# Simulating Design in the World of Industry and Commerce: Observations from a Series of Case Studies in the United Kingdom

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## Introduction

A requirement of the United Kingdom's National Curriculum is that all children gain economic and industrial understanding through aspects of the subject Design and technology (DES, 1990). To some extent, visits to industry, visiting speakers, work placements and simulations answer this requirement, but each has limitations. While a good teacher will use a variety of teaching techniques, the costs of visits and placements are high, so simulation offers an apparent cost effective technique.

The author's experience visiting many schools in the UK indicates that few teachers appear to use simulation or realize the potential of the technique. This observation formed the start point for this inquiry which focused on a type of simulation in which small teams of children simulate companies designing and making products for the market place. An illuminative paradigm (Parlett & Hamilton, 1983) was considered appropriate initially, using unfocused observation, informal interviews with pupils and teachers and, in some cases, Nominal Group Technique (Lomax & McLeman, 1984; O'Neil & Jackson, 1983). These techniques allow categories of factors to emerge as the study proceeds rather than having observers report on the frequency of factors which the researchers have decided to focus upon. On the negative side, such techniques do not allow accurate quantification of data and reliability can only be established when a category or factor emerges repeatedly over many different cases and via different observers. However, signposts for further, more focused research can be established.

There were two broad goals of this study: 1) a fuller understanding of these simulations, (allowing more focused subsequent enquiry); and 2) the subsequent dissemination of this understanding to teachers. The inquiry has illuminated some of the advantages and limitations of this approach to simulation. It has also shown that there is a place for unfocused observation as

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a technique in beginning to understand learning in “live” situations, where variables cannot be fully defined or controlled. A number of findings have arisen which would not have been uncovered if observers had operated focused schedules of observation.

## A Review of the Literature

*Simulation*

Rediffusion (1986 section 1.3) stated that “Simulation, as used in training, is a dynamic representation of a system, process or task.” The term “dynamic” is important. Participants interact with the simulation and each other. Roebuck (1978, p. 107) reinforced this point describing simulations as: “...organizational devices for arranging interactions.” At the core of simulations, therefore, are a model (the “representation” in the Rediffusion definition) and the interaction of participants with that model and with each other.

The range and application of models used in designing has been described by Evans (1992) and Tovey (1986). Designers use models to accelerate and develop their thinking on a task; for example, a model of the systems in a dump truck. When a similar model is used to teach people how these systems interact by allowing them to work directly with it, it becomes a simulation. The simulation model does not have to be physical. It could be computer based, verbal, or written description.

Turning to interaction, Jones (1989) stated that participants should operate with autonomy within the simulation. Participants should be allowed to make their own mistakes; the iterative nature of the simulation should then be used to identify these and allow the participant to rehearse new strategies. The teacher's role, therefore, is threefold: establishing the “environment” of the simulation; monitoring the simulation in action; and assisting with de-briefing to maximize learning (Dawson, 1990; Glandon, 1978; Perry & Euler 1988; Rediffusion, 1986; Shirts, 1976; Thatcher, 1986).

Simulations are often confused with academic games which are: “...contests usually amongst player opponents operating under rules to gain an objective” (Adams, 1977, p. 39). The important difference is the rigidity of the rules. Jones (1990, p. 355) considered games to be “...closed systems in which the rules are self contained and self justifying.” In a simulation there may be rules or a general description of the principles by which the model operates. These are not rigid rules but may operate dynamically. A game is a closed system with specific objectives; a simulation is open. The objective of a simulation is one of assisting participants to learn from the experience and to be able to transfer that learning to a real world context.

