There are many claims about the usefulness of computer games for learning. Computer games can stimulate users and encourage the development of social and cognitive skills, but frequent use can exacerbate negative psycho-social tendencies, be addictive and have health implications. This review of the literature about the use of computer and video games for learning will help with the design of learning materials.

ISBN 1-85338-904-8

This publication was supported by the Learning and Skills Council as part of a grant to the Learning and Skills Development Agency for a programme of research and development. The m-learning project is also supported by the European Commission Directorate-General Information Society (IST-2000-25270).

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The use of computer and video games for learning

A review of the literature

Alice Mitchell and Carol Savill-Smith

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Alice Mitchell and Carol Savill-Smith

Published by the Learning and Skills Development Agency

www.LSDA.org.uk

Registered with the Charity Commissioners

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Information Services
Learning and Skills Development Agency
Regent Arcade House
19–25 Argyll Street
London W1F 7LS.
Tel +44 (0) 20 7297 9144
Fax +44 (0) 20 7297 9242
enquiries@LSDA.org.uk

Copyeditor: Karin Fancett
Designer: David Shaw and associates
Printer:

1529/09/04/2500

ISBN 1-85338-904-8

Further information

For further information about the issues discussed in this publication please contact:

Jill Attewell
Manager, Technology Enhanced Learning Research Centre
Learning and Skills Development Agency.
Tel +44 (0) 20 7297 9100
jattewell@LSDA.org.uk

This publication was supported by the Learning and Skills Council as part of a grant to the Learning and Skills Development Agency for a programme of research and development. The m-learning project is also supported by the European Commission Directorate-General Information Society (IST-2000-25270).

Acknowledgements

We would like to thank Jill Attewell, Manager of the Technology Enhanced Learning Research Centre at the Learning and Skills Development Agency, for her support, advice and contribution to the editing process, and Helen Rendell for assisting with the identification of research material for this review.

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Preface

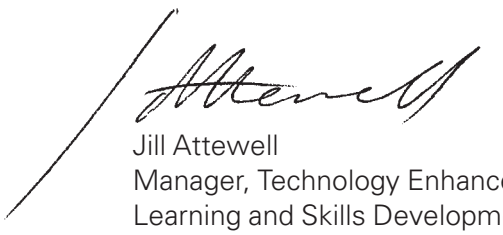
Computer games are very popular with many young, and young-at-heart, people. They can be played on a variety of devices. Handheld machines such as the Game Boy console and, increasingly, mobile phones allow the play to take place in different situations and when travelling. At the other end of the spectrum are sophisticated, but relatively static, dedicated games consoles with high specification graphics, such as the Sony PlayStation 2 or Nintendo's GameCube. The design and production of computer and video games for entertainment takes place within a very competitive industry. This development requires considerable investment in terms of both multimillion Euro budgets and time. A new game can take years to develop, and in the highly volatile computer hardware and software markets success is not guaranteed. However, the computer games market is booming and growing.

This research report is the result of a literature review conducted by Ultralab and the Learning and Skills Development Agency (LSDA) during the m-learning project. The main focus is on research involving the use of computer and video games for learning. The motivation for this review was to investigate the potential of games-oriented learning materials and systems and to inform the project's research activities. The report highlights many interesting pedagogic and technical issues and is, therefore, a useful reference for teachers, trainers, developers, researchers and others with an interest in the use of computer and video games for learning.

The m-learning project is a three-year, pan-European research and development programme with partners in Italy, Sweden and the UK. Its aim is to investigate the potential of handheld technologies to provide learning experiences relating to literacy and numeracy skill development for young adults aged 16–24 who are outside full-time formal education settings, and to encourage the development and achievement of lifelong learning objectives. The m-learning project is coordinated by the LSDA, and project partners listed below include commercial companies and university-based research units:

- Cambridge Training and Development Limited, UK
- Centro di Ricerca in Matematica Pura ed Applicata – the Centre for Research in Pure and Applied Mathematics, based at the University of Salerno, Italy
- Learning and Skills Development Agency, UK
- Lecando AB, Sweden
- Ultralab, based at Anglia Polytechnic University, UK.

Further information about the m-learning project can be found at: www.m-learning.org



Jill Attewell
Manager, Technology Enhanced Learning Research Centre
Learning and Skills Development Agency

Section 1 Introduction and overview of the literature

1.1 This review

A review of the published literature relating to the use of computer and video games for learning was required by the m-learning project. It was needed to inform the project partners about various matters relating to the use of such games (eg current pedagogy), and to assist with the design of learning materials and with the microportal interface being developed for the m-learning project. More information about the project can be found at: www.m-learning.org

There are many claims found in the literature for and against the usefulness of computer games in encouraging learning. It is asserted that the use of such games can stimulate the enjoyment, motivation and engagement of users, aiding recall and information retrieval, and can also encourage the development of various social and cognitive skills. Against this, it is claimed that frequent use of computer games can exacerbate negative psycho-social tendencies (such as those towards social isolation and even violence) and that their use is addictive and can also have health implications.

There has been a distinct increase in the volume of material published about the use of computer games since the year 2000. This research review synthesises the key messages from the current literature base of about 200 items. The main categories of information found were:

- general descriptive articles about the use of computer and video games and new software programs coming on to the market
- explorations into how different game attributes affect users' preferences (eg sound, colour)
- general overviews of the potential of computer and video games for education
- commercially available market reports
- research articles based on pre- and post-testing of users playing computer games designed for specific educational subject areas such as finance, modern languages etc
- research considering the effects of games use on individuals (eg on their metabolism and physical characteristics)
- research into gender issues concerning the use of games
- studies of the relationship between the use of games and lifestyle choices (including home use)
- earlier research reviews and meta-analyses (few of which found reference to studies about learning).

The largest single area reporting research was in the field of psychology.

The review has synthesised the findings as they relate to each of the research questions posed in this report.

1.2 Research questions

The following research questions guided this review:

- what is the impact of the use of computer and video games on young people?
- why use computer games for learning?
- how have computer games been used for learning?
- what are young people's experiences and preferences in using computer games for learning and for leisure?
- what are the recommendations for the planning and design of educational computer games (or 'edugames')?

Because the aim of the m-learning project is to use mobile technologies to try to re-engage young adults (aged 16–24) in learning and to start to change their attitudes to learning and improve their life chances, the m-learning partners also wished to find out if studies had been conducted using computer and video games with young adults who have:

- literacy, numeracy and other basic skill needs
- social and behavioural issues relating to youth education.

Where studies have been found that have findings in these areas, these have been noted.

1.3 Definitions of the terms: 'play', 'games', 'computer games' and 'video games'

It is important to define and explain the words play, games, computer games and video games for the purposes of this review.

First, **play**: something one chooses to do as a source of pleasure, which is intensely and utterly absorbing and promotes the formation of social groupings (Prensky 2001, page 112). Fun, in the sense of enjoyment and pleasure, puts us in a relaxed receptive frame of mind for learning. Play, in addition to providing pleasure, increases our involvement, which also helps us learn (Prensky 2001, page 117). Play has been further defined as:

…an intellectual activity engaged in for its own sake, with neither clearly recognizable functionalities nor immediate biological effects … and related to exploratory processes that follow the exposure of the player to novel stimuli. (Fabricatore 2000, page 2)

Second, a **game**: seen as a subset of both play and fun (Prensky 2001, page 118). A game is recognised as organised play that gives us enjoyment and pleasure (Prensky 2001). Dempsey *et al*. (1996, page 2) define a game as:

…a set of activities involving one or more players. It has goals, constraints, payoffs and consequences. A game is rule-guided and artificial in some respects. Finally, a game involves some aspect of competition, even if that competition is with oneself.

A game can be informed by concepts of 'as if', where the user suspends belief because they are immersed in the imaginary world of the game (Fabricatore 2000). Competitive games may involve undertaking chances in an imaginary setting. They motivate via challenge, fantasy and curiosity (Randel *et al*. 1992).

Third, **computer games**: Prensky (2001, pages 118–119) states that computer games can be characterised by six key structural elements which, when combined together, strongly engage the player. These elements are:

- rules
- goals and objectives
- outcomes and feedback
- conflict/competition/challenge/opposition
- interaction
- representation or story.

Game types include action games, adventure games, fighting 'beat 'em up' games, platformers (where game characters run and jump along and onto platforms), knowledge games, simulation/modelling/role-playing games such as management and strategy games, drill-and-practice games, logical games and maths games (Kaptelinin and Cole 2001; Becta 2002). Game play can be competitive, cooperative or individualistic (Becta 2001, page 1).

Finally, **video games**. According to Fabricatore (2000, pages 3–4), there are two key elements which distinguish video games (although this distinction is not exclusive). These are: 'Videogames always include an interactive virtual playing environment' and 'In videogames the player always has to struggle against some kind of opposition'.

Griffiths (1996, 1999) states that there are many different types of video games, each with their own distinctive qualities. They can be divided into nine categories (some of which correspond to the computer game types listed above): sports simulations (eg golf, ice hockey), racers (eg Formula One racing), adventures (fantasy games), puzzlers (or brainteasers), weird games (those that do not fit into another category), platformers (see above), platform blasters (similar to platformers, but require blasting everything that comes into sight), beat 'em ups (involving physical violence such as punching or kicking) and shoot 'em ups (involving shooting and killing using various weapons). However, Griffiths (1996) points out that only two of the above, namely puzzlers and weird games, contain games with educational components, and he suggests (page 58) that it is these types of games that could be used in schools in order to:

…foster learning and overcome some of the negative stereotypes that many people have about computer games.

It should be noted that the terms computer games, television games and video games have now generally become synonymous because of the blurring of the boundaries between computing and video technology. The distinction in the past was because video games required dedicated games consoles solely for their use and these generally could not be linked together, whereas computer games could be played on a variety of desktop computer platforms, could be linked together with sometimes hundreds of players playing at the same time, and could be used for other purposes (such as office applications). However, increasingly video games consoles offer hard drives on which to store games, with ports that allow them to be connected more widely using modems/broadband access, so enabling video games to become more sophisticated, powerful and a direct competitor to computer games. Thus, this review has covered both computer and video games, and any finding will relate to both, unless specified otherwise. The terms 'playing' and 'gaming' are used to denote the playing of computer games in general.

A glossary of specialist terms relating to the use of computer and video games can be found at the back of this report.

1.4 Hardware systems capable of delivering games

There are many different types of hardware associated with computer games. These include:

- games machines located in amusement arcades
- specialised games 'consoles' (powerful computers with high specification graphics capability for use in homes, eg the Sony PlayStation 2, Microsoft Xbox and the Nintendo GameCube)
- personal computers (ordinary desktop computers)
- handheld devices, such as the Nintendo Game Boy and Game Boy Advance, and other handheld devices such as palmtop computers
- mobile phones that incorporate games
- other specialist applications in unconventional places (eg car headrests, the backs of airline seats and even wristwatches).

The market for mobile games is a growth market for the games industry: newer devices have higher definition colour screens and enhanced memory, and functionality and development costs are lower for mobile games than for games on more traditional platforms. The mobile games market is predicted to grow substantially as personal digital assistants (or PDAs) and mobile phone technologies converge and their applications become less constrained by the limitations of the device.

1.5 The findings of previous literature reviews/meta-analyses

Before conducting this review, the authors consulted other earlier literature reviews/meta-analyses for pertinent findings. Eleven literature reviews were identified as having been undertaken in areas associated with the use of computer and video games. They have concentrated on five main themes, namely:

- investigations into whether there is a link between violent tendencies and aggression in people who use computer games, in that they would then imitate what is seen on screen (Ellis 1990; Griffiths 1999; Anderson and Bushman 2001; Bensley and Van Eenwyk 2001)
- specific examinations of their use with a particular age group such as children (Emes 1997; Harris 2001)
- investigations that have taken a broad review approach (Berson 1996; Griffiths 1996; Cesarone 1998)
- a comparison of the effectiveness of games and conventional classroom instruction in the teaching of students (Randel *et al*. 1992)
- an investigation on instructional gaming and the implications for technology (Dempsey *et al*. 1994).

These past analyses highlighted a number of issues about the use of computer and video games.

- The literature base is relatively sparse (Griffiths 1999; Anderson and Bushman 2001).
- The findings conflict in their outcomes (Emes 1997) – for example, some studies found little evidence that violent video games lead to real-life violence (Bensley and Van Eenwyk 2001) whereas others suggested they did (Anderson and Bushman 2001).
- Well-controlled studies of the adolescent use of video games are lacking (Bensley and Van Eenwyk 2001).
- Some studies have methodological problems in that the results depend on a single type of research method, for example observation of children's free play (Griffiths 1999).
- Longitudinal studies are needed (Emes 1997; Griffiths 1999; Anderson and Bushman 2001; Harris 2001).

It was also found that only four of the above reviews considered the relationship between the use of computer and video games and academic performance or learning (Randel *et al*. 1992; Dempsey *et al*. 1994; Emes 1997; Harris 2001). Here, again, it appears that few firm conclusions can be drawn from the studies. Randel *et al*.'s (1992) review, which is based on early studies up to 1991, found differences depending on the educational areas where the games were used. The best results were found to be in the areas of maths, physics and language arts (as opposed to social studies, biology and logic). The authors concluded that the beneficial effects of gaming were most likely to be found when specific content is targeted and objectives precisely defined, although it is interesting to note that in many studies students reported more interest in game activities than in more conventional classroom instruction. Dempsey *et al*.'s (1994) review found games serving a range of functions (eg tutoring, exploring and practising skills, entertainment and attitude change) and drew together assertions from the literature that might be useful in deployment or design of instructional games and associated research.

