical principles through design, but to impart powerful problem solving skills in the process of design itself. Modularity, recursion, debugging, variables, heuristics and prototyping are skills and ideas often employed to design and build programs and by successfully manipulating the Turtle, Papert felt these problem solving elements would be learnt and possibly transferred[7] away from the microworld.

The notion of a microworld is somewhat fluid, being developed and applied over time by a world-wide community of LOGO practitioners and others in the fields of computing and education. Celia Hoyles calls microworlds "computational worlds

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[3] To short-sell is to sell a commodity or instrument that is not owned at the time of the sale, thereby locking in a price. The expectation is that the price will fall and the product can be bought on the market for the lower price before it has to be delivered, hence realising a profit.

[4] The lack of any kind of dividend or yield payments make the drugs traded much closer to commodity dealing than equity or bond trading. However, the general trading principles remain the same. From now on, the drugs will be referred to as commodities.

[5] The author is not claiming spontaneity *independent* of the surrounding cultural and historical milieu. The role of social and cultural factors will be discussed at length later in this paper.

[6] This is the attempt to predict market movements using (more complex) measures as described above and with various graphs and associated theories. This is contrasted with Fundamental Analysis, which looks at the financial statements of a company. In reality, both measures are used.

[7] Transferability of learning is a problematic issue (Noss & Hoyles, 1996, Ch. 3, pt.5).

where mathematical ideas are expressed and developed”, (Keitel, & Ruthven, 1993, Ch. 1) but adds that “…the very essence of these worlds is moulded and shaped by the discourses into which they are inserted…”

In fact, the notion of the microworld can be stretched beyond standard classroom mathematics (and perhaps beyond mathematics entirely). Papert’s example of the process of simple pairing of physical objects that a child goes through shows that the child is in a “self-constructed microworld” (of pairs). What is important is that the microworld is “stripped of complexity, simple, graspable…the child is allowed to play freely with its elements” (Papert, 1980, p. 162). Papert even describes the Turtle microworld simply as “…a self-contained world in which certain questions are relevant and others are not.” (Papert, 1980, p. 117). Clearly, there are degrees of narrowness, when attempting to define the essential characteristics of the notion of microworlds.

One definition that is particularly useful is that given by Noss and Hoyles:

> “Thus it retains an essentially Piagetian framework within which learning is regarded as a consequence of breakdowns – incidents where predicted outcomes are not experienced…Thus the development of a microworld involves predicting where these breakdowns might occur: at the core of the microworld there is therefore a model of a knowledge domain to be investigated by interaction with the software.”
> (Noss & Hoyles, 1996, p. 65)

Edwards, who provides a structural and functional view of microworlds, gives us another useful examination. The structural view is intended to “…distinguish a list of characteristics which seem to be common to all these [microworld] environments” (Edwards, 1995, p. 143 my brackets). It includes computational objects that reflect the structure of a subdomain, a linkage of more than one representation of the object, the ability to combine objects and goal(s) and activities. The functional view looks at how humans actually use and interact with the microworld. This list includes manipulating objects by executing operations, interpreting feedback to ‘debug’ one’s personal understanding of the underlying model and extending the microworld and solving problems/tasks (*ibid.* p. 143-144). Combining these views, we can model the major features of a microworld.