*Simulations in relation to teaching and learning*

Some workers have pointed out that simulations are less effective for teaching factual knowledge than other techniques of teaching and learning (Jones, 1990; Percival, 1978). The main advantages are in exercising and reinforcing previously learned knowledge. For example a pilot uses a flight simulator to practice “textbook learning” of how to react to emergencies. In simulations exercising personal interactions, Shirts (1975) pointed out that the simulation designer should work from a “general intent” rather than attempt learning of a specific knowledge base. Having said this, it is possible to embed more conventional learning within the context of a simulation. For example, a teacher may interrupt a simulation to teach concepts or skills which emerge as being necessary at a particular point.

The key to what must necessarily be a brief survey of simulation in relation to teaching and learning is the concept of transferability of learning from the simulation to other contexts. Putnam (1987) and Voss (1987) have shown that transfer will be weak or non-existent unless teachers use various techniques to assist pupils in this respect (Adey, 1990; Klauer, 1989). These are discussed below.

An essential, though not unique, feature of simulation is a cycle of briefing, activity, and debriefing. Simulations can be flexible, enabling the teacher to start with a short cycle based on a very simple model and through a series of iterations assist pupils build confidence (Adams, 1977). This ties with cyclical models of learning such as Hampden-Turner's (1986). Perry and Euler (1988) pointed out that the iterative nature of simulations help pupils recognize the relevance of their work and Megarry (1976) showed how learning improves once learners recognize the importance of the work. Thatcher (1986) pointed out that at de-briefings, the teacher should encourage learners to be active in analyzing their reaction to the simulation. A teacher-imposed de-brief was of far less value.

Simulation texts often use the term “fidelity” in discussing the degree to which a simulation represents real life (Rediffusion, 1986). Evans and Sculli (1984) showed that the learning benefits from a simulation are not related to high levels of fidelity. Boreham (1985) showed that learning transfer may be improved by lower fidelity as this removed peripheral factors and helped the learner to concentrate on central factors. After several iterations, however, increased fidelity may improve the learner's confidence in that context.

Percival (1978) reported that simulation appeared to improve motivation in children and particularly for those of lower intellectual ability. Lower levels of fidelity in simulation models may be a key to this. Evans and Sculli (1984) showed that competition can have a motivational effect within simulations. This, however, diminished if the levels of competition were allowed to develop. What levels of competition are most effective in raising motivation appear to be highly problematical to predict. It could be expected that the reaction to a competitive situation will be individual and the overall effects in a class complex.

One feature often used in simulations is that of extended periods of time totally focused on the simulation rather than pupils following a conventional timetable. Lindsay (1988) pointed out the time wasted in a conventional timetable due to stopping, starting, and the need to constantly re-focus pupils' direction. Grimes and Niss (1989) and Parlett and King (1970) showed that "concentrated time," rather than conventional time tabling, developed higher levels of motivation and that levels of learning were at least as good as learning the same material within a conventional timetable.

## Research Design

This inquiry used a series of ten case studies of simulations. The general aim was an increased understanding of this type of work. More specifically, it was intended to discover more about childrens' reactions to this form of work; to identify the limitations of the approach and to build an understanding of how such simulations should be planned and executed for maximum effectiveness.

All case studies were "live" in that the teachers involved had their own teaching and learning objectives; the inquiry had to fit around these. It was necessary to be eclectic in data collection methods whilst ensuring that the general principles of data triangulation (Cohen and Manion, 1980) were followed. The methods used are described below and in Table 1.

### *Observation*

Direct participant and non-participant observation were used in all cases. The reflexive limitations of observation were reduced by triangulation (Cohen & Manion 1980) in time, investigator, and location. Time, in that the case studies covered a period of three years. Investigator, in that there were observations from the author, teachers and other researchers. Location, in that contexts and events were studied in different geographical and social areas, both within schools and on a residential course.

Observation was open-ended. Observers were briefed to note anything of interest but particularly to evaluate the effectiveness of the simulations in relation to their planning and execution, the response of the children, and any difficulties which arose. Normally, observers compared notes at meetings immediately after each session. These meetings allowed free discussion, helping observers to recollect any points they may have witnessed but been unable to note. Multiple observers helped to limit the problems of idiosyncratic observation.