The two remaining reviews, by Emes (1997) and Harris (2001), found no clear causal relationship between academic performance and the use of computer games. However, the number of studies included within the four reviews varies widely; for example, the Dempsey *et al*. (1994) review considers 94 studies, while in Emes (1997) the findings were based on three studies, and in Harris (2001) on two studies.

These reviews were also examined for research to do with social and behavioural issues relating to youth education. Here, again, there appears to be a paucity of research. Of the few studies identified, one (noted in Dempsey *et al*. 1994) was a study on video game playing and psychopathology. It found that videogame playing was a social activity and not a serious achievement activity. Another study (noted by Harris 2001) investigated the gambling habits of young offenders aged 15–21 (at a youth custody centre) who had stolen to fund their coin-operated computer game playing habit. Although critical of the methodology used, Harris (2001) noted that those of the young offenders who had stolen had started playing computer games at a younger age, played more frequently, encountered more relationship problems, took more time off work and regularly neglected their food intake.

The literature base relating to the use of computer games for learning appears to remain small and, as with research relating to social and behavioural issues, it has not been the core focus of a review since 1992. None of the 11 reviews focused on studies which had taken place with learners who had basic skill needs; indeed, Randel *et al*. (1992) noted that until 1992 there had been no studies on the use of games with students who had not succeeded in traditional classroom instruction and suggested it would be useful to investigate the usefulness of games for students with marginal skills or marginal motivation. Meanwhile, the user population includes young adults with basic skills needs who are outside formal education. The paucity of research noted above, the needs of the user population and the recent rapid technological developments in computer games, lead us to conclude that further research is needed that particularly focuses on the potential use of computer games for learning by young adults.

This research report has not reviewed in depth the associated areas of palmtop computers or mobile phones as these are the subject of separate publications, the first of which has already been published by the LSDA (see Savill-Smith and Kent 2003).

Section 2 What is the impact of the use of computer games on young people?

2.1 Prevalence

In the 1970s video games became a significant source of entertainment for young people (ie children and young adults). Nowadays such games can be played on relatively low specification technology gaming platforms, including mobile devices (Kirriemuir 2002). This makes the games accessible to people who may not own an interactive television or personal computer. Many young people spend a significant amount of leisure time each week playing computer games, often 7 hours or more (Anderson and Bushman 2001; Walsh 2002). Such games have become for many children the chosen form of play (VanDeventer and White 2002).

Both males and females enjoy playing computer games. (Although Section 6.1 deals specifically with gender issues, it is interesting to note here some research findings with the caveat that this is a fast-moving area and research findings often lag behind the current situation.) It has been found that males are more likely to play to impress friends and for a challenge (Griffiths and Hunt 1995) although girls, too, have been found 'to perceive themselves to have peer approval for moderate amounts of game playing' (Cesarone 1998, page 3). Males play significantly more and far more regularly (Griffiths and Hunt 1995; Griffiths 1997b; Harris 1999; Subrahmanyam *et al.* 2001), and gender disparity in time spent playing is greatest for 14–18 year olds (Subrahmanyam *et al*. 2001). There is a view that females are put off by aggressive distractors (ie violent characters and incidents). This view is backed by findings that females 'prefer less aggressive and less demanding games' (Griffiths 1997b, page 234). However, this may be a faulty over-generalisation (Chappell 1997): there are those (eg Cesarone 1998) who find that both boys and girls enjoy violent computer games. A slight tendency of girls to be more academic has been found: although boys are substantially heavier users of the internet, girls tend to use the internet more for schoolwork than boys and spend more time communicating via e-mail (Mumtaz 2001). Others found that girls use word processing and educational software rather than computer games (Selwyn 1998; Harris 1999; Subrahmanyam *et al*. 2001).

Citing Stone (1995, page 9), Schleiner (2001, page 221) reports that:

Post-industrialist capitalist economies are developing into cultures of 'play' in which a pervasive 'play ethic' is superseding the work ethic.

Schleiner (2001, page 221) also points out that:

Within technoculture and disseminating out across class, ethnic and geographical barriers, younger generations into their late 20s are devoting increasing amounts of recreation time to addictive computer games … At its most extreme, a new type of subject/player is emerging, who takes her or his game play very seriously. This person is often called a 'gamer'.

2.2 **Health issues**

We found various materials on the impact of frequent gaming on young people's health. Players have complained of eyestrain, headaches, chest pain, fatigue and mood swings (Tazawa *et al*. 1997). This is compatible with findings that where game play causes sleep deprivation it is also associated with black rings under the eyes and muscle stiffness in the shoulder (Tazawa and Okada 2001). Medical experts appear concerned about metabolic and heart rates (Dorman 1997; Emes 1997), that frequent gaming may be associated with health problems such as tendonitis and repetitive strain injury (Emes 1997; Cleary *et al*. 2002), and that computer games could trigger epileptic seizures in susceptible persons (Funk 1992, 1993b; Emes 1997; Ricci and Vigevano 1999; Singh *et al*. 2001). This may be because the user sits close to the screen (Kasteleijn-Nolst Trenité *et al*. 1999). Ricci and Vigevano (1999) note that, while the role of the software itself is still unclear, 'a brighter image has a higher probability of provoking discharges than a darker one' and flashing lights and geometric patterns present in some games may activate a seizure (page 31). However, they also point out that:

> *Seizure activation by VGs* [video games] *may result from non-visual activating factors, such as cognitive or decision-making factors, sleep deprivation, emotional excitement, or hand movements.*
>
> (Ricci and Vigevano 1999, page 31)

Furthermore, there is the view that considers such side-effects to be 'relatively minor or temporary' (Griffiths 2002a, page 1) and that finds playing computer games is comparable to a mild intensity exercise: with normal use, playing may neither improve nor harm physical fitness (Emes 1997).

2.3 **Psycho-social issues**

There are psychological and social issues associated with playing computer games.

Bosworth (1994) found game users are no more likely than non-game users to be involved in risk-taking behaviour such as alcohol or drug abuse:

> *However, those who felt games were important were likely to report more depression.* (Bosworth 1994, page 118)

Roe and Muijs (1998) found some justification to associate frequent gamers with social isolation and less positive behaviour towards society in general, while Gupta and Derevensky (1996) found indications that frequent players gamble more than low-frequency players. There were reports of stealing and delinquency to finance play (Griffiths 1996) and of negative outcomes in terms of self-esteem, particularly with girls (Funk and Buchman 1996).

Self-esteem is an important issue (Cesarone 1998; Roe and Muijs 1998; Colwell and Payne 2000). Roe and Muijs (1998) found that increasing proficiency at computer games may afford players a temporary sense of mastery, control and achievement that they had hitherto felt themselves to be lacking. Such artificial raising of self-esteem may lead to interactions with computer games becoming a substitute for social relationships.

For both males and females, particularly where there is low self-esteem, the 'compensatory' effects of recreational gaming may reinforce a tendency to escapism or to addictive behaviour. This in turn may eventually also lead to feelings of inadequacy and depression. However, these views are not unequivocally shared. For example, the Glissov *et al*. study (1994, page 367) 'did not support the commonly held view that heavy computer users are less sociable than their peers', while the Colwell *et al*. (1995) study indicated that gamers, particularly boys, spend more time with their friends, both online and offline, because gaming is a source of collaborative activity as they swap information and ideas about the game. The authors found:

…no support for the theory that computer games are taking the place of normal social interaction. (Colwell *et al*. 1995, page 195)

Later studies (Colwell and Payne 2000; Subrahmanyam *et al*. 2001) consider that further investigation is justified.

Those who play to excess may do so for any of the following reasons: fun, challenge, nothing else to do, their friends did, the compensatory effects on their imagination and fantasy life, the arousing or tranquillising effects, or because they have an oral, dependent or addictive personality. Boys were 'more likely to be classified as "dependent"' than girls (Griffiths and Hunt 1998, page 475) but: 'females are just as likely as males to become "addicted" to home computer games' (Griffiths 1997b, page 235). Griffiths and Hunt (1998, page 475) found that:

The earlier children began playing computer games it appeared the more likely they were to be playing at dependent levels.

Emes (1997, page 413) concluded:

There is no personality stereotype of a frequent video game player. Video game playing may be a useful means of coping with pent-up and aggressive energies. The research on this subtle topic is minimal.

Games can also be played online (see Section 2.5). It is useful to point out here that Griffiths and Davies (2002, page 379) consider there is a lack of knowledge on the topic:

Because online gaming is so new, very little is known about the psychology of online gaming and its relationship with educational pursuits. What data there are, suggest that gaming in general (particularly online fantasy gaming) is associated with introversion, lower empathic concern and low feminine identity.

In view of the possible strong and negative effects of frequent gaming, Funk (1993a) suggests that parents should be educated about the need to monitor the extent of game playing and to influence game selection. Cesarone (1998) also refers parents to recommendations in the Educational Resources Information Center (ERIC) digest, which include:

…knowing the content and procedures of the games, paying attention to game ratings, establishing explicit game-playing guidelines, and educating children about the differences between media and real-life violence. (Cesarone 1998, page 1)

2.4 Effects of violent computer games

Games appear not to be free of cultural values – in fact quite the contrary:

The influence of computer games over the youth of today is akin to that of the cultural influence of music, political movements and even religion on youth culture of the past.

(Jayakanthan 2002, page 98)

In this respect it is important to note that violence and competition are integral features of many recreational computer games. Unlike educational computer games that reward pro-social behaviours, recreational computer games are not designed to that end (Ellis 1990). There are frequent concerns voiced in the literature (eg Anderson and Bushman 2001; Bensley and Van Eenwyk 2001) about the potentially negative impact on young people of repeated exposure to violent computer games. A main concern is that gaming does present unique dangers: the addictive nature of video games, the encouragement to identify with the aggressor and active participation in the violent game (Anderson and Dill 2000). The concerns are heightened by the increasing numbers of those playing computer games and by the progressively more explicit and realistic representations of violence (Ellis 1990; McCormick 2001). Marketing strategies may be reinforcing negative trends (Quart 2001). If aggression is a personality trait influenced by situational and social factors (Winkel *et al*. 1987, cited by Ellis 1990, page 38), it is of concern that studies observing children's free play consistently pointed to children becoming more aggressive after having watched or played a violent video game (Funk 1992; Griffiths 1999). How far this is developmental is open to speculation; for example, would the effect lessen once they reached adolescence? Anderson and Dill's (2000) findings suggest the opposite:

The effect of violent video games appears to be cognitive in nature. In the short term, playing a violent video game appears to affect aggression by priming aggressive thoughts. Longer-term effects are likely to be longer lasting as well, as the player learns and practices new aggression-related scripts that become more and more accessible for use when real-life conflict situations arise.

(Anderson and Dill 2000, page 788)

Anderson and Bushman (2001) consider that short-term effects can be significant in contributing to long-term effects:

Each violent-media episode is essentially one more learning trial. As these knowledge structures are rehearsed, they become more complex, differentiated, and difficult to change … even a few rehearsals can change a person's expectations and intentions involving important social behaviors … Even non-violent games can increase aggressive affect, perhaps by producing high levels of frustration.

(Anderson and Bushman 2001, pages 355–356)

Bensley and Van Eenwyk (2001, pages 244–245) draw attention to a number of theories seen to support the view that playing such games exacerbates aggressive tendencies.

- Social learning theory: players of computer games observe and imitate behavioural models; where players receive positive reinforcement (such as more points, increased status) for antisocial behaviour they may afterwards transfer this behaviour into real-life action with the same reward expectation.
- Arousal theory: after playing an arousing computer game, players of aggressive disposition, or those who are angry, may act in the manner just observed.
- Cognitive priming theory: violent computer games activate related cognitive structures. For example, they evoke thoughts of aggression in players, who may be more likely to interpret ambiguous behaviour as aggressive, and to respond in kind.
- General affective aggression theory: longer-term increases in aggression may also result if the extent of playing has led to aggression-related knowledge structures or 'scripts'.

There is significant support for these theories in Aristotelian philosophy (cited by McCormick 2001), which proposes that participating in simulated immoral and violent acts erodes the individual's character, reinforcing virtueless habits. Aristotle's theory is relevant to Schleiner's (2001) concerns that in the fantasy realms of violent and horror games such as Tomb Raider:

…the disgust and revulsion for that which transgresses boundaries between self and other, … order and the unclean, law and deviance … is transformed from repulsion to visceral thrill.

(Schleiner 2001, page 224)

It is held likely (McCormick 2001) that the cumulative effects of playing or even just observing violent computer games and horror games do impact negatively upon personality development. However, there are further perspectives such as individual differences that need to be taken into account here, as Scott (1994, page 130) points out:

There may also be individual differences in the effect of game playing. Some people may be able to spend a great deal of their free time playing arcade videos without any resulting aggression.

There is also a view that the so-called negative effects of playing violent computer games could actually be beneficial in an educational context. For example, violent computer games can provide a useful outlet to alleviate frustration. They provide a safe outlet for aggressive tendencies and can be useful in managing aggression. Bensley and Van Eenwyk (2001, page 245) show how this view can be supported by the catharsis theory expounded by Aristotle, the hypothesis being that observing aggressive play has a relaxing effect by channelling latent aggression and therefore has a positive effect on behaviour. They show (Bensley and Van Eenwyk 2001, page 245) that the view can also be supported by Hull's (1943) drive reduction theory, which hypothesises that behaviour occurs in response to 'drives' such as hunger, thirst, feeling cold etc. When the goal of the drive is attained (ie food, water, warmth) the drive is reduced, and this constitutes the reinforcement of the behaviours that lead to the drive reduction, and ultimately learning.