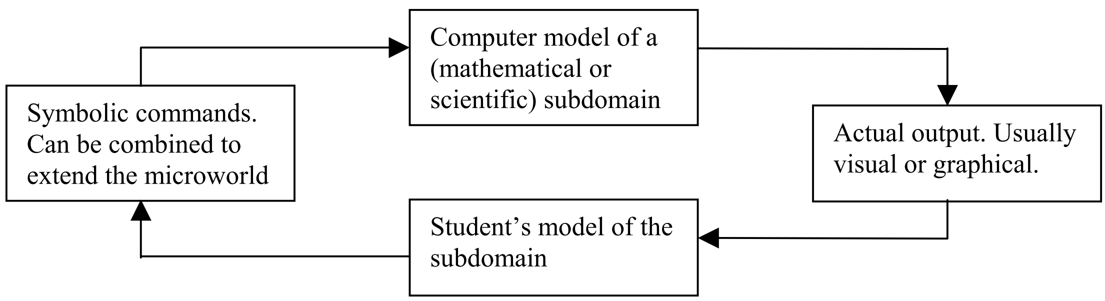

Figure 1 An iterative model of learning in a microworld environment

In this description of a microworld the computer model of the subdomain remains constant, while the student’s model is iteratively adjusted to minimise cognitive conflict - the difference between expected outcome (the result of the student’s model) and the actual outcome (the result of the computer's model). The user experiments with the computational object and generated graphical output by using a set of commands that are 'translated' by the computational model. This interaction has goals and it is by engaging in the pursuit of these goals that cognitive conflict occurs.

These descriptions helps us compare the notion of the 'classical' microworld with the simulation of DopeWars in order to highlight the similarities.

At the core of DW is an underlying mathematical model of the behaviour of (commodity) markets. Turtle geometry has a similar mathematical model in that users can only access this model using a transitional object (Papert, 1980, p. 161), and the object – the turtle - only understands commands. This model, (axioms for maths or "laws" for physics), is "implicit, waiting to be 'discovered' by the learner"(*ibid.* p. 131). These axioms and laws "…lie beneath the surface as far as the child's direct experience is concerned" (Groen and Kieran in Edwards, 1995, p.134). The DW player is not presented with an explicit set of equations describing the behaviour of the markets. DW provides an interface to the underlying model that accepts only certain commands which include Buy, Sell, Jet (move) and Select (commodity type and amount) allow the player to ask certain questions of the model. You cannot ask the DW model to RIGHT 30 or FORWARD 120 any more than you can ask Turtle geometry to Buy 3 (units of) Opium. Hence, DW has both an underlying model and a transitional object/interface, just as 'classical' microworlds do.

Microworlds are described as exploratory, but we need to unpack the idea of exploration if we are to draw any comparison with DW. It would be difficult to think of an activity being exploratory if there lacked an element of interactivity, whether computers are involved or not. Similar to the idea of interactivity is that of decision-making, either independently or collaboratively. Students need to make decisions when traversing pathways of knowledge otherwise it would be difficult to say that *they* are having the exploratory experience. Also, the pathways being traversed need to provide new information, rather than regurgitating what the explorer already knows. Finally, the ability to set goals seems relevant here as well. The explorer should be able to decide where he/she wants to go, as well as how they want to get there. This would seem essential for any sense of 'ownership' of the exploratory process.[8] Turtle geometry seems to promote this sense of exploration. It is interactive (the screen turtle, shapes and commands), it allows decision making (the choice between different commands and input parameters), it provides new experiences[9] (interesting shapes and even interesting errors!) and teacher permitting, it allows goal setting (deciding what *kind* of shape to draw, rather than *how* to draw it). Similarly, DW seems to exhibit this sense of exploration. It is interactive (the commands, quantities and descriptions), it allows decision making (what to buy, how much, where to travel to), it provides new experiences (the success or failure of various strategies) and allows goal setting (deciding what kind of strategy to employ, rather than how to execute the strategy). The kind of exploration experienced in

[8] This unpacking is hardly systematic, but is an initial attempt by the author and result of the difficulty of finding a relevant notion of 'exploratory'.

[9] This phenomenological richness is one important difference between Turtle geometry and other forms, as noted by diSessa (1987) in Keitel & Ruthven, 1993, p. 3

DopeWars is clearly structurally very similar to that of Turtle geometry and other microworlds.

One area where there is a structural difference between turtle geometry and DW is with the issue of extensibility. This is the ability to 'grow' the set of commands at ones disposal, by integrating old commands appropriately. The notions of programs, modularity, sub-procedures, user defined functions and object orientedness are all represented in programming. The implication is that the tool-set is never necessarily complete. One may consider the various strategies in DW as building blocks to a greater strategy, or one may view the fact that strategies are ultimately combinations of simple commands, but this analogy is between DW and 'classical' microworlds is certainly not as strong as the others.