The advantage of such open-ended observation is that it may identify factors which the researcher has not identified prior to the exercise. The disadvantage is that it prevents a reliable measure of numbers of incidence.

Such an approach has value in the initial study of such situations. The results can be used to identify more focused questions for further research.

*Interview*

During any case study there were episodes where observers moved in and held informal, open-ended interviews with individuals or teams. These interviews were used to clarify points raised by observation and as such did not use an interview schedule. Data took the same form as the observations; written notes which reported the meaning of the interview rather than verbatim transcripts.

A variation on the interview was the group report back session used in case study 3. Here a group of 25 teachers from 6 schools reported back on innovation in their own schools based upon the training course conducted by the author. The author was able to question these teachers in order to clarify any points from their presentations.

*Nominal Group Technique (NGT)*

NGT is a form of group brain-storming technique used to evaluate learning programs (Lomax & McLeman, 1984; O'Neil & Jackson, 1983). It was used to gather data in case studies one, two, and five with sample sizes of nine, nineteen, and eighty respectively. NGT differs from group discussion techniques in that interaction is restricted to prevent associated problems, such as minority /majority opinion (Levine & Russo, 1987). Nevertheless, the technique seeks to capitalize on the potential of group discussion.

Group(s) were established with a maximum membership of 18. Scribes were appointed and each group asked to evaluate the simulation they had just had. Anonymity was assured. Members were allowed ten minutes to note their own responses. Discussion was not allowed so that dominant personalities were prevented from imposing directions. Each member then read out their first five responses in turn. Once all had listed five, the process was repeated, with members listing their next five and so on. Members could use the points raised by others to develop their own thinking and adding to their list. When there were no new points to add, members could ask for clarification of any points. No criticism was allowed. The scribe then consolidated the list with the agreement of members. This was done to reduce the list to a series of statements with which one could agree or disagree. Members then responded with a number weighting from 1(disagree or of low importance), to 5 (strongly agree or of high importance).

The data gained were entered in a spreadsheet where the mean weighting and standard deviation were calculated for each statement. The results appear to be quantitative but the reader should remember they are qualitative observations from multiple participants and observers. The number and standard deviation allow judgment on the strength of feeling for a statement. The detailed results and initial analysis are beyond the scope of this paper and can be found in Denton (1992).

**Reduction and Analysis of Data**

All data generated was in the form of written notes or statements. These were reduced to the minimum number of words without losing the meaning. Lists were then produced which could be scrutinized for emerging categories; a very basic form of factor analysis. These categories, for example observations or NGT responses which referred to perceived increased levels of student motivation, could be given a degree of reliability (non-numerical) by the frequency with which they were made and the degree to which they triangulated by being made by different observers and different methods. NGT results were more straightforward, producing numerical weightings of participants' agreement /disagreement with each statement.

This process was done separately for each case study. It was then possible to compare data across the ten case studies. If specific observations from different case studies aligned then a degree of reliability was established, differences lowered any reliability. From this process emerged categories of observation which had some reliability in the contexts of the case studies. As the results generated are necessarily verbal descriptions and lengthy it is inappropriate to follow convention and list all results before discussion. The basic categories established are, therefore, reported and discussed point by point.

**Treatment in the case studies**

There were ten independent studies. These are summarized diagrammatically below. The simulations varied from hours to five days. In some cases, the simulations were run in normal lessons over a period of weeks. In others, the timetable was suspended and the event run over periods of up to five days of concentrated time. Despite the differences all followed a general model. Pupils were placed into teams of 3 to 7. These were selected on the basis of mixed ability, gender and ethnicity. This was done to achieve broad based teams without natural peer groups. A task was set: a response to a design opportunity such as the production of prototype meals and packaging for inter-city buses.