Whatever the case, as the interest in computer games is unlikely to fade there is a need for those concerned with promoting health to understand ways in which computer games technology can be harnessed to improve health (Dorman 1997, page 137).

2.5 Effects of the newer generation of games

Multi-user domains, multi-user dimensions or multi-user dungeons (MUDs for short) are:

…interactive, adventure-type environments where the goal is to slay monsters, gain experience and find treasure, or social areas where the purpose is to wander, enter into personal relationships and participate in a MUD community. (Turkle 1995, cited by Lee 2000, page 178)

Users can add new objects, including spaces, exits and their own notes. In certain MUD environments a user can assign new types of behaviour to the objects that they create (Lee 2000).

Artificial intelligence (AI), has enabled the design of a type of game where virtual 'actors' can be for example 'virtual' team mates or opponents, each with their own goals and motivations, not always apparent to players. AI is:

…the science and engineering of making intelligent machines, especially intelligent computer programs … The ultimate effort is to make computer programs that can solve problems and achieve goals in the world as well as humans. However, many people involved in particular research areas are much less ambitious. (McCarthy 2003, pages 2 and 5)

Thus, these virtual entities:

[can] *receive sensory input both from the virtual world and from the participant …* [and] *have the capability to learn and hence adapt to any aspect of their environment … Each category is progressively more 'intelligent' and central to the action in the game.*

(Waldern 1994, cited by McLellan 1994, page 77)

With 'embodiment', or putting on a 'smart costume' (to see a representation of yourself or the character whose role you are playing):

…this changes what your body can do. Your voice changes. Perception may change. (Waldern 1994, cited by McLellan 1994, page 79)

Hence the concern at the cognitive and social effects of the increasingly realistic simulated worlds in the newer generation of games. Players have appeared:

…significantly more introverted, less feminine, less androgynous and showed less empathic concern than controls.

(Douse and McManus 1993, page 508)

However, seen in wider context, this is a behaviour pattern:

…similar to that of the shy, introverted intellectual who is drawn to the computer. (Shotton 1989, cited by Douse and McManus 1993, page 508)

It has been observed (Phillips *et al*. 1995) that much of the large-scale published research on playing computer games and the associated impact on cognitive development was carried out with arcade games or first generation video games. It is interesting to note that excessive use of the newer online games has been associated with the same behaviour patterns. Fundamentally the game features remain the same, so it could be expected that the effects will remain the same. In particular, the multi-user online games might blur young people's perceptions of the difference between real life and virtual reality, to the extent that they become desensitised to aggression and violence (Subrahmanyam *et al*. 2001).

McCormick (2001) is concerned that increasingly sophisticated technologies enable us to impact on others' lives:

…at a greater distance and with greater anonymity than ever before. And we find that the technology itself is capable of having morally significant effects on us when we use it. In the case of violent video games, technology has created a buffer that alters the character of interactions that humans could have only had face to face before. From my computer terminal, I can guide my game alter-ego to do and say things that I would never think of doing in real life. When the gulf between us and our representative in a game is wide, such as the gap between me and a chess piece that wages war on my behalf in a chess game, we have little difficulty in separating reality from simulation. But when we look through our game character's eyes, and that character acts and talks like a human (or a superhuman), and that character interacts with what appear to be other humans, we are confronted with the visceral and organic fact of our own involvement in an activity that feels remarkably like the real thing.

(McCormick 2001, pages 286–287)

He therefore calls for development of:

…a new fourfold moral dynamic that includes not just how people's actions affect each other, but how the interactions between my game representative and my opponent's game representative affect me and my opponent.

(McCormick 2001, page 287)

2.6 What is the impact of frequent gaming on academic performance?

While no clear causal relationship between gaming and academic performance has been seen (Emes 1997), this review finds signs of both positive and negative effects. On the one hand, frequent players are less positive towards school (Colwell *et al*. 1995; Roe and Muijs 1998). This ties in with indications (Bruno 1995, page 101) that teacher-defined 'at risk' students display strong preferences for non-directed time-consuming activities such as watching television and playing computer games.

Frequent gaming reduces the time available for homework, which can negatively affect academic performance (Roe and Muijs 1998). It has been found that academically unsuccessful boys spend more time playing video games (3 hours or more at a time) than their high-achieving peers (Benton 1995; Colwell *et al*. 1995). Frequent playing of video games may encourage a preference for iconic representation, while instant gratification may lessen the readiness to make the kinds of effort required to enjoy the rewards of reading (Walsh 2002).

On the other hand, there are encouraging signs that game playing can actually benefit school performance. For example, the Pillay (2003) study found signs that:

…playing recreational computer games may influence children's performance on subsequent computer-based educational tasks. However, the extent of this influence depended on the types of games played during the learning phase. Linear cause-and-effect games tended to encourage means–end analysis strategy, whereas adventure games encouraged inferential and proactive thinking.

(Pillay 2003, page 336)

Frequent gaming is said to help users to adjust to a computer-oriented society (Greenfield *et al*. 1994). In action and adventure computer games, images tend to be more important than words; this shifts the development of representational skills (ie showing things as they are normally seen) from the verbal to iconic, with players visually manipulating images on a screen in different locations. In these ways players develop the spatial awareness (which can be simply defined as the skill of understanding where things are in relation to other things) and the cognitive skills (as when a person thinks or uses a conscious mental process) that are so crucial to many computer applications. Here boys are seen as likely to have the edge on girls (Phillips *et al*. 1995).

Until recently, girls have been seen to use personal computers less than boys:

They don't log on as often as boys, they don't play games, join computer clubs, or take advanced classes as often as boys. And when they get older, they don't pursue careers in technical fields as often as men.

(Furger 1998, page 6)

Previously there has been a shortage of women in the computer science industry. In 1996, for example, when opportunities in the field were seen to be at an all time high, girls earned just 16% of bachelor's (ordinary) degrees and 20% of master's degrees in computer science and only 12% of all doctoral degrees (PhDs) in computer science and engineering (Furger 1998, page 154). The gender imbalance in computer literacy is seen as directly linked to the gender imbalance in computer gaming culture: missing out on computer games means that girls miss out on what can be a lead-in to programming skills and associated career opportunities with high earning potential (Natale 2002). This imbalance may be linked to a perceived reluctance of girls to explore – or to the scarcity of female role models who are comfortable even with using computers – mothers, acknowledged by many girls as highly influential figures in their lives, have historically lagged behind fathers in this respect (Furger 1998). Girls may also have been discouraged by male stereotyping in the industry, by marketing or by other factors. However, the 'digital divide' in respect of confidence levels in using computers may be narrowing. More recently (Miller *et al*. 2001) found that both male and female adolescent students attributed their learning of computer skills to 'messing around' (page 136) on the computer or just watching someone, and therefore concluded that females have the confidence to experiment as well as males.

Learners growing up in the digital age are far more experienced and able at processing information rapidly than were their predecessors and are bored if they have to 'power down' at school (Mumtaz 2001; Prensky 2001). Ten main cognitive style changes have been observed in the 'games generation' (Prensky 2001, pages 51–52):

- twitch speed versus conventional speed
- parallel processing versus linear processing
- graphics first versus text first
- random access versus step by step
- connected versus standalone
- active versus passive
- play versus work
- payoff versus patience
- fantasy versus reality
- technology-as-friend versus technology-as-foe.

These changes pose considerable challenges for the educators and business trainers who wish to promote literacy skills, as Kress's (2003) experience suggests:

At times I watch our son and his friends – and it is boys usually – playing around with their PlayStation. The skills which they demonstrate – skills of visual analysis, of manual dexterity, of strategic and tactical decision-making at meta-levels – leave me entirely perplexed … All the games make use of the visual, but they always make use of much more: there is a musical score, there is rudimentary dialogue, and there is writing – usually as in comic strips, in a box above the rest of the visually saturated screen. The speed at which the written text comes can be adjusted. The pace at which it is set by the players is always too fast for me to read: I can never follow the text fully. Occasionally I have attempted to test whether the players have read and followed the written text, and have found each time that while they have, I have lagged behind. But in lagging behind in reading, I have not, at the same time, been paying attention to the other features of the screen and of the game, all moving at great speed, nor have I been physically manipulating the controls. (Kress 2003, pages 173–174)

Section 3 Why use computer games for learning?

3.1 Computer games engage

Many reasons are cited for why computer games engage the users. Some of the reasons given are listed below.

- They are seductive, they 'use technology to represent reality or embody fantasy' (Becta 2001, page 1). Rich visual and spatial aesthetics draw you into extravagant fantasy worlds that nevertheless seem very real on their own terms; these excite awe and also pleasure where environments have recognisable features (Poole 2000).
- 'Games are played to win or achieve a goal … The key to motivation is winning while remaining challenged' (Becta 2001, page 1). They motivate via fun, 'part of the natural learning process in human development' (Bisson and Luckner 1996, page 112), and instant, visual feedback (Prensky 2001; Roubidoux *et al*. 2002). This is true both of 'mini-games', where players achieve quick outcomes (Mitchell 2003), and of complex games, such as fantasy or simulation games, which have goals and subgoals.
- Unlike many other game environments, complex computer games provide a complete, interactive virtual playing environment (Prensky 2001)
- Ambience information creates an immersive experience, sustaining interest in the game (Prensky 2001).

It is argued that good computer games are not just entertainment but incorporate as many as 36 important learning principles. Taking as long as 100 hours to win, some are very difficult. They encourage the player to try different ways of learning and thinking, which can be experienced as both frustrating and life-enhancing (Gee 2003).

Prensky (2001) identified a combination of 12 elements that make computer games engaging. These are summarised in Table 1.

Table 1 The elements that make computer games engaging
(adapted by Attewell and Savill-Smith 2003 from Prensky 2001)

Characteristics of the computer game	How characteristics contribute to players' engagement
Fun	Enjoyment and pleasure
Play	Intense and passionate involvement
Rules	Structure
Goals	Motivation
Interaction	Doing (ie the activity)
Outcomes and feedback	Learning
Adaptive	Flow
Winning	Ego gratification
Conflict/competition/challenge and opposition	Adrenaline
Problem solving	Sparks creativity
Interaction	Social groups
Representation and a story	Emotion

Prensky (2001, pages 128–129) also identified a number of reasons why computer (ie digital) games engage, a selection of which are:

- they are typically fast and more responsive, and provide a rich variety of graphic representations to generate a wide range of options and scenarios not possible with non-computer games
- they can be played against real people anywhere in the world or against the computer, which means that multiplayer games can be played at any time
- they can deal with infinite amounts of content and afford differing levels of challenge, and they can be instantly updated, customised and modified by individual players, so that the player becomes part of the creative team.

He points out that well-designed games deploy techniques that encourage players to achieve and maintain the 'flow' state (Csikszentmihalyi 1990), a state of intense concentration and passionate involvement, where challenges are closely geared to ability. As can be seen from Table 1, Prensky (2001) considers that, for any game that is focused towards learning, it is the feedback in the game which encourages learning.

The Becta project (2001, page 2) identifies that:

For many games players the ultimate motivation is mastery – the promise that with enough energy and concentration you might 'master the machine', or at least the software.

A table in Becta (2001) highlights 'features that contribute to motivation' and is reproduced here as Table 2.

Table 2 **Motivation** (from Becta 2001, page 2)

What indicates motivation?	Independent work Self-directed problem posing Persistence Pleasure in learning
What generates motivation?	Active participation Intrinsic and prompt feedback Challenging but achievable goals A mix of uncertainty and open-endedness
What can motivation usefully support?	Collaborative interaction Peer scaffolding of learning Creative competition or cooperation Equal opportunities
What does sustained motivation rely on?	A version of reality Relevance to the user Recognisable and desirable roles for players
What are the problems with motivation?	Motivation may lead to obsession Motivation may cause transfer of fantasy into reality Motivation may induce egotism

3.2 Learning benefits ascribed to computer games in educational settings

3.2.1 Some general benefits

It is frequently argued that computer games are valuable tools in enhancing learning. They are seen as a means of encouraging learners who may lack interest or confidence (Klawe 1994) and of enhancing their self-esteem (Ritchie and Dodge 1992; Dempsey *et al*. 1994). In training and educational settings it is suggested that they can reduce training time and instructor load, for example affording opportunities for drill and practice (which is a form of instruction where learners rehearse sets of material following the same pattern), thereby enhancing knowledge acquisition and retention (Brownfield and Vik 1983; Ricci 1994). However, recall may be promoted less by games than by lessons if games are difficult because they have multiple goals and distracting components (Oyen and Bebko 1996).

Though regulated by rules, computer games allow manipulation of objects, supporting development towards levels of proficiency (Fabricatore 2000). They are said to be particularly effective when 'designed to address a specific problem or to teach a certain skill' (Griffiths 2002b, page 47), for example in encouraging learning in curriculum areas such as maths, physics and language arts, where specific objectives can be stated (Randel *et al*. 1992), and when deployed selectively within a context relevant to learning activity and goal (Kirriemuir 2002). It is important, however, that they are used to facilitate tasks appropriate to learners' level of maturity in the skill (Din and Calao 2001). Moreover, for skills to be enhanced by game playing, players must possess such skills to some degree already (Subrahmanyam *et al*. 2001).