The extensibility of LOGO requires the formalisation of the building blocks of 'larger' tools. Since the extensibility of DW is questionable, so is the formalisation. Extensibility requires an interface between the parts of the system and this interface needs to be formally specified (for example, using functions, function parameters and return values). Another way of putting this is that DW strategies are as formalisable as they are extensible and it would be difficult to make a strong case for the extensibility of DW strategies given the length of this paper. Indeed, the relationship between formalisability and extensibility has only been sketched here and certainly requires further exploration on the author's part before it can be used to imply characteristics of microworlds. We can perhaps only argue for a similar tendency towards greater complexity on the part of both turtle geometry commands and DW profit-seeking strategies.

As highlighted in the quote from Noss and Hoyles above, implicit in the notion of microworlds is the Piagetian belief that learning occurs as the result of breakdowns, or cognitive conflict. This is harnessed in turtle geometry by providing learners with rapid feedback demonstrating the success or failure of their programs in achieving what was desired, as well as the ability to investigate the source of the conflict further by engaging in 'bricolage' with the original program (Papert, 1980, p. 173). In DopeWars too, the player can easily experience the results of his/her strategy employed, both immediately by noting the profit or loss of each trade and at the end of every game by noting the overall profit or loss. In either case, the results of strategies are compared to expected outcomes and the strategies are easily modified.

This final comparison of cognitive conflict serves to highlight the theoretical underpinnings of microworlds in the constructionism of Papert and the earlier cognitive constructivism of Piaget.

One could characterise constructionism as "learning-by-making", but Papert warns us against such a superficial rendering of the theory (Papert & Harel, 1991, p.1). Papert points out the relationship between constructionism and constructivism[10], saying that the former shares the latter's notion of learning as "…'building knowledge structures' irrespective of the circumstances of learning." As Papert says:

[10] Here, constructivism is taken to refer to the *cognitive* constructivism of Piaget and others, as opposed to the *social* constructivism of Vygotsky et al., although the result *may* be the same if all forms of constructivism are used.

> "It (constructionism) then adds the idea that this (learning) happens especially felicitously in a context where the learner is consciously engaged in constructing a public[11] entity, whether it's a sand castle on the beach or a theory of the universe."
> (Papert & Harel, 1991, p. 1, my addition in parenthesis)

Papert makes a distinction in the claims of constructionism. The "weak" claim says that constructionism is better, for some students, than other ways of learning and the "strong" claim says that it is better than instructionist methods of learning, period. However, Papert's position is that science has not yet been able to show us the "best way" of learning, and may not be able to for a long time. (Papert & Harel, 1991, p.2).

Papert thus proposes an alternative to this "pipeline" model of transmitting knowledge, that is, instructionism. Constructionism develops and integrates a number of ideas. One of them is, as mentioned, learning-by-making. This allows students to direct their own goals and to "…think, to dream, to gaze, to get a new idea and try it and drop it or persist, time to talk, to see other peoples work and their reaction to yours…" (*ibid.*). This, Papert called 'soap-culture math', after the inspiration he received from an art class sculpting figures from soapstone. It is a partnership between science and fantasy, between math and art. "What is important is the vision being pursued and the questions being asked." (Papert & Harel, 1991, p.3).

Another idea important to constructionism revolves around the organisation of the work being undertaken. It is an issue of style. Some students prefer a top-down style (instructionist, abstract, propositional) and others a bottom up style (constructionist, bricolage, reification). Throughout, there is a negotiation between the creator (bricoleur) and the creation, between the "programmer and the work in progress." (*ibid.*).

This distinction between constructionism and (traditional school) instructionism has its basis in epistemology. Epistemological Pluralism is the theory put forward by Papert, Sherry Turkle, Harel and others, which aims to challenge traditional, instructionist notions of the nature of knowledge and of knowing, by taking it's lead from studying sources such as feminism, computer cultures and the ethnography of laboratory practice. It favours allowing people to think in their own ways.

We can see then, that DopeWars is a good example of a microworld. The author had good reason to believe that, as a constructionist learning environment, DW offered itself as a theoretically justified tool to help students acquire an intuitive and thorough understanding of what is usually approached in a formal, abstract and ultimately ineffective manner.