Each team was a "company," developing the product and launching it on the market at a trade exhibition. The product had to be designed and developed, including cost. A simplified business plan had to be established, point of sale advertising developed and a sales display set up. A deadline was given, usually the last morning. Demonstrations ("inputs") were given at specific times, but could be attended by only one member from each team. This member was responsible for gathering information which had to be communicated to the team. At the start of each working session a briefing was held. This reminded teams of the key events of the session and raised observations on performance in any previous session within the simulation. A debriefing was held at the end of each day, or working session, in which pupils evaluated the experience up to that time.

**Table 1**
*A Summary of Case Studies*

| Case Study | Average Age | Number in Sample | Timetable or Dedicated | Residential or in School | Time | Evaluation method |
|---|---|---|---|---|---|---|
| 1 | 17 yrs | 9 | timetable | school | 2 hrs | teacher & researcher observations, NGT |
| 2 | 12 yrs | 19 | timetable | school | 10 wks at 90 mins per | teacher & researcher observations, NGT |
| 3a | 12 yrs | 25 | dedicated | school | 1 day | teacher observations |
| 3b | 15 yrs | 50 | timetable | school | 8 wks at 35 mins | teacher observations |
| 3c | 14 yrs | 100 | timetable | school | 4 wks in timetable + 1 day | teacher observations |
| 3d | 13 yrs | 100 | pilot in TT + 1 day dedicated | school | 4 wks in timetable + 1 day | teacher observations |
| 3e | 17 yrs | 50+ | dedicated | school | 2 days | teacher observations |
| 3f | 12 yrs | 100 | dedicated | school | 2 days | teacher observations |
| 4 | 15 yrs | 60 | primed in timetable + 5 days dedicated | school | 5 days | teacher observations researcher interview |
| 5 | 17 yrs | 80 | dedicated | residential | 5 days | teacher & researcher observations, observations from visiting researchers, team-work profiles, NGT |

On the final session, “trade displays” were set up and a simulated “market place” held. For this teams took the role of buyers, having a purchasing power of £1000. This had to be spent using criteria that the buyers felt were important. The financial position for each company was established on the basis of orders placed. In parallel staff prepared written feedback on the design work. Their assessment focused on the team product rather than trying to identify the work of the individual. A final debrief was held. These opened a great many points for discussion.

## Results: Categories and Discussion

The nature of the data and the categories established are necessarily qualitative. To follow convention and report the results fully followed by discussion would mean much repetition. The categories are, therefore, defined and described below with an immediate discussion.

### *Pupil Motivation*

All teachers in the studies reported that they observed an increase in pupil "motivation" over that they would expect for "normal" design and technology work in their school. Discussion with teachers enabled an agreed working definition of "motivation" as the level of purpose and energy demonstrated by pupils in relation to their work. These observations were by teachers who normally worked with the pupils, therefore the level reported was a simple comparison and not an objective measure. However, when each of thirty teachers involved with the case studies reported a perceived increase in level of pupil motivation, some degree of reliability is gained even if it is not possible to put a numerical measure to it. This was particularly noticeable in the case of pupils teachers felt were normally less motivated and less intellectually able. This confirms the findings of Percival (1978) who, in a literature survey, claimed evidence that simulation may boost motivation and that simulation may have a marginally more positive effect on the motivation of "less able" pupils. Adams (1977), writing on simulation games, also considered that participant motivation is increased.

The increase in motivation may be largely due to novelty effects. To the researcher, such effects are not helpful. However, it is worth taking the perspective of the teacher. Could such novelty effects be used in order to boost motivation at appropriate points in a learning program? Questions would need answering as to the frequency with which such events were run before they became "normal" and novelty effects diminished.

### *Pupils' Perceptions of Relevance*

A number of NGT results related to pupils' perceptions of the relevance of the simulations to their futures in relation to "normal" design and technology work. Statements such as "similar to real life work," "good working under pressure," and "good for developing personalities and communications" all have high mean scores and low standard deviations meaning there was strong agreement amongst all pupils.