Even simple types of game can be designed to address specific learning outcomes such as recall of factual content or as the basis for active involvement and discussion (Dempsey *et al*. 1996; Blake and Goodman 1999). Exploratory, interactive games are good vehicles for embedding curriculum content such as maths and science concepts that may be hard to visualise or manipulate with concrete materials. Riddles and interactive computer games have been used successfully with college students to enhance creative and other forms of critical thought (Doolittle 1995). Complex games, in particular, have the potential to support cognitive processing and the development of strategic skills. Brain oscillations associated with navigational and spatial learning occur more frequently in more complex games. This increases users' learning and recollection capabilities and encourages greater academic, social and computer literacy skills (Natale 2002).

3.2.2 **Benefits of simulation games**

Simulation games enable engagement in learning activities otherwise too costly to resource or too dangerous, difficult or impractical to implement in the classroom (Berson 1996) as well as those that are hard to accomplish by other means (Thomas *et al.* 1997).

Imaginative, well-produced simulation games can be seen as interactive stories:

Stories are one of the most fundamental and powerful synthetic experiences available to us. (McLellan 1994, page 76)

Participation in these stories can change learners' relationships to information (McLellan 1994) by encouraging visualisation, experimentation and creativity in finding new ways to tackle the game (Betz 1995; Gee 2003). Furthermore, simulation games are flexible and complex enough to cater for different learning styles (Sedighian 1994; Kirriemuir 2002), for example via the graphics (Berson 1996). They broaden learners' exposure to different people and perspectives (Berson 1996), encourage collaboration, and support meaningful post-game discussion (Kirriemuir 2002). They put the learner in the role of decision-maker and push players through ever harder challenges – you learn through trial and error as the games:

…give feedback in no uncertain terms. If you do the wrong thing, you lose your company, you lose your luggage, or you lose your life. (Filipczak 1997, page 29)

And:

…as your skills improve, your reactions get faster, you make decisions quicker – or you get up off the floor and try again. In short, the designer puts the user in a learning environment and then increases the complexity of the situations. (Filipczak 1997, page 31)

The instant feedback and risk-free environment invite exploration and experimentation, stimulating curiosity, discovery learning and perseverance (Kirriemuir 2002).

Other significant learning benefits of computer simulation games have been found to include use of metacognition and mental models, improved strategic thinking and insight, better psychomotor skills, and development of analytical and spatial skills, iconic skills, visual selective attention, computer skills etc (Pillay *et al.* 1999; Kirriemuir 2002; Ko 2002; Green and Bavelier 2003). Outstanding gaming expertise is linked to 'expert' behaviours such as self-monitoring, pattern recognition, problem recognition and problem solving at a deep level, principled decision-making, qualitative thinking and superior short-term and long-term memory (VanDeventer and White 2002).

Effectiveness is enhanced where learners are afforded opportunities to contribute to content design in dealing with actual, real-world problems (Kusunoki *et al*. 2000). This is active learning as players experience the subject domain or situation in new ways, form new affiliations and thereby prepare for future learning and problem solving in the domain or transfer of learning to related domains (Gee 2003). In the context of lifelong learning such games afford opportunities to use technologies within a realistic framework as a means to an end and so can play a small but significant role in preparing learners for the world of work (Saunders and Smalley 2000). There are indications that construction of meaning is the important process underlying transfer, irrespective of 'whether such meaning is constructed more inductively or more deductively' (Greenfield *et al.* 1994, page 81). However, the extent of transfer may not be significant (Henderson *et al*. 2000), hence:

…the importance of providing numerous practices instead of relying on the software to teach higher order cognitive skills.

(Henderson *et al*. 2000, page 105)

A structured approach is advocated in the classroom (Carter 1995):

The teaching strategy is exactly the same as conducting a real experiment: good worksheets, structured questions and finite goals are necessary … I have no doubt that left to their own devices the children would have concentrated on the game and ignored the biology. (Carter 1995, page 28)

Ko (2002, page 219) noted that:

…there were already different play patterns from the beginning of the games between the good problem solvers and the random guessers

and was concerned that:

More attention should be given to each piece of educational software, with careful consideration of why a specific package would be useful, what activities the child does with it and how, and what concepts are learned through it.

(Ko 2002, page 231)

Ko's concerns tie in with VanDeventer and White's (2002) recommendation that future inquiries should focus on identifying and testing strategies for intentional transfer and should also seek knowledge and insights on how expertise is acquired by different learners.

3.3 Opportunities with new and emerging technologies

Khan (2002) reported that advances in artificial intelligence (AI) include attempts to employ game environments in intelligent tutor systems (ITS – ie software that was originally developed to respond to learner needs, providing effective coaching):

Advances in game AI, better human–computer interface, speech recognition, sound compression schemes and stunning graphics capabilities have provided ITS [with] *everything required in an interactive, adaptive and intelligent learning tool. Evolution of new modes of learning is bound to revolutionise the ways in which we teach and learn today.*

(Khan 2002, page 134)

Khan explains how, in an adventure games (AG) environment, the player can experience a role or roles in a near real-life setting and at the same time learn about the setting itself. Played at expert level the game can support the development of intuitive skills at coping in that environment:

Researchers now tend to agree that the AG-like game environment can be used for informal training in general and for industrial training in particular. A new breed of ITS is evolving. The games parents would encourage their children (and teachers would insist their students) to play have started arriving on our machines.

(Khan 2002, page 135)

Others (eg Filipczak 1997; Griffiths and Davies 2002; Gee 2003) note that online adventure games such as MUDs and fantasy role-play games have potential for offering a variety of experiential learning opportunities. Inherently social, these types of game support both 'social learning' and 'situated learning' (ie learning that does not just happen in people's heads but is embedded in the social and cultural world). They also support pattern recognition and reasoning on the basis of patterns that players pick up in the real and virtual world:

…patterns that, over time can become generalised, but that are still rooted in specific areas of experience.

(Gee 2003, page 8)

They also enable exploration of interpersonal relationships (Filipczak 1997; Gee 2003). As AI becomes more highly refined, it:

…could be developed to allow children to experience and experiment with social situations that would otherwise be unsafe, yet receive a more realistic level of feedback and response from the AI than a predefined set of responses would achieve. It may also increase understanding of responsible action, as each interaction with the AI can produce more subtle and varied responses.

(Becta 2001, page 4)

Such games can encourage cooperative and competitive behaviour within a strategic context and therefore may have even stronger potential for education than 'traditional' games where the player interacts only with the computer (Griffiths and Davies 2002). As part of an intranet (a password-protected local network), they would allow learners to interact simultaneously with other users and with the environment itself, fulfilling objectives like attaining high levels, exploring, making friends and acquiring knowledge and skills (Lee 2000). The combinations of video, audio and text are useful in encouraging multi-modal literacy:

…ie we never just read or write, we always read or write something in some way … Literacy is multiple … we have to think beyond print.
(Gee 2003, page 14)

The rapid technological development of handheld consoles such as the Game Boy Advance has encouraged speculation about developing educational software to support blended learning. This blended learning might include classroom-based learning linked to learning online and/or outdoor activities such as museum visits and field trips (Kirriemuir 2002). More recently Wu *et al*. (2004) found:

With the recent advances in mobile networking, context-aware computing, and sensor-based computing, researchers and game designers are able to explore the potential of combining these new technologies to develop mobile, context-aware, augmented reality multiplayer games.
(Wu *et al*. 2004, page 55)

3.4 **Some educational considerations**

Stoll (1999) takes a stand against using computer applications to make learning fun. He argues:

What seems like a game to someone will feel like work to another. The intention should be enlightenment, not entertainment. Learning isn't about acquiring information, maximising efficiency, or enjoyment. Learning is about developing human capacity. To turn learning into fun is to denigrate the two most important things we can do as humans: To teach. To learn. (Stoll 1999, page 22)

He also reminds us of the hidden cost of learning via computers:

The opportunity cost is our time … The time you spend behind the monitor could be spent facing another person across a table or across a tennis court. Disguised as efficiency machines, digital time bandits steal our lives and undermine our communities.
(Stoll 1999, page 209)

This view gives pause for thought, not least by reminding us of the existence of bias. Here it is useful to note that teacher bias towards a particular learning method and teacher input into debriefing are important variables that can affect the effectiveness of games in encouraging learning (Randel *et al*. 1992). Other variables include player characteristics such as gender and personality, learning style, academic ability and gaming ability (Bredemeier and Greenblatt 1981, cited by Randel *et al*. 1992).

Clark (2003) has highlighted a number of risk factors that can impact negatively on learning via computer games. For example:

- learning objectives may not be congruent with game objectives
- games can distract from learning as players concentrate on completing, scoring, winning
- games require suspension of belief; it may be difficult to retain learning acquired in that state
- we may fail to reach male and female audiences to the same extent
- we risk alienating our learners by 'hijacking' what is seen as their world; they may feel patronised.

The Becta project (2001, pages 3–4) points out further disadvantages. Games may:

- be pitched at the wrong level of interest and challenge for the user
- be too easy or too difficult, resulting in decreased motivation
- take a long time to work through, which can cause problems with timetabling and set curricula
- be poorly designed (eg there can be problems with a confusing interface, insufficient feedback and illogical rules or constraints)
- be addictive, which can be to the player's detriment.

Also:

- much games software is gender specific and/or peopled with violent and stereotyped characters – as the game provides no opportunity for reflection on this stereotyping and behaviour, it is implicitly condoned
- computers are designed for single users, which can make collaboration superficial if it involves taking turns on the keyboard
- while 'interthinking' is possible via use of electronic networks, it is not currently the focus of computer games.

Greenfield *et al*. (1994) concluded that communication media are more than mere information channels, because, as distinct symbol systems, they are powerful cultural tools that influence everyday cognitive processes. This would suggest that an important area for educational research would be whether games are a tool to assist the representational skills of society at large.

Section 4 How have computer games been used for learning?

4.1 Use in clinical practice and associated research

Computer games have been successfully deployed in clinical practice. Some examples (all cited by Griffiths 1997a) are listed below.

- Treating attention deficit, resulting in improved scanning and tracking (Larose *et al*. 1989). It was found beneficial if the game becomes progressively more difficult as attention wanes (Pope and Bogart 1996).
- Providing cognitive–attentional distraction (eg in treating pain and nausea). Used, for example, with patients suffering from the effects of a stroke or burns or with children undergoing chemotherapy (Vasterling *et al*. 1993).
- Treating schizophrenia (Samoilovich *et al*. 1992) and promoting and increasing motor skills (Sietsema *et al*. 1993).

Computer games have also been useful in supporting analysis into the development of attention in children: PlayStation 2 games were found useful at Bangor University in assessing children's competence at visual processing (Kirriemuir 2002).

4.2 Supporting reading and maths

Computer games have been particularly effective in raising achievement levels of both children and adults in areas such as maths and language, where specific objectives can easily be stated (Randel *et al*. 1992), and have been used to support National Curriculum learning (Kirriemuir 2002). Information-processing educational game components that have been designed to imitate popular computer games have been found to help poor readers to make significant learning gains, with the greatest improvement shown by the poorest readers (Schwartz 1988) and resource-deprived learners (Herselman 1999). They have also had positive effects on motivation and classroom dynamics (Rosas *et al*. 2003). Further information on these studies is found in Section 5.2 below.

The use of quiz games has also led to positive results in long-term student retention (ie ensuring they complete a course) by attracting higher student interest than traditional classroom approaches (Randel *et al*. 1992). For example, in training environments such as the Naval Training Systems Center in Orlando, Florida, computer-based versions of board games such as Serious Pursuit were adapted to cater for service personnel whose jobs required a pre-existing knowledge base for certain tasks. This prompted development of GameShell, a software program to house question and answer databases. When these games were used there was better retention. This was attributed to more focused attention, because the students enjoyed the approach (Ricci 1994).

4.3 **Simulation games: supporting participative learning**

Simulation games require active participation, and this affords opportunities for the learning material to be integrated into cognitive structures, thereby aiding long-term retention (Randel *et al*. 1992). Gaming experiences range from:

> *…navigating through interactive narratives (Ico); collaborating in complex problem solving (MindRover); raising digital life forms (Creatures); participating in persistent virtual communities (The Sims Online); exploring detailed simulated worlds (Thief); and playing with feature-rich authoring tools (Civilization III).*
>
> (Squire *et al*. 2003, page 18)

Simulation games have been used in schools to enhance children's spatial abilities and general cognitive development, with both boys and girls performing equally well (de Lisi and Wolford 2002), while Jayakanthan (2002) reports that versions of strategy games like Sim City have been used in schools to encourage learning in subjects such as geography. Simulation games have also been used in business environments, for example in teaching administration skills. Off-the-shelf games simulations such as Doom II have been used in conjunction with free tools downloaded from the internet to provide cost-effective military training, for example where real-world environments or locations may be unavailable to troops.

Complex games have been useful in encouraging attitude change, in supporting the development of critical thinking, in problem solving and in developing decision-making skills. They have been explored as a means to foster learners' understanding of theoretical models and interaction effects and to support the development of team, social, communication and resource sharing skills (Ritchie and Dodge 1992; Berson 1996; Helliar *et al.* 2000; Hollins 2003; Squire *et al*. 2003). Here, though, gender differences have been found (Inkpen 1994) in the way children approach the gaming environment. Girls were found to perform better when two played on one computer. Boys, on the other hand, were seen to be more successful when two played together, but on separate computers. Girls were observed to make fewer 'contact' requests (ie requests made by touching their partner or the computer mouse). Boys were seen to be more likely to refuse to pass over control of the mouse.