Implementation

[11] The author takes the use of the word "public" to mean *mediated* in some way, perhaps on a computer screen, intelligent LEGO bricks or even a CMC environment, as opposed to expression taking place only in the mind.

In the implementation, we are concerned with describing the actual context participants and activities engaged in, both how they began and how they developed over time.

A useful way to approach the analysis of the DopeWars implementation is to utilise Activity theory. Activity theory is useful because it allows us to paint a rich picture of the context of the educational setting. In actual fact, we will be concentrating on a specific subset[12] of the theory – a model of the hierarchy of the activities, the process of internalising knowledge and the role of mediation of mental and cultural tools. Whilst investigating internalisation, we will develop the notion of the microworld and its setting on the trading floor, as a Zone of Proximal Development (ZPD).

Activity theory (AT) is based on the work of Vygotsky in the Soviet Union earlier in the twentieth century. It was developed and extended by Leont'ev, into what is known as 'second generation' activity theory to take account of the separation between individual and collective activity. I will be using the methodology presented by Jonassen and Rohrer-Murphy, which sets out a six step approach to the activity theoretic analysis (Jonassen & Rohrer-Murphy, 1999). The six steps are to clarify the purpose of the activity system, to analyse the activity system, to analyse the activity structure, to analyse the tools and mediators, to analyse the context and lastly, to analyse the activity system dynamics. It would be helpful to present the framework upon which this methodology is based, below.

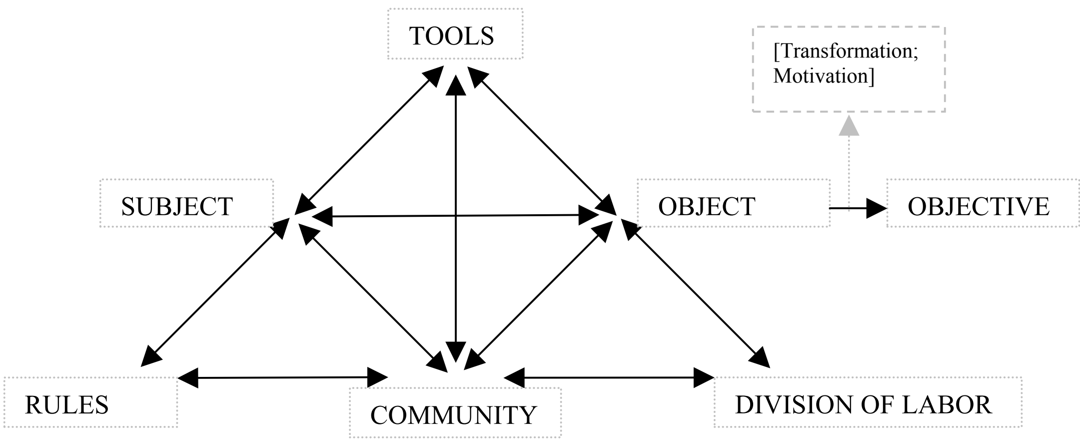

Figure 2 The framework of Activity Theory

And, the hierarchical conception of activity:

Level		**Driver**
Activity	→	Motive/Objective
Action	→	Goals
Operation	→	Condition

To clarify the purpose of the activity system, we need to look at the motives and goals of the participants. The transformation sought by the middle-office staff was an

[12] It seems a very particular notion of consciousness is being used here. It would be difficult to see how an idea of consciousness as an immaterial substance could be sustained along with Activity Theory. Also, object-orientedness is not taken to mean that, objects exist in an objective world independently of human thought and existence, (for example, John Locke's 'natural kinds', or Platonic 'Forms'), but rather that an object is given meaning, by culture and society, prior to an individual's experience of it.

intuitive understanding of trading strategies. This was both because of a desire to perhaps one-day ‘progress’ on the desk as a broker-dealer, but more immediately, to minimise the risk of missing errors, caused by dealers, in the paperwork that an untrained eye would not catch. A lesser motive was an attempt to alleviate periods of boredom. The workload of the middle-office staff depended entirely on the level of activity of the dealers and brokers. There would be periods of intense activity interspersed with relatively quiet phases.

