Game-based learning in Design and Technology: an evaluation of a multi-media environment

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Abstract
This paper reports on an evaluative study of an interactive learning environment entitled ecoWarrior. The learning environment, aimed at D&T A level students, aims to introduce learners to issues in eco-design and sustainability.

The paper discusses the implications of using interactive media and game-based learning as a way of delivering the abstract concepts which constitute the area of ‘sustainability’ to learners. The benefits of the interactive medium in terms of stimulus and motivation to the learner are discussed. Through the evaluation of ecoWarrior, evidence is provided of the advantages of using game-based learning in the context of the D&T classroom.

The implications which the interactive digital medium of delivery makes for learning theory are explored. The constructivist paradigm is taken as the basis for the pedagogical design of the learning environment. The specific roles of socio-cultural constructivism and cognitive constructivism are explored as making a distinct and necessary contribution to learning and teaching practices.

The evolving roles of teacher and learner in a setting which includes an interactive learning environment are discussed. As interactive learning environments are a relatively new phenomenon in classroom teaching and learning practices, the degree of intervention which is necessary by the teacher and the nature of this intervention are currently unresolved. The findings of the ecoWarrior evaluative sessions make practical suggestions, based on evidence from observation data, on how this intervention can be resolved.

Keywords
game-based learning, constructivism, interactive learning environments, D&T, teachers’ role, exploratory talk

Introduction
Within Design and Technology, creativity and original thinking need to work alongside the process of active reflection. The implementation of this relationship between creativity, play and reflection-in-action in a learning package requires a new medium of delivery. Digital game-based learning has the capacity to bring together some of the key conditions for developing creativity and original thought in the learner, amongst which are stimulus, problem solving and collaboration.

Through the evaluation of an interactive learning environment entitled ecoWarrior, this paper explores the potential of the digital medium for learning and its implications for the way the roles of teacher, learner and computer are negotiated. Approaches to learning theory as applied to interactive learning environments are explored.

Literature review
Game-based learning is rapidly moving into the mainstream of educational practices. The BECTA Computer Games in Education project has shown that amongst the most significant benefits of game-based learning are the motivation and opportunities provided for collaboration between learners, which result in the development of social skills (BECTA, 2001). This answers a commonly posed fear of parents and educators, of individualised instructional packages as confining students to a computer screen without an opportunity for social interaction. As Underwood identifies:

‘…there is a growing body of evidence to show that children are more likely to work collaboratively when working on computer tasks than they are on classroom tasks, as long as the task allows for some level of collaboration and cooperation’.

(Underwood and Underwood, 1999:11)
Other than social interaction, game-based learning contributes with the elements of stimulus and task-orientated learning. Researchers ascribe the increased levels of motivation observed to several factors:

- pleasure in the outcome of the game;
- interest in the content of the game;
- pride in mastering the game rules.

(BECTA, 2001)

Furthermore, the digital medium is unique in its capacity to respond to the needs of the present ‘games generation’ of learners who are accustomed to discovery approaches to learning and active participation such as make up the structure of computer games (Prensky, 2001:49). This generation is not used to linear exposition, in the form of traditional paper based learning resources. This makes it apparent that in terms of learning theory, constructivist, discovery-based approaches are much more appropriate and responsive to their learning needs.

As applied to interactive learning environments, constructivist learning theory adopts two distinct approaches – cognitive and socio-cultural constructivism. Cognitive constructivism sees the role of education as providing the learner with a rich set of cognitive tools which aid the process of knowledge construction. A good example is Papert’s notion of microworlds – a type of computer-based learning environment which aims to teach Newton’s laws of motion in physics. By using the direct manipulation interaction style learners are able to explore a set of abstract concepts in a way which would be unavailable to them in a real world situation (Papert, 1980).

While researchers in D&T have explored the value of such approaches to the subject (Coldwell, 1996:82), there has not been so far a systematic exploration into how cognitive constructivism could be used to make conceptually difficult knowledge in D&T accessible to learners. One such area is sustainability.

The socio-cultural constructivist perspective on the other hand, sees learning as situated in the social world and actuated through social interactions and dialogue. Vygotsky emphasises the importance of dialogue for arriving at original solutions and problem solving (Vygotsky; 1978). Mercer builds on this perspective by identifying exploratory talk as the type of dialogue which is most likely to lead to original thinking (Mercer, 2000:99). In their theory of situated learning, Lave and Wenger describe learning as situated in, and co-produced by, a social world (Lave, 1991:89).