A key appeal of the games is found to lie in providing learning opportunities within contexts that are relevant and attractive to the learners (Kirriemuir 2002). The context is more than just a motivator:

> *…it becomes a critical component of the learning environment. In good educational games, narrative events situate the activity, defining goals, constraining actions, provoking thought, and sparking emotional responses as students struggle to resolve complex, authentic problems … From a situated learning perspective, these narrative constraints and possibilities shape action, and become part of students' understanding of a domain in fundamental ways.*
>
> (Squire *et al*. 2003, page 18)

The combination of interactivity within a familiar and yet novel situation, with clear and agreed aims for learning, proves very effective (Kirriemuir 2002). For example, a game with a job-relevant context has encouraged young adults who lacked the basic skills to perform their jobs to engage in intensive instruction. The game served to guide their learning and to elicit performance via visual stimuli, motion sequence and audio feedback (Brownfield and Vik 1983).

Simulation games have been found to be most effective in encouraging discovery learning where the system provides two kinds of instructional support: learner-requested background information and elaborate system-initiated advice (Leutner 1993). However, the role of teacher mediation remains important, in explaining or augmenting the game (Lawry 1994; Kirriemuir 2002). For example, task cards were used with games, requiring learners to describe their strategies and to provide tips to others, thereby stimulating reflection and writing skills (Kaptelinin and Cole 2001). Working with sections, rather than the whole game, may be more useful to particular learning objectives. This means the teacher must know the content behind the titles and understand controls, menus and skill levels of the game, and this requirement thus increases teacher workload (Kirriemuir 2002).

Section 5 Examples of using computer games to encourage learning

5.1 Criteria for selecting the examples

In selecting the studies highlighted below, our attention was directed particularly towards examples of computer games, educational or otherwise, being used to encourage the kinds of learning likely to be of relevance to m-learning target audiences. Accordingly, we were looking for instances relating to the learning of basic skills, engaging adolescents in learning, supporting information retrieval, encouraging social learning and supporting multidisciplinary learning. In the light of the development of the m-learning project's Learning Intelligent Agent and Learning Management System, we were also interested in the impact of system-initiated advice. Finally, mindful of the high level of gaming expertise that many of our target audiences might possess, we looked for examples of encouraging the development of complex skills.

5.2 Teaching basic skills

5.2.1 Comparing teacher-based tuition with practice on four educational computer games

In Australia, the Schwartz (1988) study compared componential and traditional approaches to training students' reading skills. The research group were 24 primary school children (15 male and 9 female):

…with average intelligence and no oral language comprehension deficits – but who were 18 months or so behind their peers in reading comprehension.

(Schwartz 1988, page 193)

Remedial treatment consisted of teacher-based tuition for half the children, with the rest receiving practice on four educational computer games. The tutor-led group were trained using DISTAR:

…a teacher-directed programme for the acquisition of certain decoding and comprehension skills.

(Schwartz 1988, page 193)

These skills related to the skills trained by the selected computer games: the main focus of both approaches was word decoding and phonics. Table 3 highlights key features.

Table 3 Overview of the DISTAR and computer games training features selected for the intervention
(adapted from Schwartz 1988, pages 193–196)

	DISTAR training		Computer games training
a	Letters and combinations of letters taught as sounds	**a**	Letter Match: using a response button, students decide as quickly and accurately as possible whether two letters are the same or different
b	Reading aloud vocabulary presented by the teacher, including sounds practised in **a** as well as some that were new	**b**	Word Match: like Letter Match above, but this time with real words or pronounceable pseudowords (ranging from single-syllable high frequency words such as deer, dog and fox to more difficult words such as gorilla, guerrilla, suite and sweet)
c	Story reading: short passages. Follow-up: answering questions posed by teacher and also in their workbooks	**c**	Speed reading: reading a series of words and pseudowords aloud. Accuracy monitored by the teacher, who also corrects pronunciation
d	General reading: time set aside at end of session to read a continuing story self-selected from the Level 2 storybook	**d**	Last word: reading a short sentence and deciding whether its last word is appropriate given the preceding context

The results were found to be positive for both approaches, with almost all students improving their reading comprehension test scores after training. It is interesting to note that:

…the poorest readers made significantly greater gains in the componential training condition than in the DISTAR condition.

(Schwartz 1988, page 189)

The results were also stated to show that remedial computer games training:

…can be a practical adjunct to a traditional tutoring programme.

(Schwartz 1988, page 189)

5.2.2 Considering the use of strategy games and twitch games

In South Africa the Herselman (1999) study investigated the benefit to sixth grade primary school learners of computer assisted language learning (CALL) via five educational computer games supporting the primary school curriculum. The study differentiates between strategy-game literacy, requiring higher-order thinking skills for problem solving, and twitch-game literacy:

When learners are twitch-game literate they will be able to use basic level skills like seeing (eye–hand coordination), printing (concentrating) and clicking (reaction) to win a game.

(Herselman 1999, page 204)

It was found that the games motivated both resource-affluent learners (RAs) and resource-deprived learners (RDs) to continue playing through the challenges. RAs preferred strategy games, becoming bored with twitch games after a while, while RDs preferred twitch games. Overall, recognition was the highest intrinsic motivational factor, with comprehension and fantasy the lowest motivational factors. RAs and RDs returned control and curiosity respectively as second highest motivator, possibly because RAs have higher strategy-game literacy and are not so curious about game outcome. RAs rated competition higher than fantasy, RDs reversed the order. The computer mouse, where used, was felt by both RAs and RDs to improve hand–eye coordination, concentration and reactions, but not keyboard skills. RDs were not used to operating the mouse and tended to prefer the keyboard. Colour and sound were seen to enhance concentration. Playing games was also linked to 'significant improvement in all the learners' language proficiency', with 9% improvement reported at the most disadvantaged school and with least improvement at the school with most RAs.

5.2.3 Considering the effects of using educational video games on learning, motivation and classroom dynamics

In Chile, the Rosas *et al*. study (2003) evaluated the effects of introducing educational video games into the classroom and found indications of positive effects on learning, motivation and classroom dynamics. Subjects were 1274 first and second year students (age unstated) from economically disadvantaged schools. The video games had been specifically designed to support development of their reading comprehension, spelling and mathematical skills.

The sample was divided into experimental groups (EG), internal control groups (IC) and external control groups (EC). Students in the EG groups, used the experimental video games during an average of 30 h over a three-month period … The results show significant differences between the EG and IC groups in relation to the EC group in Math, Reading, Comprehension and Spelling, but no significant differences in these aspects were found between the EG and the IC groups. Teacher reports and classroom observations confirm an improvement in motivation to learn, and a positive technological transfer of the experimental tool.

(Rosas *et al*. 2003, page 71)

Like Din and Calao (2001), who successfully used the Sony PlayStation Lightspan games with socially disadvantaged kindergarten children to facilitate age-appropriate tasks in spelling and reading, they called for further research before causality could be established. However, they concluded that their own study did indicate that:

…the introduction of educational video games can be a useful tool in promoting learning within the classroom.

(Rosas *et al*. 2003, page 71)

5.3 Engaging adolescents in learning

5.3.1 Encouraging body awareness via games and simulations

Bosworth (1994) used specially developed computer games and simulations as tools to reach and engage adolescents in Body Awareness Resource Network (BARN) health promotion activities. The data relating to use indicated that the games were the most heavily used components of each topic area. Further, anecdotal evidence from interviews suggested that the interactive games fulfilled the goals of attracting and engaging a wide spectrum of adolescent users to the BARN system. Survey data suggested that attraction was higher with younger users and slightly more with boys than girls. Gender differences were highest at ninth grade level (adolescents aged approximately 14, as defined by the NCES 2002) but these differences were unexplained.

There was no consideration of means other than computer games of reaching and engaging students.

5.3.2 Encouraging safer sex negotiation via a specially developed computer game

Thomas *et al*. (1997) used the interactive computer game: 'Life Challenge' time travel adventure game. This game had been specially developed by the New York State Department of Health 'as a tool for encouraging adolescents to develop skills and a sense of self-efficacy in HIV/AIDS prevention programmes' Thomas *et al*. 1997, page 71). The time travel adventure game format provides information and opportunities for skill practice – safer sex negotiation – in a non-threatening environment. Field tests were undertaken in 13 sites serving high-risk adolescents (actual age range undefined). Analysis of 211 audio responses found participants took the negotiating tasks (with chosen partners) seriously. Although the game was not intended as a 'stand-alone' intervention, the study found statistically significant learning gains on both knowledge enhancement and self-efficacy scores, with best results for those with low baseline self-efficacy levels. The conclusion was that computers used in this way have a unique role to play in health education interventions, affording practice opportunities otherwise very difficult to achieve. The opportunity to listen to actual message content highlights 'the differentiation between self-report of perception of self-efficacy'. Other advantages included the branching capacity of computer software which, unlike linear resources such as pamphlets and videos, allowed messages to be tailored to the user. It also allowed branching for partner preference, the feature users liked best. Finally, the technology was seen as a cost-effective means of widening access to health education programmes.

5.4 Supporting learning of information retrieval via a prototype educational game

Halttunen and Sormunen (2000) trialled a prototype educational game to support learning of information retrieval (IR) at the University of Tampere in Finland. The prototype used was the Computer-Supported Learning Environment (CSLE) Information Retrieval Game (IR Game). The IR Game was developed at the university as a rapid query analysis tool for use in different types of search situations.

A basic function of the game, query effectiveness feedback, was seen to be highly motivating and to encourage learning. It supported analysis and evaluation of the learner's query performance:

Feedback concerning the performance of one's own query, the chance to freely reformulate the query and to further evaluate the effect of changes on performance was seen as a highly motivating and learning advancement. Furthermore the feedback mechanism allowed students to pay attention to the analysis and evaluation of query formulation and search keys. This was contrasted with the heavy browsing and evaluation of search results, which is typical when operational databases are used for educational purposes.

(Halttunen and Sormunen 2000, pages 303–304)

Feedback was found useful in encouraging a broad understanding of central phenomena of information retrieval, with a few students constructing mental models and others finding:

…graphical presentation of search results more informative than numerical values (Halttunen and Sormunen 2000, page 304)

However, it was not clear how much this was because of the novelty value. Surprisingly, the feedback mechanism was perceived at the same time to inhibit learning, by encouraging attention on performance measures achieved rather than by encouraging analysis of the search task situation. Equally surprisingly in this regard, the 'Hall of Fame' feature, which showcases the best query formulations and achieved results, was not mentioned as an inhibiting factor, possibly because the feature is one of the most 'game-like'. However, in general the game was said to have disappointed in entertainment value.

Students did not cope well and were demotivated where they used similar strategies to those they had used with traditional databases. A video log indicated that they seldom read long documents on screen. Linguistic expressions in search requests were seen as too predefined and artificial – complementary tutoring was important. The 'Give a Hint' function was well used. However, students were disappointed that it did not provide the interactive, situational help and ideas that they had expected. The social situation was found to enhance learning but also inhibited learning when some members dominated. Some found knowledge transfer to real-life search tasks and systems difficult.

Where the same features of the game could be seen as both inhibiting or enhancing learning, it was suggested that this may relate to a learner's prior IR experience and/or learning style. There was a need to evaluate outcomes over the longer term, and in computer-based and tutor-led environments.

5.5 Encouraging social learning

5.5.1 Computer-based dialogue games to encourage collaborative learning

The social constructivist theory (Vygotsky 1962, 1974) emphasises the collaborative aspect of learning, and assumes that actions are influenced by social and cultural factors. This theory informed an 'investigation by design' (IBD) study by Ravenscroft and Matheson (2002, page 93) that used a discourse (ie conversation) analysis scheme called 'DISCOUNT'. This scheme incorporates principles of Socratic dialogue (ie it sets out to use a rigorous questioning technique originally developed by the Greek philosopher Socrates to clarify concepts and search out contradictions). Ravenscroft and Matheson (2002) sought to encourage 'successful dialogue' (ie collaborative argumentation, exploratory talk and constructive conflict). They created 'computer-based dialogue games supporting conceptual change and development in science' (Ravenscroft and Matheson 2002, page 93). The games incorporated participant goals, participant roles, dialogue tactics and rules.

The strength of the IBD approach was seen to lie in its 'pedagogical fidelity and flexibility', whereby the 'rigorous and systematic nature' of the approach enabled re-use, development and synthesis of existing game models. An empirical study evaluated a dialogue game that used IBD: it was felt the game would benefit from additional didactic tactics, hence it was modified to develop an 'elicit information' game. Both types of game were then evaluated in a further empirical study. Results were said to:

…clearly demonstrate the effectiveness of both dialogue games in stimulating improvements in the students' understanding of the physics of motion. It was also noted that the dialogue games worked differentially in addressing the conceptual difficulties experienced by students … [one game type] *was more effective in addressing alternative conceptions about the context, …* [whereas the other type] *appeared slightly more effective in addressing incompleteness in the students' models…*

…Taking the results of the evaluation study collectively, a striking finding is that the addition of up to 30 minutes of a stylised collaborative inquiry dialogue about a topic produces significant improvements in students' knowledge and conceptual understanding compared with 'conventional' teaching alone.

(Ravenscroft and Matheson 2002, pages 98–99)

5.5.2 Supporting constructivist learning via two different interactive game environments

Edwards (1992) undertook a comparison of learning in two interactive environments, working with 16 high school and middle school students whose average age was 11 years and 9 months. The study used observation (videotape), supplemented by students' notes and sequence of moves for each game (recorded on computer or on paper). In study one, learners spent 1.5 hours working with the software 'Graphing Equations' and the software game 'Green Globs'. There were two pairs and two learners working alone. In study two, all learners worked in pairs, using TGEO, a Logo-based microworld for transformation geometry. The two different software applications were seen to support the same kind of learning, each supplying tools for students to build on their own knowledge, providing visual feedback and allowing independent, self-directed exploration of patterns beyond the goals of the game. Students said they enjoyed the games and learned from them. A variety of strategies were observed in each group. Limitations of the study were the small samples, the short time learners spent using the software and software/group variables. A need for a longitudinal study and comparison of the results to use of randomly selected educational software was identified.