Analysing the activity system requires us to define the subject, the relevant communities and the object of the activity. The subjects were the middle-office staff playing the DW game. There were three main players, two of whom expected to progress on to the trading desk in the medium term, either as brokers or as dealers. There was little, if any, division of labour, yet there was interaction, in the form of both competition and cooperation; helping each other along only made the competition more interesting. The community included the main middle-office subjects, the author and the trading desk broker-dealers. Their primary object was to understand trading strategies. This would take the form not of an explicit quantitative exposition of either the market behaviour[13] or the instruments traded, but an intuitive grasp of the strategies designed to maximise profit, (rather than minimise risk), and a language that could be used between the players to communicate their thoughts.

To analyse the activity structure over time, we need to define the activity and decompose it into its component actions and operations (Jonassen & Rohrer-Murphy, 1999, p.74). The activities started by the subjects familiarising themselves with the software. Buying, moving between markets, selling, watching for profit or loss and thinking and discussing about random market conditions were all difficult tasks initially. When these commands were (somewhat) mastered, after about half an hour of playing, the subjects attempted to see if they could deliberately try and make a profit. Initial theories were developed regarding the types of commodities the players should pursue, whether to run or hide from the law and whether to borrow more from the loan shark or repay ones debt immediately. At this point, the players were still exploring the game and its features, to see if they could find patterns. The development and testing of simple, rudimentary theories were the main *activity* of this stage, whilst the *actions* consisted of the buying, selling, watching indicators and discussing findings. This period lasted for approximately 10 hours of playing time, over 1 week. Finally, through a process of Piagetian cognitive conflict, the players found some theories to be useful and others not so helpful. They were, at this point very confident of being able to challenge some of the higher scores posted on the DW website, at least given a little more practice. They were familiar with market movements (even though they were still random), pinned down the most productive buying and selling strategies, realised how to react to the law (again, based on random, average outcomes) and how to deal with borrowing and saving from the loan shark and the bank. The activity here was the attempt to maximise profit over the period of a number of ‘days’ and the action goal was to optimise every trade and interaction with the ‘law’ and the loan shark. The operational conditions were the basic commands of buying, selling as well as discussing outcomes. Also included as conditions throughout the move from activity motivation to action goals to operation, are the constraints of the staff’s short attention span (due to surrounding events

[13] Possibly in the form of statistical data and operations on this data, for example various averages.

competing for attention), avoiding the broker-dealer's attention (due to their short-termist view on training as discussed above) and a minimised impact on time (due to alternative activities competing for time).

To analyse the mediators, we need to consider the tools and rules available to the subjects. The primary tool used by the subjects was the DopeWars game itself. This included the interface, consisting of the textual and numerical descriptions of situations. Graphics were not a feature of the game, although this 'feature' could be seen as a tool, in that it reduced visual complexity and lowered the initial learning curve. A language was developed to mediate the theories and observations on the part of the subjects. This language was derived mostly from the game, although the subjects affinity with the jargon of the trading floor may have contributed, or at least lowered resistance to expressing ideas. Another tool at the disposal of the subjects but little used was an Excel spreadsheet. It is not known if the spreadsheet was used to keep track of the success of particular strategies, but the subjects certainly did not use the tool to model the market behaviour. The rules of interaction between the subjects included communicating successful trading strategies with each other in a language related directly to the game (that is, not too abstract). Another rule was to try to not make it obvious to the trading desk members that the main players were spending a substantial part of their time playing the game, and also to not try to beat each other unfairly.

The context is spread across the subject and the community, or the internal and the external and we need to look at both when analysing context. The subjects believed that there was a good chance of moving from middle-office to the front office in a broker-dealer capacity. They did not believe they would be in the role of either a quantitative or research analyst with it's associated emphasis on mathematics and financial accounting. Rather, the requirement would be to learn and apply successful trading strategies at the earliest opportunity. The most important members of the community, at least for the subjects, were the brokers and dealers on the trading desk to which they were assigned. These front-office staff had various requirements, the most urgent and important of which was to maximise profits. This would require new entrants in to their work group to be fast learners and to have an 'intuitive' understanding of market fundamentals. They also required the middle-office staff to be on constant standby and to spot any errors in the paperwork.