An increase in pupils' perceptions of relevance may assist attention and motivation. Megarry (1976) observed that it is only when the learner recognizes the importance of the question that answers are remembered or understood. A less obvious factor was the way in which the iterative structure of the simulations supported teachers in helping pupils to recognize this relevance. This supports Perry and Euler's (1988) observations. The mechanism for this was the regular de-briefing and re-briefing sessions. Pupils were helped to reflect on their experience and teachers were able to “build the simulation” by reminding pupils of the context and acting much as a sports coach does during match breaks. In the work of Adey et al. (1990) reflection emerged as an important strategy for promoting the transfer of learning.

The iterative nature of simulations assist the learner in recognizing relevance. The knowledge gained is fed into the next loop of the simulation. This iterative model of learning has been highlighted by several writers on simulation including Thatcher (1986) and Laveault and Corbil (1990). They propose cyclic models of concrete experience — reflective observation — abstract conceptuality — active experimentation. As each cycle is completed, the person rises to a new level and the cycle continues (see also Hampden-Turner, 1971). Similarly, the motivational effect is supported by Myers (1990) who claims that Academic Engaged Time (AET) can be improved by positive feedback.

*Motivation in Relation to the Participation of Industrial Staff*

All case studies incorporated a simulated commercial environment. Some also incorporated commercial and industrial staff into the simulation. There were indications that pupil motivation increased when these staff were involved. This observation is based on direct observation of pupil behavior and informal interviews. As none of the case studies allow a direct comparison of involvement of commercial/industrial staff with non-involvement this observation must necessarily be seen as subjective and lacking reliability. Nevertheless the indications were strong enough to merit reporting as a signal that other researchers may find interesting to follow up.

This appears to again support the work of Perry and Euler (1988) and Megarry (1976) discussed above. The case studies had been structured to follow the advice of Shirts (1975) and concentrated on exercising and reinforcing knowledge rather than attempt specific factual learning. However, there are dangers in loading simulations with detail (Boreham, 1985) and particularly in using them to promote factual learning (Adams, 1977, Jones, 1990; Percival, 1978). Excessive detail (high fidelity) detracts from the central aims of the simulation by making the pupil focus on detail such as remembering facts rather than exercising learning in a context. It is also worth contrasting the work of Earl (1990) who found that the "response" to a simulation was dependent on the context being identifiable by the pupils. He gives an example of pupils in Scotland responding to a desert survival simulation. When this was rewritten as a sea survival exercise the response was improved. The tasks and commercial context within the case study simulations appeared to be well within the pupils' cultural identity.

Low levels of fidelity may also stimulate debate at debriefings as pupils attempt to seek clarification of the context and to point out the simplicity of the model. This debate could lead to better understanding. Pupils need to be able to recognize when they need more information and develop techniques to find it.

*Suspended Timetable*

Some case study schools operated the simulations within a normal timetable over a period of weeks. Other schools suspended the timetable and operated the simulation over the whole school day for up to five days of "concentrated time." There were no schools which ran both concentrated time and "in timetable" simulations, so a direct comparison of motivational levels is dependent on the observations of the author. There were many indications that motivational levels developed to a higher level in the concentrated time studies. Typically staff had difficulties getting children to stop working and leave rooms at break, lunch times or after school. Teachers also reported that in concentrated time studies there were many requests from pupils for more work of that kind.

These effects may be due to a novelty factor, but there was also the possibility that operating in concentrated time assists pupils develop an identification with the simulation. Breaks or demonstrations inhibit this process through two mechanisms. First, breaks prevent pupils from building an intense identification with the simulation — "living the simulation." Secondly breaks disturb what levels of identification are built, meaning that staff have to attempt to re-build identification on rejoining the simulation. It would be reasonable to assume that the longer the break the more difficult it would be to re-build the identification. An over-night break during a five day suspended timetable event is easily "repaired." A week long break after only an hour of work, if a simulation is run in timetable, means that levels of identification were not built to the same extent and are more difficult to rebuild.