5.5.3 Discovering how others think via a collaborative learning game

Kusunoki *et al*. (2000) wanted pupils to discover how others think by encouraging collaborative learning in a classroom. They used a game system that integrates physical and virtual worlds to teach urban planning and environmental issues. Within the classroom the game was found to support active learner participation and externalisation of learners' thinking in interactions and discussions. This was particularly apparent as play progressed, where pupils were found to discover the way of thinking of other pupils. Most said they wanted to play the game again. Motivating factors had been that, with the system, learners not only had the freedom of access to given pieces but were able to create and contribute new pieces. As well as designing content, learners were dealing with an actual problem that was relevant to the real world. Limiting factors were that only one type of game had been selected, and also that the trial time was very short. There was little information about the pupils' discovery of others' thinking or contextual information about other use of computers/computer games by the participants – or about other forms of classroom activity encouraging collaboration. However, the authors noted that one group was dominated by a 'leader type' pupil. Hence, future research would seek to clarify the influence of individual personalities on group performance. The authors also intended to investigate the relationship between task complexity and distributed cognition.

5.5.4 Encouraging social and cognitivist skills

A study by Young and Upitis (1999) researched whether the educational computer game 'Phoenix Quest' (PQ) could support the development of cognitive and social skills. Furger (1998) was cited to suggest why PQ characteristics are attractive to girls: it is open-ended, players do not race against time and they can choose the length of time spent in each play. However, although all participants liked the PQ puzzles, the boys played the game significantly more often than the girls. They played to complete or 'win' in the shortest possible time, observing each other and trading strategies – mostly with boys, and even forming groups to do so. Other examples of adaptive interpersonal socio-behavioural competence included peer acceptance, positive peer reactions and friendships. No real evidence of negative social behaviour was observed.

Boys progressed further in two of the classes, girls in one, with little gender difference relating to progression in the fourth class. Peer comparisons were common. Challenge was an attractive games feature. The game was perceived as a girls' game, because of the female protagonist Julie. The girls corresponded more regularly with Julie, counselling her through perils, but did not correspond with the male protagonists as much as the boys did. Significantly for cognitivist objectives, 25% of students, particularly girls, did not relate to the maths aspects of PQ without guidance. Further research was recommended to establish ways in which teachers can engage students to communicate and navigate through new ideas and concepts within the computer game context.

5.5.5 Learners creating their own games

Minkel (2002) reports two 4-day workshops organised by software and computer games designer Alan Watts for 10 youngsters (age undefined), both boys and girls, at each of the Carver and Southeast branches of the Austin (Texas) Public Library. Participants learned how to organise a game development project: brainstorming ideas, setting up timelines and duties, and creating rules, graphics and sound. Using Macromedia Director Shockwave Studio, and with input from the children, Watts programmed the results into game code. The finished games ran in a web browser (eg Internet Explorer) via the Shockwave plug-in. The youngsters acted as beta testers (early game testers) and, after debugging, Watts burned the games onto CD-ROMs and gave a copy to each participant. Although the complex coding was seen to be too problematic for some participants, educational gains were considered to include learning how to work as a team. A follow-on session was envisaged for those able to deal with programming concepts.

5.6 Supporting multidisciplinary and vocational learning via computer simulations

Betz (1995) investigated whether computer simulations increase learning in an interactive multidisciplinary environment. The learners were freshmen engineering students in Materials and Methods of Construction One.

Initially they were asked to choose between two forms of independent study: using a computer simulation or reading an article. Each activity would require the same amount of time and work input, following which an examination would test how much had been learned, with the result counting towards class grades. The simulator option was not described as a game, to avoid creating student bias. A total of 69% of the experimental group and 72% of the control group opted to use the simulator; most of the reasons given related to computer literacy. The simulation game used was Sim City 2000, described as:

…a comprehensive city systems simulator with three dimensional graphics. The game includes elements of architecture, urban planning, sociology, economics, political science, environmental science, mathematics, demographics, history, management, computers, etc. This simulator approximates 'real world' conditions and phenomena of designing and building a city. It demonstrates the potentially successful or disastrous consequences of complex decision-making … It is not a game you can win, rather you set goals and try to achieve them.

(Betz 1995, pages 198–199)

The reading material was a composition of selected extracts from the bibliography in the Sim City 2000 user's manual.

The decision was made to compose a reading that would attempt to identify a wide range of social, political, economic and environmental impacts when solving problems in the construction and architectural engineering technologies. Student awareness of the non-technical consequences of their work was the goal of this reading.

(Betz 1995, page 200)

The experimental group used both the simulator and the reading. The control group used only the reading. Both groups were assigned an independent reading task, with one week to complete and an exam to follow. No classroom time or discussion time was allocated. Two weeks prior to receiving the reading assignment, the experimental group had to sign up for the simulator activity, which was to be completed within three weeks. The examination consisted of 20 multiple-choice and true/false questions that tested knowledge, understanding and application of the concepts. A 'blind' follow-up survey (ie an anonymous survey) was given to the experimental group at the end of the study, to focus on student perceptions and attitudes.

The examination results indicated that there was a tendency for the experimental group who used the simulator to learn more. The survey results showed that this group preferred using the simulator to reading. It was the simulator and reading in combination that facilitated understanding of the issue:

The reading provided the concepts and theory that gave them strategies when using the computer simulator;

while the simulator provided

…the visual and casual images to allow students to see what happens when they applied the reading.

(Betz 1995, page 204)

A further comprehensive study was envisaged using a larger population group. Meanwhile the view was that:

Increased learning occurs by problem solving in a complex interactive multidisciplinary environment and by 'seeing' causal relationships between individual actions and whole systems. The broader implications of using computer games in the classroom are for students to become more effective learners and thinkers enabling them to make connections across the curriculum. (Betz 1995, page 195)

Support for the Betz findings appears in Roubidoux *et al.*'s (2002) study, which found that the instant feedback and accessibility afforded by a computer simulation was appreciated by learners. The researchers worked with two heterogeneous groups of fourth year medical students from the University of Michigan Medical School. They introduced a specially designed interactive breast imaging game as a compulsory adjunct to their course. The initiative was to test student acceptance and motivation for the intervention. It was found that the images contributed significantly to educational value (93.6%), due not least to the instant feedback provided by the game. The website was also liked as it provided additional reinforcement of learning beyond that of the handout/lecture (88.8%) and was easily accessible (96%). Over 70% of the students thought that it would be appropriate for other medical activities also, while 74% would recommend the game to others. However, the authors acknowledged that this first phase of a continuing project did not investigate the effect on a radiologist interacting with the game, nor did the study test the hypothesis of whether the problem solving inherent in the game would improve retention of the material. The results could also have been affected by the novelty value of the website: an internet search had identified no other web-based computer games for medical students.

Further insights concerning the effect of simulation games on vocational learning come from Helliar *et al*. (2000). They used 'Finesse', a portfolio management game, to teach finance to HE (university) students at undergraduate and postgraduate levels. The game had been developed at three universities and enabled students to build on material already covered in lectures and tutorials. Goals were to:

- demonstrate to students ways of applying theories and models learned in the classroom
- afford them instant access to new material so that they could update their portfolios
- support the development of transferable skills via teamwork in a cooperative learning environment
- minimise the time tutors spent monitoring the system, so that they could focus on the educational content
- ensure uniformity of access from different computing platforms in different institutions
- encourage frequent use via easy and flexible access
- provide realism via an element of competition and a benchmark for students to map their performance.

An earlier manual version of the game had met with difficulties. It proved costly in terms of lecturers' time, requiring a person-day a month to manage the portfolio transactions of the groups. To keep it manageable, portfolio changes were only possible on a monthly basis. A limited menu of available securities meant that only 150 equity investments were permitted within the time constraints. Realism was undermined in that transaction costs were crudely accounted for: only capital gains were recorded, ignoring dividend income, which is important to investors in planning expenditure. Finally, lecturers were unable to monitor group interactions or to evaluate the proportion of the group involved in making the different transaction decisions.

There were indications that the web-based computer game met all its objectives. It enabled application of theory and also teamwork throughout the entire game period. Students seemed familiar with the system's features and screens. Most had considered transaction costs and theory in decision-making and had read widely. They appeared to be aware of, and to have made decisions in respect of, different investment strategies and general economic indicators. Questionnaire responses suggested that they had enjoyed the game, especially the vocationally relevant features concerning share dealings and portfolio evaluations. The game could be accessed via many sites and was therefore considered transferable to other educational establishments. However, the historical information provided by the system did not seem as helpful to students as had been hoped.

5.7 System-initiated adaptive advice versus learner-requested non-adaptive background information

Leutner (1993) investigated the effects of adaptive and non-adaptive instructional support for guided discovery–learning with computer-based simulation games. The simulation game Sahel Zone was used for the study. In this game the student plays the role of farmer, making general decisions in the course of the farming year and also determining the use of 10 lots of land that differ in steepness. Decisions are affected by unchangeable climate and ecological factors. During the game, in 'exploration with adaptive advice' mode, the learner is provided with warnings if their decisions are likely to lead to problems.

Experiment one was conducted with 64 seventh grade students (equivalent age unstated) from schools in the Nürnberg region of Germany. Students were randomly assigned to groups with 16 in each. A pre-test measured knowledge, intelligence and some non-cognitive aptitudes. A week later the experiment took place: four different program versions were installed on eight PCs in a computer room, then the groups of students were allocated to each PC at random. A short tutorial computer program was used prior to game play. There then followed a 45-minute experimental exploration phase, where students could restart the game as often as they wished, and a 30-minute test phase, where students demonstrated their skills. A week later, a criterion-reference test measured verbal domain and verbal game knowledge. Game functional knowledge was also measured.

Experiment two was conducted with 38 university students: 19 per group, allocated at random. Material and procedure were adopted from the previous experiment, with all activities taking place on the same day.

There were signs that system-initiated adaptive advice increased verbal domain knowledge but decreased game performance. Learner-requested non-adaptive background information, on the other hand, had longer-term effects. These findings are similar to those of two studies carried out by Small and Samijo (1997), who used the game Myst to investigate the motivational effects of providing informational clues to users of a CD-ROM game. Participants (39 undergraduate male and female volunteers) showed a significant decrease in curiosity after receiving informational clues but the opposite was the case where they received informational help sheets (ie they displayed significantly greater curiosity where they were free to look up the information as and when they needed it).

Leutner's (1993) study highlighted the need for attention to the individual differences in aptitude when fitting the learning situation to the specific needs of a student. Future research would need to approach the subject from a process perspective.

5.8 Supporting the acquisition of a complex skill

Day *et al*. (2001) investigated the acquisition of knowledge structures by 86 men via a complex video game: Space Fortress. The main objective of the game is:

…to fly a ship in frictionless space while battling a space fortress and avoiding being damaged or destroyed by the fortress and foe mines.

Control of the ship was via a joystick with an inbuilt trigger for shooting mines. Bonus points could be scored by depressing a 'friend or foe' mouse button at appropriate times. An information panel displayed component scores and total score, plus a range of information needed for navigation and action. Game play took place over three consecutive days. It included a 40-minute introduction that made use of videotaped instructions, mini individual practice sessions and a videotaped review of instructions and strategies. There were nine acquisition sessions, each involving 10 games and conducted in two parts: eight short practice games, performed with a partner and swapping roles after each game, and two short test games, performed individually. The players completed a two-game retention session, then a 10-game reacquisition session. This was followed by a two-game transfer session, where the joystick was replaced by keyboard controls. Finally, participants completed a two-game return-from-transfer session, using the standard joystick version of the game. Findings supported proposals that:

…knowledge structures should be regarded as a potentially useful training criterion and that they play an important role in the development of skilled performance (Kraiger et al*. 1993; Kraiger and Wenzel 1997).*

(Day *et al*. 2001, page 1030)

The findings were also consistent with proposals by others (Gagne and Glaser 1987; Glaser 1990) that structured knowledge aids retention and transfer.

An important implication of the study was said to be that:

…measures of knowledge can be viable indices of training outcomes. However, this viability appears to be dependent on the techniques and operationalisations that are used.

(Day *et al*. 2001, page 1030)

A limitation of the study was acknowledged to be that knowledge structures were only assessed post-acquisition. In view of the 'novel and unique' nature of Space Fortress, this was seen as less critical. Nevertheless, it was acknowledged that a pre-test would be useful in assessing trainees' prior knowledge structures. Future research was called for to investigate how participants' knowledge structures change during the course of acquisition, retention and transfer. Such research should assess whether the findings of the current study could be generalised to different techniques of measuring knowledge structures.

Section 6 What are young people's experiences and preferences in using computer games for learning and for leisure?

6.1 Recreational games and gender issues

Both males and females enjoy computer games with fun, challenge and struggle against some kind of opposition. The very process of game play (ie the activities and strategi es inherent to engaging the player with the game at each level and motivating them to complete the entire game) is in itself motivating to the user (Prensky 2002). There need not be violence: the struggle can be to raise the level of one's own performance, such as in quiz games (Mitchell 2003). Players like games with goals and scoring opportunities where the speed of an answer counts. They like audio effects and unpredictability (Malone 1981, cited by Randel *et al*. 1992). This has been observed both with young children (Malone 1981) and with young adults (Mitchell 2003).