Finally, in analysing the dynamics of the activity system, we need to consider the relationships between the components of the system – whether they contradict, how formal they are and how they have changed over time. We have seen that there are contradictions between the realisation of the need for training and the unwillingness to articulate this need and between a requirement to maximise profits, minimise risks and errors and an unwillingness to allow the middle-office staff time off to train either formally or informally. The relationships between the front and middle office staff are superficially quite informal. Lively banter, jokes and general small talk serve to integrate front and middle office into a tightly knit team. However, at a deeper level, the relationship is extremely formal. Each member of the front office has a large degree of power over the middle office staff and this power is accepted by all involved. The author had a more informal relationship with both middle and front office. Soon after the implementation of DopeWars, the expectations of the middle-office staff subjects were realised when first one member was requested to join a team of brokers in Tokyo and another was asked to join the desk in London as a junior dealer. The third returned to South Africa and decided to pursue a career outside Merrill Lynch and investment banking altogether[14].

Having conducted the analysis, we are now able to model the activity at a fairly high level:

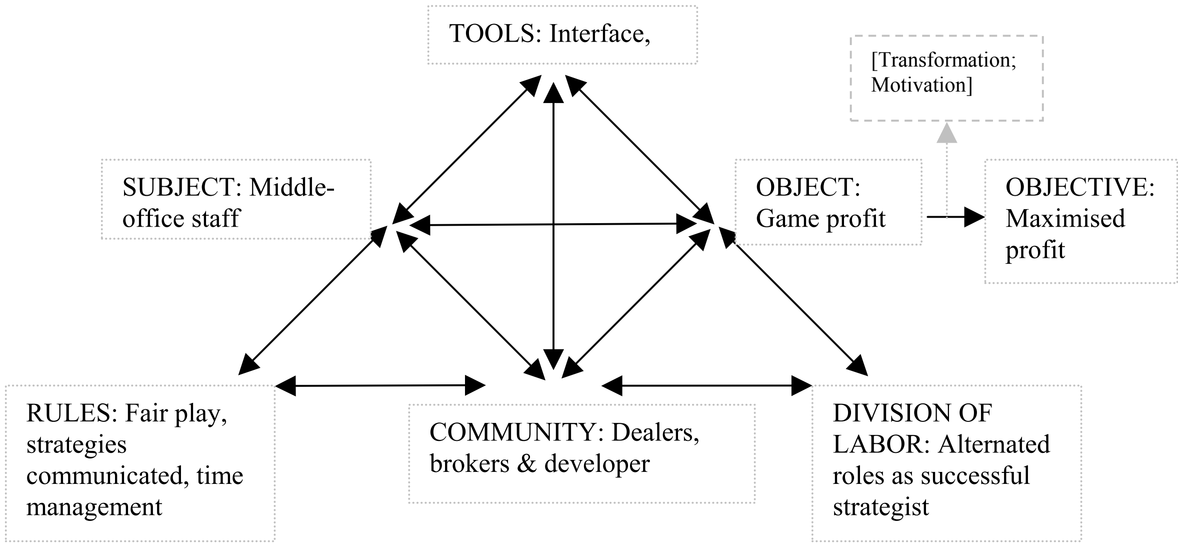

Figure 3 A high-level model of the activity

And the hierarchy of activity:

Level		**Driver**		**Eventual Result**
Activity	→	Motive/Objective	→	Maximise profit
Action	→	Goals	→	Optimise every trade
Operation	→	Condition	→	Commands of buying, selling & moving. Discuss outcomes. Short attention span. Avoiding broker-dealer's attention. Minimal time impact.

Whilst this analysis was useful in drawing out contextual features of the situation, we still need to explore the process of Internalisation. Internalisation is an important principle of activity theory. It is the means by which mental processes are derived from external actions. The learning process 'translates' inter-subjective mental processes into intra-subjective ones, in the Zone of Proximal Development (ZPD), which provides the means to the end of Internalisation (Wells, G. p.320). Vygotsky defines the ZPD as:

> "…the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers."

[14] Interestingly, he was the most 'highly' educated of the three, having received a degree in economics from a respected university.