Researchers have explored the value of discussion as providing a basis for original thought in D&T (Head and Dakers, 2005; Hamilton, 2004; Koutsides, 2001; Stables, 2004; Ehiyazaryan, 2004). A case in point of how the socio-cultural perspective has been implemented within D&T education through interactive media is the InnoEd project – a collaborative learning environment which aids learners in design exploration by employing collaborative learning tools such as videoconferencing (Thorsteinsson, 2004:185).

What such research highlights is that, in order to provide a meaningful learning experience, a learning package needs to have the ability to combine individual learning goals with collaboration and social interaction. The question is – can interactive media and computer-based learning offer both of these approaches within one learning environment where the learner is in charge of deciding the degree and context of use of either approach?

ecoWarrior is a learning environment which was built to enhance learning and creativity in the D&T A level learner by bringing together a combination of game-based learning, narrative and interactive media. The learning environment aims to introduce learners to abstract concepts in eco-design, challenging the learner to turn these into actual project ideas.

ecoWarrior implements the best of both approaches – the learner has the opportunity to both engage in developing their understanding of complex issues in sustainable design, which is where game-based learning is employed, as well as to share this thinking, situating it within a social world. This paper discusses the issues and the advantages of combining these two approaches within a single learning environment.
Methodology
This research focuses on understanding how two different approaches to learning theory can be brought into a single learning environment and how this impacts on learning and teaching practices. Further, the pedagogical potential of game-based learning is explored.

In order to evaluate the learning which occurs, research looked at the process of meaning making through exploratory talk. Simultaneously, the impact of game-based learning was evaluated by looking for changes in the learners’ attitude, such as an increased degree of motivation and stimulus. Since such changes can only become visible over an extended period of time, the methodology adopted was longitudinal study (Bryman, 2004).

Two schools participated in the study. The multimedia learning environment ecoWarrior was implemented in the curriculum of both schools aiming to contribute to identifying project opportunities at AS level.

Students were video recorded to gather observational data regarding the effect of bringing a computer-based learning environment into the traditional D&T classroom setting. Insights into learners’ affective reactions were sought as a way of judging their degree of stimulus and engagement with the system and whether their interactions were deep or surface (Bekier, 2005).

The researcher acted in the role of participant observer due to two main reasons. Firstly, the nature of the wider research of which this study is part, action research, seeks as its outcome a positive intervention in learning and teaching practices (Cohen, 2003:226). Secondly, as the use of virtual learning resources is only starting to move into the mainstream of educational practices, the role of the teacher is to a large extent undetermined. The teachers present became participant observers alongside the researcher, aiming to uncover the optimum role which could be adopted by a teacher.

The methods of data analysis were grounded theory and discourse analysis. The value of grounded theory was in allowing for hypotheses to emerge from the data gathered (Glaser and Strauss, 1967:21), while the use of discourse analysis was in understanding more fully the affective factors at play as manifested in learners’ dialogic interactions.

Evidence and analysis
The most immediately visible games design metaphor, which was used in the ecoWarrior learning environment, was the interaction style of direct manipulation. Abstract concepts in eco design were represented as animated icons which could be manipulated. The purpose of such visual representation is similar to Papert’s ideas of creating a microworld which allows the learner to directly manipulate abstract concepts. In this way the abstract ideas of sustainable design – such as ‘durability’, ‘compostability’, ‘sustainable energy sources’ – can be related to case studies of actual products in the context of their use in real life situations. In situating abstract knowledge in the context of the real world this knowledge ceases to be abstract and allows for the learner to internalise it (Vygotsky, 1978). Following are several instances in the data gathered which exemplify this phenomenon:

Example 1:
Observation: A pair of learners – A and K – is looking at the Marble table case study. They are reading the story of the product carefully, pointing at the text and at the image on screen. They have dragged ‘durable materials’ already and scored a point. K points to ‘abundant materials’. They read the description.
K: Well it must be abundant – it’s made out of stone.

Example 2:
There are disappointed exclamations where the learners have ‘lost a life’.
Y: Is it non-toxic? It’s non-toxic.
B: (reads off screen) ‘Mono materials – those that consist of pure materials’ – so that’s going to be... yes! Right we’ve got two more.
Y: What is that one? Lightweight – strength to weight ratio.
They drag it and score a point.
B: Oh yes!
B and Y win their game.