Research findings into different play patterns of boys and girls suggest that females enjoy games with characteristics which they consider to be fun, such as games played against the computer, puzzles and quiz games (Griffiths and Hunt 1995; Yelland and Lloyd 2001; Mitchell 2003). Females have also been bored by lack of screen variety in some simulation games (Dempsey *et al*. 2002).

As noted in Section 2.6, where women are not attracted to simulation games this may be because of factors such as marketing as well as game design (Subrahmanyam *et al*. 2001). Computer games were traditionally designed and marketed almost exclusively for males by males (Griffiths 1996), with a focus on violence and competition and under-representation of female characters. Males play to win and are significantly more likely to play sports simulations and violent games and adventure games. Such games may have tended to appeal less to females because they require visual and spatial skills such as depth perception and image solving, areas where males have tended to perform better (Mackoby and Jacklin 1974, cited by Phillips *et al*. 1995). Or, their lack of appeal may relate to girls having been socialised into feelings of incompetence and alienation from the world of computer technology, which they may perceive as:

> *…precise and unforgiving, often lacking in creativity and having little connection to people.* (Koch 1994, page 14)

Vail (1997) reports that girls like games with a story-line that is based on reality, with realistic–familiar characters and emotional issues to resolve. She reports a conversation with Sheri Graner Ray, the product developer for a games manufacturer:

> *Females, she says, are not as visually stimulated as males but are more likely to be stirred emotionally. In resolving conflicts, males want a head-to-head conflict, while females prefer compromise and diplomacy. Girls don't want to be lone heroes in virtual reality, saving the universe on their own. They want companions. They take their opponent's feelings into account. In the end, females want emotional issues resolved. 'They want stories that engross them, characters and endings,' says Ray. 'The solution must benefit the player and the other characters'.*
>
> (Vail 1997, page A21)

Vail (1997) also indicates that girls are more task-oriented than boys, pointing to the success of the game Barbie Fashion Designer and suggesting that, rather than being turned off by computer technology, girls need applications to enable tasks relevant to their interests, for example educational software like Barbie that allows use of the computer as a creative tool. Similarly, others' findings (eg Kiesler *et al*. 1985; Subrahmanyam *et al*. 2001) point to the need for more educational games software that is designed to be consistent with feminine values and goals.

Gender differences may already be changing. Schleiner (2001) notes that considerable shifts in gaming culture appear to be taking place, with an increase in online games and the number of female players. There are also popular female characters, for example Lara Croft, seen as the first female 'cyberstar'. However, Lara's 'gender make-up', far from being in tune with feminist values (ie 'non-individualistic, non-competitive, community-oriented' (Schleiner 2001, page 222)) is seen to incorporate a range of configurations:

…Lara as Female Frankenstein Monster … as Drag Queen … as Dominatrix, Femme Fatale … as Positive Role Model and even as a Vehicle for the Queer Female Gaze … delighting in the abject annihilation of her foes. (Schleiner 2001, pages 222–224)

6.2 **Educational computer games**

Educational software is typically disliked by students 'because the fun factor is missing' (Leddo 1996, page 23). Educational games are preferred to standard classroom instruction, but – and this is a big but – students:

…would never voluntarily play such a game outside of class. (Leddo 1996, page 24)

Crucially, learning games need to be perceived to be as good as commercial games. To sustain engagement, fun, speed and ease of use are key, as is variety: in context, mission and complexity (Mitchell 2003). An overview of player position is important in adventure games. Some learners like games with elements of 'mystery, intrigue and suspense' (Dempsey *et al*. 1996, page 7). Graphics, colour and audio effects are liked, so quality and design is important (Dempsey *et al*. 1996; Leddo 1996). Learners ask for novelty, surprise and humour, with little break in action – instruction should flow with the game and be clear and concise. High quality functionality should include help functions, tips and 'winning prototypes', to facilitate and sustain both engagement and incidental learning (Dempsey *et al*. 1996, page 9). The nature of performance feedback and remediation is very important; for example, games characters themselves might 'offer instruction by making suggestions and offering wisdom' (Leddo 1996, page 25). Players want the game to be fast and challenging; a time element should be incorporated in graphic form (Mitchell 2003). They want the game to become more difficult as they improve. However, increased confidence is important in encouraging adults to persevere with a game of skill. This is particularly important for females (Dempsey *et al*. 1996; Leddo 1996), and so game structure should not be too complex for player experience (Jacobs and Dempsey 1993, cited by Dempsey *et al*. 2002). Players want control over as many options as possible: speed, level of difficulty, timing, sound effects and feedback (Dempsey *et al*. 1996; Leddo 1996).

The Leddo study (1996) found that most of the females did not feel that it was important to complete the games successfully and were much less likely to express confidence in achieving successful completion. Issues of race and gender were keenly felt and spontaneously raised. For example, females complained that commercial games are male oriented. A balance of gender and ethnicity was requested. Proposed solutions included an option to play the game from the perspective of a main game character or to enable user choice via a character editor (ie a tool that allows modification of the character's gender, ethnicity etc).

Dempsey *et al*. (1996) found that females were less engaged by simulation games, for example finding the screen designs lacking in variety. A later Dempsey *et al*. study (2002) found that adults perceive simulation, adventure, arcade, board, puzzle and word games as a means of supporting the development of problem-solving and decision-making skills, and want the structure of the game to address the specific topic. There are mixed findings concerning some features of computer games. Some studies (eg Dempsey *et al*. 1996) found that violence in simulations distracted from learning, whereas Leddo (1996, page 24) had found that virtually all students, male and female, wanted 'some sort of combat/shooting in the game'.

6.3 **Mobile games**

Games designed for mobile devices have considerable potential for encouraging learning with young adults. According to small-scale research with young adults carried out by Ultralab (Mitchell 2003), the following aspects appear to be important.

- The correlation between visual aspects of the solution and achieving a correct answer acts as an attractor.
- Good graphics and design are appreciated (eg where the game moves from numeral or icon to word, thereby aiding spelling).
- Short, simple mobile games are liked, to complete quickly then move on to the next.
- Self-image is involved: completing lots of easy games boosts confidence.
- People are easily bored when revisiting resources, except where a game is found to be 'tricky', so a plentiful number and variety of games is important (eg interactive storybooks along the lines of a role-play game, games connected with aspects of physics, such as 'angles and force', games navigating roads using maps and directions).
- Casino-type card games, snooker games, darts and pin-ball games were thought useful for supporting the development of cognitive and spatial skills on mobile phones, though some would have to be in black and white, to suit a small screen.
- Simulation games like The Sims were thought unsuitable for most mobile screens – again size was an issue.
- Examples of skills you could learn in mobile simulations would be handling money and communication, especially if there was multiplayer functionality.

Section 7 What are the recommendations for the planning and design of educational computer games (or 'edugames')?

7.1 Design for blended learning solutions

Blended learning (a term that is increasingly found in relation to the use of computers for learning) is where students follow a programme or course that uses a combination of face-to-face (ie taught) and online media (eg an educational computer game).

Designers producing blended learning materials should bear in mind that educational games software, like any educational software:

…should incorporate or embody a sound educational philosophy, and should have clearly stated educational objectives and content.

(Becta 2001, page 6)

For example, games should afford purposeful interactivity 'to do with learning objectives or providing the learner with opportunities for understanding through collaboration, investigation or experience', while the design of learning tasks should encourage 'both individual accountability and productive interdependence' (Becta 2001, page 6).

Game design should acknowledge the role of the teacher (Becta 2001, page 6) and should facilitate the teacher's meaningful intervention (Lawry 1994). To this end the opinions of users are also important:

Design teams should include teachers, with feedback from child evaluators incorporated during development.

(Becta 2001, page 6)

Teacher–designers should identify gaps in the curriculum and associated instructional goals and objectives that would be effectively addressed by a game (Kelly and O'Kelly 1994). Although teachers lack the production resources of commercial developers and may lack sophisticated programming and design skills, many do, however:

…possess three qualities that will permit them to fill the instructional niches that are too small for the commercial producers: experience with students, knowledge of curricula, and desire to expand and apply their professional skills. Thus, teachers who invest the time in developing the necessary skills can focus on the design of instructional games, as well as other computer-based instructional support materials, that reflect the specific interests and instructional needs of the children in their classrooms and schools.

(Kelly and O'Kelly 1994, page 163)

7.2 Focus on structure rather than content

Designers of learning and teaching materials should examine features of games that make them successful (Randel *et al*. 1992). For example, Van den Herik *et al*. (2002, page 277) found that when resolving the game is the main target:

…decision complexity is more important than space state complexity as a determining factor … [and] *there is a trade-off between knowledge-based methods and brute-force methods … knowledge-based methods are more appropriate for solving games with a low decision complexity, while brute-force methods are more appropriate for solving games with a low state-space complexity …* [and] *there is a clear correlation between the first-player's initiative and the necessary effort to solve a game. In particular, threat-space-based search methods are sometimes able to exploit the initiative to prove a win.*

This is compatible with findings from the Becta Computer Games in Education Project:

What is captivating for players about games tends to be their structure rather than their content. Structure involves dynamic visuals, interaction, and the presence of a goal and rules that govern play.

(Becta 2001, page 1)

Aspects of games that are suitable for incorporation into educational software are listed in Table 4.

Table 4 Aspects of games suitable for incorporation into educational software (Becta 2001, page 1)

Technological	Narrative	Personal
Graphics	Novelty	Logic
Sound	Story-line	Memory
Interactivity	Curiosity	Reflexes
	Complexity	Mathematical skills
	Fantasy	Challenge
		Problem solving
		Visualisation

Designers should take note of new developments in game design. These include new 'graphical techniques, plot and character development, user interface design, and making the player learn' (Kirriemuir 2002, Section 10) as well as new intelligent search methods, developed using retrograde analysis in building databases (Van den Herik *et al*. 2002). Examples (Van den Herik *et al*. 2002, page 306) of new games incorporating such developments are:

- Lines of Action, a complex game where the solution is not expected until 2010
- Amazons, a complex game 'that often decomposes into independent subproblems, which are often one-player puzzles'.

Computer games offer selectable levels of difficulty, reinforcing learning with rewards, but these are intermittent – reinforcement is only partial. This is deliberate, to sustain interest in the game, but is a difficult balance to strike, particularly in view of widely differing gaming skills of potential players (Poole 2000).

Challenge is crucial. Games that no one can play do not sell, but instead of keeping them short and simple to facilitate learning, commercial designers:

…keep making the games longer and more challenging (and introduce new things in new ones) and still manage to get them learned.

(Gee 2003, page 6)

This is achieved via building in the same learning principles used in effective classrooms. According to Gee (2003, pages 49–50) essentially these principles are as follows:

- 'active, critical learning principle – all aspects of the learning environment … are set up to encourage active and critical, not passive, learning
- design principle – learning about and coming to appreciate design and design principles is core to the learning experience
- semiotic principle – learning about and coming to appreciate inter-relations within and across multiple sign systems (images, words, actions, symbols, artefacts etc) as a complex system is core to the learning experience
- semiotic domains principle – learning involves mastering, at some level, semiotic domains, and being able to participate, at some level, in the affinity group or groups connected to them
- metalevel thinking about semiotic domains principle
- learning involves active and critical thinking about the relationships of the semiotic domain being learned to other semiotic domains.'

7.2.1 'Edugaming': a new design approach

Fabricatore (2000) considers that the learning principles and learning gains associated with computer games should be exploited when designing games for educational purposes. Too often he finds 'edutainment' producers seek to make the game subservient to the educational process. Where the resulting products are marked by the absence of the role of struggle, they lack cohesion between game and cognitive task and are not true games.

He calls for a new approach by designers of educational simulation games that involves:

…not thinking what gaming experience can be the most motivating frame for some specific controlled learning activities, but rather how to create a virtual environment and a gaming experience in which the contents that we want to teach can be naturally embedded with some contextual relevance in terms of the game playing … learning tasks must be contextual to the game in the sense that they must be perceived by the player as a true element of the game-play.

(Fabricatore 2000, page 15)

Referring to Nintendo's Super Mario Bros, a leisure game where bricks scattered through every scenario are integral to game play and enhance the fun, he suggests that these:

…could be hiding anything else, for instance letters or numbers, and they would still be perceived as part of the game-play.

(Fabricatore 2000, page 15)

For proof of concept, he designed and produced six Game Boy games. He reports (page 16) that these were successfully tested in classrooms with around 300 children aged between six and eight, supervised by their teachers. The supervisors acknowledged unintentional as well as intentional learning gains and also:

…general improvements in terms of discipline, concentration and eagerness to understand technological issues related to the games they were playing.

Fabricatore calls this alternative design approach 'edugaming', where there is:

…no unnatural barrier separating learning from gaming.

(Fabricatore 2000, page 16)

The concept of 'edugaming' appears to coincide with Prensky's (2001) views on the creation of digital game-based learning. Prensky (page 179) notes that games should be fun first of all and then should encourage learning second. He considers that many games that purport to be game-based learning really are not true games, but notes that users know the difference. He advocates that designers of learning games should ask themselves the following questions (in the order given).

- Is the game fun enough that someone who is not in its target audience would want to play it (and would learn from it)?
- Do people using it think of themselves as 'players' rather than 'students' or 'trainees'?
- Is the experience addictive? Does it produce great 'word of mouth' among users? … Do users want to play again and again until they win, and possibly after?
- Are the players' skills in the subject matter and learning content of the game – be it knowledge, process, procedure, ability etc – significantly improving at a rapid rate and getting better the longer he or she plays?
- Does the game encourage reflection about what has been learned?

Identifying reflection as a 'disappearing skill', he suggests that simulation games should be designed to encourage this at multiple levels in order that users of such games can integrate new experiences into their current understanding. This view is shared by others (eg Stretch 2000; Becta 2001).