The manner in which breaks or demonstrations are managed and presented may be an important factor in determining whether an effective link is re-established with the simulation. No specific data has been gathered on this aspect. However, it is hypothesized that the way in which inputs are closed would be important, as would be the manner in which staff re-direct learners to the simulation. These questions would need to be resolved by closely focused observation of inputs of differing length and structure in a series of simulations.

*Roles/Freedom to Interpret/Time-Planning*

Jones (1990) made the important point that participants in a simulation must be allowed to interpret their roles with autonomy. In the case studies, this principle was taken further and pupils were left to develop their own team structure rather than have it imposed by staff; specific roles were not set. Teams were deliberately made up of pupils who were not in friendship groups in order to make them work at establishing relationships rather than rely on those already established on social, cultural or gender grounds.

In nearly all cases, teams claimed they had developed cooperative structures rather than conventional management pyramids. This was an interesting observation of the cultural morés of the sample of English pupils. Observation showed that most teams struggled in the early stages of these simulations because they had to establish a working structure and identify how they were to tackle the task. The five day suspended timetable events, particularly, exhibited a regular pattern of difficulties and struggle over the first two days followed by a rapid rise in confidence, motivation and application.

It is interesting to contrast this with the work of the Cognitive Acceleration through Science Education (CASE) Project (Adey et al. 1991). Here the principle of "cognitive conflict" was put forward as a key element in developing the ability to think. The CASE Project considers that pupils need to be made to confront and struggle with problems if they are to develop reasoning. They criticize much school work as being non-challenging:"...there is a strong temptation for teachers and learners to enter into an unspoken conspiracy to avoid undue mental effort." (Adey et al. 1990 p. 2)

In the case studies, by not pre-ordaining specific roles and giving freedom to manage the task, teams were caused to confront questions of suitable control and management structures. The very act of struggling to establish effective control with approaching deadlines may develop self confidence and motivation together with the "thinking skills" reported by CASE. De-briefing sessions represent the "reflection" which CASE also considered important. The CASE results indicated both long term effects and a general one which was demonstrated by better achievement in widely different subject areas.

*Deadlines*

All the simulations set clear task deadlines which modeled a product launch at a trade exhibition. There was evidence from the NGT results that pupils saw working to deadlines as very relevant. As deadlines approached work rates increased considerably. Pupils were observed to put in far more time than they were required, typically working through meal breaks or after school.

It was noticeable that this had the effect of making teams think more about the economy of time use in relation to design. Teams had to establish their own internal deadlines and effectively establish a critical path analysis. The pupils involved were generally used to having more time in Design and technology lessons to explore and develop their ideas without this pressure.

It is interesting to contrast the "economic" style of design within the simulations with reports on Design and Technology work in United Kingdom schools by Her Majesty's Inspectors (HMI, 1992) and Smithers & Robinson (1992) for The Engineering Council. These criticized Design and Technology in the UK for allocating insufficient time to making activities and over-emphasizing "paper" design. The approach to designing within the case studies appears to have helped pupils focus on the ultimate aim of design in a commercial context — the efficient and effective production of products.

*Pupil-Staff Relations*

Staff and pupils reported a change in their relations. The effect was positive, represented by improved pupil respect for staff. There were indications that staff, in turn, viewed pupils differently but the results were not specific enough on this point.

*Teachers' Reactions — Need for Contact*

Much of the literature on simulation emphasizes the importance of allowing pupil autonomy (Jones, 1989; Shirts, 1975). This principle was built into the simulations and certainly NGT results pointed out how pupils valued "being left alone more." Good teachers need not reduce pupil autonomy when working closely with pupils if they manage the interaction well. However, close contact certainly tends to reduce autonomy. Many teachers managing the case studies reported that they found it difficult to break contact and allow pupils autonomy and involved themselves as much as they normally would. On interviewing, these teachers they admitted that they "needed" close contact with the pupils and their work and found the distance necessary to give pupils autonomy uncomfortable.