These two examples provide evidence of how learners were able to manipulate abstract concepts – lightweight, mono materials etc. – in the context of an actual product being analysed. By thinking about how these concepts relate to the product learners situate their knowledge in a real world context. In this sense we can see that,
through the way the learning content is delivered, multimedia is able to make a unique difference in the type of knowledge learners have access to.

A further advantage of the medium of delivery is the degree of motivation and stimulus which learners display when interacting with the learning content under the form of a game, as illustrated in the second example. The excitement and exclamations which accompany students’ interactions show a deep degree of involvement in the activity and are a result of the direct influence of game-based learning. While this may seem a detraction from the purpose of the learning content, it is in fact an essential element of learning. The stimulus, which is evident in learners, is a manifestation of the fact that the learning content is working on their affective layer and is influencing their degree of motivation and level of engagement with the learning content.

Further, the interaction style of direct manipulation – characteristic of game-based learning – draws learners into an active mode of engagement with the learning content, which naturally predisposes them to conversing with each other and verbalising their thoughts. In the majority of their interactions learners naturally adopted a discussion-based, collaborative approach, even where the learning environment had not prescribed it.

While these interactions are undoubtedly meaningful and contribute to learning, the depth of discussion was limited to the performance of a specific product in terms of sustainability. The ecoWarrior learning environment further offered tasks of a different nature which aimed to engage learners in actively producing a response to the content, in the thinking mode of reflection-in-action. These were activity-based sketching tasks, where learners were required to come up with an improvement of an existing design or a new idea related to a specific concept in eco design. The following excerpts are examples of the type of discussion which developed amongst learners:
If you can bend laminates – you know how you can bend them... so it’s all one piece – so it will be – in the corner like that and – the one on the other side (drawing) – its bamboo laminate. It is like plywood – but made out of bamboo. So it’s not a bamboo pole...

C: Yes I know.

Teacher: What you are thinking of is that it is not a bamboo pole.

T: Yes it’s not a bamboo pole... What they do is they take a sliver out the side... And then you can press them down and make them flat – and you have a chunk of wood there. And it can replace timber or laminates or whatever.

Teacher: That’s nice – I like that.

C: So what do you have to do?

T: Use the design that you have and try and replace any woods you have with bamboo laminates.

C: We can have an armchair – made out of bent laminate.

T: Or chopping board. You can have a chopping board.

C: A chopping board just made out of bamboo laminate.

What we see in this example is a complex exploratory thinking process at work which develops collaboratively in dialogue amongst two learners and their teacher. Mercer identifies exploratory talk as the type of conversation most likely to produce creative thought (Mercer, 2000:73). The definition which Mercer gives for exploratory talk is that every participant in the conversation should ‘engage critically but constructively with the other person’s ideas’ (Mercer, 2000:98). In the dialogue illustrated we can see that the ideas which emerged from the discussion were built up on each other. They were a result of the collective contributions of all participants in the conversation, therefore they were indeed exploratory talk.

It is necessary to note that this process involved not only verbal discussion but also reflection-in-action on the side of the learners, who were translating their collective thinking in the form of a sketch. The notion of reflection-in-action has been used to describe the activity of design thinking as an interaction between mind and hand (Kimbell et al 1990:19), which is exactly what we are witnessing in the dialogue shown. The outcome of the discussion is that learners arrive at ideas about design opportunities which bamboo, as a renewable material, offers them.

There are several elements at play which act as conditions for making this creative thinking process possible. Firstly, we have a multimedia learning environment which provides dynamic, multiple representations of content to the learner, combining elements of animation, sound, text and imagery as well as links to external web resources. As discussed in the literature review, this style of information delivery which relies on discovery and multiple data representations is what the current generation of learners is most likely to respond to and be stimulated by.

Further, the content is set to the learner not as passive exposition but in the form of a task-oriented, problem-solving activity to which the learner is required to respond. As the literature review suggests, D&T learners are more likely to respond to a constructivist, active learning model which involves them in the activity of meaning making creatively, as well as reflectively.

The role which discussion plays is that of a vehicle for thought. A single learner viewing the content and trying to respond to it would not have the benefit of the different perspectives which come into play where several participants are engaged in the discussion.
The role of the teacher has also been identified as significant in interactions where a computer based learning environment is involved. This role has a specific value, which is unique to the teacher and is related to situating learning within the authentic activities of the subject setting (Lave, Wenger, 1991). The following excerpt illustrates this point:

Camera moves to learner B. He is looking at the products page and at the grass chair.