(Vygotsky, L. S., 1978, p.86)

The ZPD thus proposes that development and learning are facilitated by and dependent on social interaction mediated by various tools. In the activity analysis given above, we saw that the subjects made use of a couple of important tools – the interface of the software and language. The interface (textual and numerical symbols) was the mediator between the subject and the software designer – the individual who modelled the behaviour of the markets, and spoken language was the mediator between the subjects (players) as they collaborated with each other. The activity-related social interaction between subjects and between subject and game designer is the intermental plane within which discourse practices are first encountered and then constructed on the subject's intramental plane (Wells, G., 1999, p.319).

The subject's interaction in activity need not only be with teachers (or in this case instructional designers), according to Vygotsky, but also with his or her peers (Vygotsky, 1978, p.90) and these peers need not *always* be more capable. Activities are composed of component tasks and different peers can be better at different tasks allowing them to act as instructors some of the time and learners at other times (Mercer, 1995, p.75). This peer-to-peer instruction represents a form of scaffolding on two levels. Firstly, even though an instructional communicative interaction may only last a couple of minutes it is a form of scaffolding in that the instructor-peer would become less engaged the more the learner-peer seemed to understand and vice versa. Secondly, the level of instructive interactivity (whoever was playing the role of instructor) decreased over time, as what was once an activity for the subjects became first an action then an operation. In other words, the more the subjects mastered the activity and the more they realised their objectives, the less need there was for peer-to-peer instructional interaction[15].

So by using the ZPD, we are able to see how the subjects learnt the various successful trading strategies. The environment of assessment, mediation and scaffolding depended on the activity system outlined earlier in order to facilitate the internalisation of knowledge about trading strategy and profit maximising.

Evaluation

The rationale for the DopeWars game was that it was a constructionist microworld. As such, it was expected to encourage deep exploration of the subject matter and acquisition of powerful mathematical insights.

What was achieved in the implementation was something quite different. The players did get a powerful intuitive understanding of trading strategies and market behaviour, but they did not delve into the mathematics of market models, contrary to expectations. Instead, they developed a way of communicating their ideas amongst themselves. They explored language as a tool to express their thoughts, theories and observations and they accepted (perhaps implicitly) certain rules to their interaction.

[15] It would be interesting to look closer at both the tasks that different peers mastered at different rates and the actual conversational content and levels that was generated between the subjects.

The reasons for this divergence were found when we took a closer look at the activity system within which the players were operating.

Firstly, the players' objective was not aimed at acquiring an understanding of the underlying mathematics of the game (except for the most superficial, e.g. general price trends). The players were middle-office staff expecting (and working) to move at some point on to the trading desk as a broker or a dealer. These roles placed far greater emphasis on understanding trading strategies, as opposed to quantitative and research analysts, who prized mathematical understanding far more.

Secondly, the players would be expected to abide by certain rules if and when they joined their colleagues on the desk. These rules include discussing ideas and observations among team members, abiding by ideals of fair play, (for example returning favours, allowing time to understand and experiment), and not misleading other team members. Following these rules generates trust among the desk members and they value this trust at a huge premium. It is not surprising therefore that the DopeWars players followed similar rules when engaged in their activity.

Thirdly, the players were operating under certain constraints that were not accounted for in the idealised rationale of the constructionist microworld. They had constant distractions, an atmosphere not conducive to long-term training investment and highly irregular time slots within which to pursue this activity. These operational conditions meant that certain features of the microworld were more important than others. The bizarre premise of the game – that of being an underworld drug dealer in a modern, gritty New York City – and the ease of use and playability ensured that the players were able to give long periods of attention to the game and were motivated enough to continue with playing it. The simple, nondescript, almost business-like textual and numerical interface helped to minimise the attention the game received from the brokers and dealers (especially important considering their proximity). Also, the operationally flat learning curve (very few commands to learn) and highly repetitive (though pseudo-random) gameplay meant the players activity could be interrupted quite often without any serious impact on either the motivation to continue playing or the quality of the subject's performance.