This is interesting; these particular teachers appeared to need close contact in order to gain feedback on the progress of learning, even though they could recognize the logic of allowing pupils autonomy within the simulation. All these teachers were inexperienced with simulation techniques and it may be possible to hypothesize that, with experience, they would be able to give more autonomy. The ability to break contact with pupils offered teachers far better opportunities to observe pupils and then to intervene selectively, when appropriate.

*Competition*

Pupils did not react to the competitive aspect of the commercial context as expected. Despite the inter-team competition explicit in the model, there were many examples of inter-team cooperation by individuals. In pupil NGT responses, there was little evidence of them seeing competition as being either very relevant or motivational.

Competition in commerce is inescapable. Evans and Sculli (1984) considered that competition does increase motivation and sustain effort in simulations and games. They observed, however, that a highly competitive environment detracts from the learning potential. This may be accepted but there is a clear cultural and age gap between the managers in the work quoted above and the pupils in the case studies. It is also possible to draw a parallel with the point above that teams preferred to establish cooperative models of management rather than typical pyramid models. There appears to be a sub-cultural ideal which sees cooperation as positive but competition as being negative, though this would require more work before it could be reliably stated.

It is interesting to compare this with research in the area of management studies where workers such as Buchanan (1989) report on the potential value of management models which “flatten” the management pyramid and give increased responsibility and autonomy to people. Experiments in various companies have reduced the number of management levels and increased the autonomy and responsibility of all including “shop floor” workers. This research has shown output and worker relations have improved while time off on sickness leave has dropped in these companies.

## Conclusions

The case studies indicated that modeling design contexts, of the particular type indicated, could generate a reliable increase in motivation. This reinforces the findings in the literature. The studies raised a number of potential pitfalls in managing simulations which teachers would have to be aware of if they were not to lead to negative feedback for pupils. The simulations did not attempt to introduce factual learning and the literature indicates that this would not have been appropriate. It appears better to use simulations to periodically exercise and consolidate learning in a context which will increase pupils' perceptions of relevance. If simulations are used in concentrated time, by suspending the timetable at appropriate points, perhaps only once a year, the novelty effects of such an approach will be maintained. In this way novelty-induced increases in motivation may be used to help pupils to recognize what they can achieve with appropriate effort, so building their self knowledge and self confidence. Such simulations can also be used to help pupils understand the potential dangers of prolonged high level work rates and other questions on the moral elements of designing in society. These can be drawn into discussion during the end of simulation de-brief. The value of iteration and reflection were confirmed by the case studies and could be valuably applied more thoroughly to “normal” design and technology project work.

The observation that many teachers had difficulties in standing back and allowing pupils autonomy was unexpected. This underlines the importance of in-service support for teachers as they adopt teaching/learning techniques with which they are not familiar. If teachers were to adopt such techniques without suitable preparation there are indications that learning could be ineffective and may lead to damaging experiences for pupils.

Similarly the observation of pupils' preference for cooperative management models and resistance to competition were unexpected and interesting. This requires more work but would indicate that English pupils, whilst able to recognizing the value of cooperative work practices, also need help to be able to use competition in a positive manner.

The inquiry methodology adopted has been useful in identifying factors within the simulations observed of interest and relevance to teaching and learning. The obvious limitations of the approach means that there can be no claim to external validity in a technical sense but there is some value for practitioners and pointers for researchers. The next step is to try to identify the effects of specific factors, such as the use of concentrated time periods in relation to conventional time tabling or the introduction of personnel from industry and commerce into design and technology project work. Appropriate methodology will have to recognize the difficulties in separating out the variables in live learning situations.

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