B: That is crazy! So it’s just like – biodegradable – it must biodegrade… I want one of these – I want a grass chair.

Teacher: We can make that.

B turns to his teacher:

B: Out of grass?!

J: Have you got a high-pressure extruder?

B: (points to the screen) Look they are made out of grass.

Teacher: Excellent.

B: How good is that.

Teacher: I saw a really good one it was made out of...

B: And then when you don’t want it – just chuck it in your garden.

Teacher: …made out of cardboard and then you put it and fold it and then the cardboard can degrade.

B: That’s crazy!

The role, which the teacher played in this interaction, was unique. The teacher engaged with the content by sharing his own experience of such designs: ‘I saw a really good one made out of cardboard the other day’. He also informed the learner that it was possible to make such designs in the workshops, which led to a chain of practical questions ‘Have you got a high pressure extruder?’ In this way the teacher provided the relationship with the authentic activities of the subject setting of D&T (Lave and Wenger, 1991) – he made the relationship between what could practically be achieved in the workshops and the virtual content on screen. This intervention acted to equip the learner with the capability of designing something which could realistically be prototyped and situates his newly acquired knowledge in the context of D&T work.
Discussion and conclusions

A significant part of learning in D&T is involved with practice-based tasks and problem solving. However, when subjects such as sustainability start to be realised as part of the curriculum, learning of abstract concepts becomes necessary, as well as the development of cognitive strategies and intellectual skills (Gagne, 1985:47). The ecoWarrior evaluative sessions provide evidence of learners displaying a natural affinity towards game-based learning, where the method of delivery – relying on visual representations and using direct manipulation as the style of interaction – proves to be successful in making abstract, and therefore conceptually difficult, knowledge accessible to learners. There are, however, issues related to this method of delivery which need to be addressed.

A primary role of the interactive medium was in providing the elements of deep engagement, intrinsic motivation and stimulus to learners. Due to the nature of the interactions – the direct manipulation interaction style, the multiple, dynamic representations of data – students adopted an active form of engagement with the learning material. As a result they were more predisposed towards collaboration with each other. Further, the stimulating experience of the game allowed for the learning content to work on the affective layer of students’ learning – contributing to a change in their attitude towards the subject of sustainability.

However, from a pedagogical point of view we have to recognise that the interactive medium itself is not sufficient to bring learners to the depth of knowledge which is required for meaningful learning. The need to situate learning in the authentic activities of the subject setting is imperative. An interactive learning environment can only go as far as providing the structure for such situated learning to occur but it is ultimately the way in which teachers and learners use the environment to create meaningful discussion which would make the necessary difference in the learning potential offered.

Within the ecoWarrior evaluative sessions, the teacher’s role in providing the link between the interactive content and practical activities, leading to generative thought, such as brainstorming and sketching, proved elemental. It was observed that, in the presence of a teacher, the learning interactions acquired grounding in the authentic activities of the D&T subject setting, which would not be made available by mere software access and use.

The dialogic interactions which developed amongst learners were an indelible part of the learning process. It was in dialogue with each other that learners constructed different perspectives on the same topic and managed to arrive at design opportunities to take forward to further development.

The role of the learning environment was in contributing with a structure which encouraged such dialogic interactions – all tasks, games, interactive sequences within ecoWarrior were designed to afford collaboration. As a result the learning interactions were enormously enriched. The ecoWarrior evaluative sessions indicated that interactive learning environments have a great capacity for lending themselves to collaborative or discussion based learning. The challenge for educational multimedia therefore is to always design the learning interactions to afford collaboration.

In conclusion, it needs to be emphasised that an interactive media learning environment is not to be seen as an entity on its own which can deliver learning independently of the pedagogical structures already established and existing in the D&T classroom. A most commonly made mistake is for teachers to stand back from the interactions and adopt the role of observer, where the weight of engineering the flow of the learning interactions falls on the computer and on the learners themselves. Rather, a blended learning approach needs to be adopted where the teacher takes on the role of overlooking the process of learner-computer interactions, by providing regular feedback and acting as the link between the virtual world and the authentic design activities learners need to engage, in such as sketching, modelling and workshop-based tasks.
References


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