Conclusion

By using Activity Theory to analyse the context within which the DW game was implemented, we were able to uncover a much richer description of the environment and associated issues than would have been afforded by viewing the game as only a constructionist microworld. We were able to see exactly why the participant's did not conform to what was expected – their activity objectives, action goals and operational conditions were very different to the idealised scenario in which the author explored the game. Hence Activity Theory has proven to be a useful tool for analysing the context of the educational setting.

Looking at the game as a (non-classical) microworld allowed us to generate a powerful rationale for a useful technological innovation in a demanding educational setting. But as we have seen, the DW game was not used wholly as planned and this divergence was evaluated to judge whether the game achieved the goals set forth in the rationale.

Whilst the innovation did not fully achieve the targets set for it, we can see that firstly, the targets themselves were perhaps the result of narrow, idealistic thinking and secondly, the implementation yields important lessons for the design of constructionist microworlds.

The notion of a microworld needs to evolve beyond it's current 'classical' form, to incorporate new, more radical features (for example, subversion is almost always motivating for young students!) whilst remembering that heavy graphics and visuals are not always required to improve gameplay and 'immerse' the student into exploring the world's underlying model (see Appendix A screen-shot). Microworlds also need to account for some radically different educational settings if they are to maximise their potential as learning tool. A greater emphasis needs to be placed on collaborative, communicative tools to allow for effective teamwork in ways that realistically simulate and model various praxes. A recognition of this is perhaps what lies behind the recent release of DopeWars version 2.0,with its use of web-based messaging (message other dealers, form and join cartels and leagues) to move the gameplay activity more towards collective activity, rather than individualised collaboration without any division of labour and specialisation. Interestingly, another new feature of the game includes an inbuilt ability to track the price history of various commodities, similar to what this paper's author did manually with Excel.

It would prove very interesting to analyse a group of players using the new version of DopeWars to see just how these new communicative features contribute to greater collectivisation and if this improves any learning that takes place.

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Appendix A

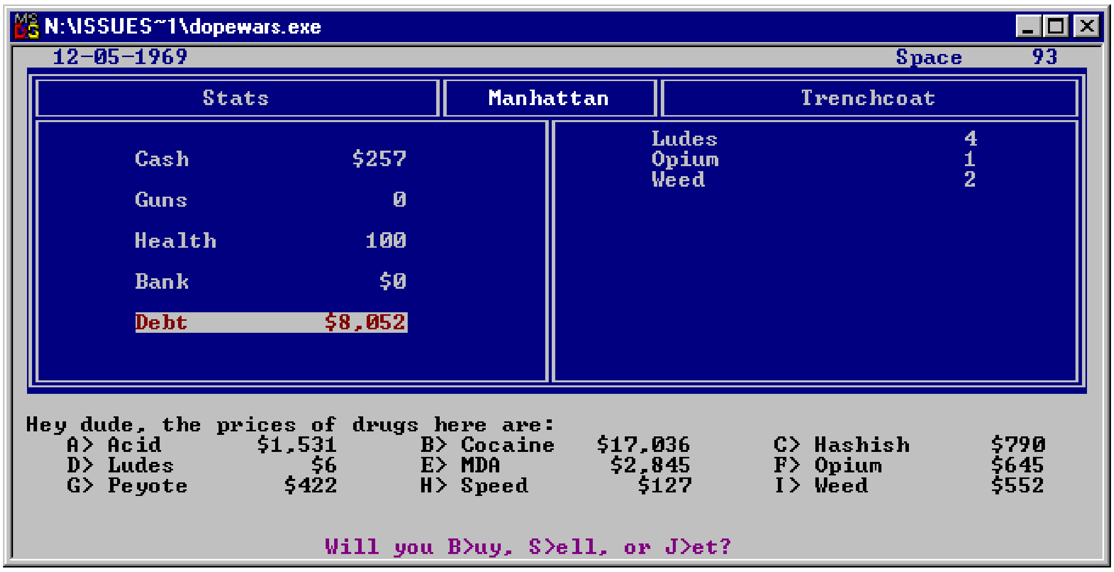

Figure 4 A screen displaying the drugs for sale, what I have bought and my financial situation

Figure 5 A screen displaying the option to move between different markets