7.3 **Encourage active participation**

Most computer games are designed for the user's entertainment, not for instruction (Dempsey *et al*. 1996). Active participation is the key, as the player seeks to understand and control his/her play cycle while challenged by some form of opposition (Fabricatore 2000). Learning is usually incidental, or intentional only in respect of becoming a better gamer. Designers of educational games should therefore seek ways of applying incidental learning or gaming strategies to an intentional learning task. Here a statement of goals and objectives is important in engaging learners in a game, as are clear instructions. 'Winning prototypes' (ie examples of how to play the game) can support engagement and also incidental learning (Dempsey *et al*. 1996).

Intrinsically motivating games, where the game structure itself encourages learning, are preferable to extrinsically motivating games, where real or imaginary rewards are given (Dempsey *et al*. 1994; VanDeventer and White 2002). To facilitate intrinsic learning (which is learning of interest in its own right):

- offer a learning environment in a story format, 'using fantasy to provoke curiosity, allowing the learner choice and control, and providing opportunities for creativity' (Becta 2001, page 6)
- ensure context is relevant to young adults' lifelong learning (Brownfield and Vik 1983; Griffiths 1996; Prensky 2001)
- embed learning opportunities in the game structure and make links to external material part of the game (Prensky 2001).

Simulations should mirror real life in three important areas: content, context and process (Stretch 2000). They should provide support for the learner, with opportunities to consult an expert. Designers need to consider the situation in which the learning takes place. Grouping of the learners must be designed and the bridge between old and new knowledge addressed, and how learners will reflect on and display their learning must be considered (Stretch 2000).

We draw together here some further recommendations relevant to designing the structure of 'edugames' (based on Kelly and O'Kelly 1994; Oyen and Bebko 1996; Becta 2001; Dempsey *et al*. 2002; Mitchell 2003). 'Edugames' should:

- provide opportunities to exercise the skills of the 'gaming generation': leading on from 'arcade' skills
- keep the start up simple: target audience thresholds of interest and concentration may be low
- keep the games and instructions fairly simple to minimise levels of frustration and time spent learning the rules of the game
- ensure a clear route through the software, and constant access to information that aids navigation
- provide short modules (to maximise the likelihood of satisfactory outcomes) but also make available longer sessions (to encourage involvement)
- consider target audience needs when determining the pace and duration of the game
- ensure that the game structure suits the learning objectives (eg when designing for memory recall, avoid incorporation of multiple goals and other distracting components that can inhibit performance)

- engage players in intrinsic learning via multimedia features that complement each other
- enable user control over the learning tools, so that they can access introductions, instructions, tutorials, clues etc as desired
- vary the nature of challenge, means of scoring etc and provide different levels of challenge
- ensure that frequent play enables progression through different skills levels and skills sets and that there is a means of recording progress if required
- integrate feedback and debriefing into the game, encouraging a focus on process as well as on performance measures achieved. Different kinds of feedback should be provided (ie system-initiated feedback as well as opportunities to access debrief or real-world feedback)
- afford the chance to correct and learn from errors so that learners can improve performance and achieve goals
- cater for learners' affective and social needs, with opportunities for interaction with human as well as virtual agents (peers, teachers, mentors)
- encourage reflection, evaluation and participative learning via opportunities for discussion, annotation and input of resources. Support and prompts should be provided to facilitate effective discussion
- ensure the game has a satisfactory way of ending.

7.4 **Cater for diversity**

This review has found a number of recommendations that individual differences concerning both learners and design-specific aspects of the situation are important and need to be considered. As the Becta project (2001, page 6) notes:

Software should be designed to be inclusive of a wide range of aptitudes and abilities, providing support for the learner and some guidance for teachers planning to use the software.

The game structure should offer users plenty of options, to suit their differing needs. Advice found in the literature for designers includes:

- make available a range of themed activities relevant to a wide range of interests and skills
- widen accessibility by developing games for different platforms (eg short, downloadable, single-user games work well on most current mobile devices)
- offer a choice of interface (eg various combinations of video, audio and text, use of colour etc)
- include learning templates and example solutions
- pay attention to gender preferences: gear games to both male and female audiences by including positive female characters
- take ethnicity into account
- enable interaction with realistic–familiar characters, not just fantasy characters
- enable use of the computer/device as a creative tool
- provide a non-game option for those who are not engaged by the learning game.

Importantly, designers who create fantasy role-play games should not only provide players with opportunities for assuming different identities, both virtual and projective (eg 'learner as scientist'), but also seek to promote an appreciation of diversity by encouraging players' reflection on the new identities they have assumed and on other identities, real, virtual and projective, that they have already formed.

In seeking to cater for diversity, designers should bear in mind players who may have special needs, such as a visual or hearing impairment, and consider making use of specialist interactive software.

7.5 Address the challenges of assessment in an open-ended environment

Performance assessment using scoring rubrics (descriptive categories) that describe different levels of proficiency is considered unsuitable for computer games as:

> *…the descriptions of the proficiency categories tend to be too imprecise for a computer to match to a student's behavior and the scoring process does not specify the cause of the student's weaknesses. Our goal is to assess the student in such a way as to bolster the instructional process.*
>
> (Leddo 1996, pages 24–25)

Therefore, instead of attempting to encode the correct solution path for each case, designers could decide, based on the learning objectives, the general characteristics of a sound problem-solving approach. The game can monitor activities and outputs; however, this is not enough to identify the underlying thought process. A possible solution here is to have the game characters probe student behaviour in the course of their interactions. Once the game has determined the status of the student's proficiency, it can make decisions on how to evolve the scenarios to embody more challenging learning objectives or to offer various forms of remediation – again these can be offered via the game characters themselves (Leddo 1996).

7.6 Counteract the potential negative impact of frequent gaming

As has been reported earlier (see Sections 2.2–2.6 above), there are a number of negative attributes connected with frequent game use. The following list, drawn together from the literature, suggests how such attributes might be negated.

- Help players keep fantasy worlds well in perspective: take advantage of mobility in the real-world environment to encourage ambient and participative learning.
- Be mindful of likely cumulative effects of violent media on personality: meet players' need for challenge and an 'opponent' in ways that can counteract aggressive mind-sets. For example, design negotiation and competitive elements into game structure and tie these closely to specific learning objectives.
- Challenge the imagination by enabling exploration and creativity within strategic contexts.
- Afford enjoyable ways to help users value the benefits of patience as well as looking for immediate payoff.
- Explore how environments and tools could encourage player creativity in enhancing and extending the game towards positive ends.

7.7 Cater for management, networking and wireless issues of multiplayer computer games

Cheung and Siu (2002, page 124) point out that:

…the development of computer games for Internet access requires consideration of issues such as the browser environment, the operating system used for delivering the computer game material, the browser software and the tools used in the client computer and the software tools used for developing the computer game material.

Smed *et al*. (2002) draw attention to specific problems posed by real-time, distributed (in the sense that players might not be located near to each other), multiplayer computer games (MCGs). Developers are advised to take into account:

- the technical boundaries (bandwidth, latency, computational power) within which the MCG is to operate
- communication architectures (peer-to-peer, client–server, server–network) and both data and control architectures (centralised, distributed, replicated)
- scalability, to allow the MCG to adapt to resource changes
- security, to combat cheating and vandalism.

In respect of security, Yan and Choi (2002) consider that it will be important for designers of educational software to seek ways of distinguishing between smart play (eg good use of tactics) and cheating. They note that players can cheat in online games in a number of ways, for example by:

- collusion
- abusing procedure or policy (eg 'escaping')
- compromising passwords and/or denying service to peer players
- lack of secrecy
- lack of authentication
- internal misuse
- social engineering
- modifying game software or data
- exploiting bugs or design flaws.

Traditional security mechanisms such as 'encryption, authentication, integrity checking, digital signature and cryptographic protocol' (Yan and Choi 2002, page 130) do not solve all these security problems. A systematic approach in preventing and detecting cheating is required, alongside management and policy means. They recommend (Yan and Choi 2002, pages 130–131):

- inbuilt cheating detection
- making players security aware and educated in how to cope with a potential security threat
- good password practice and management (eg using passwords based on mnemonic phrases, requiring re-authentication on password change, prohibition of easily guessable passwords by integrating a proactive checker with the password mechanism)
- the traditional bug patching approach
- an active complaint–response channel
- logging and audit trails
- post-detection mechanisms that enable cheaters to be punished via disciplinary means and the victim damage to be restored.

Service availability of game servers is a critical issue for online games. The problem has been addressed at Cambridge University by developing special servers (which the developers call 'XenoServers') to deliver the required quality of service (eg their 'XenoService'). It is suggested that designers can help further by ensuring server-end game software is designed to drop non-game packets by distinguishing them from game packets (Yan and Choi 2002, page 130).

The use of wireless online games is increasing rapidly. As Mok (2002) details, designers are developing games for mobile devices that offer anywhere, anytime access via new technologies such as the General Packet Radio Service (GPRS) and Java 2 Platform, Micro Edition (J2ME). They will be able to use emerging technologies such as the Interactive Dynamic Crypto to provide a safe, fair, game environment. This proposed system is being designed to enhance the security of data transmission through wireless networks and a multi-tier architecture and to enhance the performance and management of multi-user wireless online games systems that can be set up for real-time interaction.

Section 8 Summary and conclusions

The review set out to investigate the published research literature, guided by the following research questions:

- what is the impact of the use of computer and video games on young people?
- why use computer games for learning?
- how have computer games been used for learning?
- what are young people's experiences and preferences in using computer games for learning and for leisure?
- what are the recommendations for the planning and design of educational computer games (or 'edugames')?

Because the aim of the m-learning project is to use mobile technologies to try to re-engage young adults (aged 16–24) in learning and to start to change their attitudes to learning and improve their life chances, the m-learning partners also wished to find out if studies had been conducted using computer and video games with young adults who have:

- literacy, numeracy and other basic skill needs
- social and behavioural issues relating to youth education.

The following sections briefly outline the main findings relating to each research question. However, it will be seen that many of the areas report contradictory findings, and so it is difficult to be definitive. The chapter concludes with suggestions for further research.

8.1 What is the impact of the use of computer and video games on young people?

This review has found that computer games appear to be firmly entrenched in youth culture (eg Randel *et al*. 1992; Griffiths 1996, 1999; Anderson and Bushman 2001; Bensley and Van Eenwyk 2001) and are also increasingly used by people into their late twenties and beyond – no doubt as the gaming generation matures.

It has been found (eg Ellis 1990; Anderson and Dill 2000) that excessive gaming can produce severe negative psycho-social effects; these range from low self-esteem and dependency to asocial and aggressive attitudes and behaviours, such as gambling and stealing to finance play. However, against this, catharsis theory and drive reduction theory are cited (Bensley and van Eenwyk 2001) to suggest that aggressive play can also have a relaxing effect on the user and be a way of balancing aggression.

There are implications for learning: the time taken up (predominantly by males) in frequent gaming can negatively impact on schoolwork (eg Griffiths 1996, 1997b). On the other hand, computer games have been found to serve a range of educational functions (eg tutoring, exploring and practising skills, entertainment and attitude change). There are also assertions from the literature that might be useful in deployment or design of instructional games and associated research (Dempsey *et al*. 1994). Gaming skills can also be seen as a precursor to computer skills and, hence, to lucrative career options, an area where females have traditionally been missing out (Natale 2002).

It therefore seems appropriate to seek greater understanding of the games culture to find ways of designing real learning games that appeal to young people and that could have a strong and positive impact on their education (Upitis 1994; Jayakanthan 2002). Designers of educational software also need to devise a wide variety of games to suit many learner types and interests in order to benefit both male and female players.

8.2 Why use computer games for learning?

Computer games engage. They are seductive, deploying rich visual and spatial aesthetics that draw players into fantasy worlds that seem very real on their own terms, exciting awe and pleasure (Poole 2000). They motivate via fun ('part of the natural learning process in human development', Bisson and Luckner 1996, page 112), via challenge and via instant, visual feedback within a complete, interactive virtual playing environment, whereby ambience information creates an immersive experience, sustaining interest in the game. They are fast and responsive, and can be played against real people anywhere in the world, or against a computer. They handle huge amounts of content and can be instantly updated and customised by individual players (Prensky 2001).

It has been suggested (Prensky 2001) that computer games can incorporate as many as 36 important learning principles. For example, they put learners in the role of decision-maker, pushing them through ever harder challenges, engaging the player in experimenting with different ways of learning and thinking (Gee 2003). Crucially for learning, computer games can provide instant feedback (Prensky 2001).

Imaginative, well-produced simulation games encourage visualisation, experimentation and creativity in finding new ways to tackle the game (Betz 1995; Gee 2003). The combinations of video, audio and text are useful in accommodating different learning styles, thereby promoting confidence (Berson 1996) and encouraging multi-modal literacy. The games enable engagement in activities otherwise too costly to resource or too dangerous, difficult or impractical to implement in the classroom (Berson 1996), as well as those that are hard to accomplish by other means (Thomas *et al*. 1997). In the context of lifelong learning, simulation games afford a realistic framework to use technologies as a means to an end and so can prepare learners for the world of work (Filipczak 1997; Saunders and Smalley 2000; Griffiths and Davies 2002). This is active learning, as players experience the subject domain or situation in new ways, form new affiliations and thereby prepare for future learning and problem solving in the domain or transfer of learning to related domains (Gee 2003).

They enable exploration of interpersonal relationships, thereby encouraging cooperative and competitive behaviour within a strategic context (Filipczak 1997; Gee 2003) and can support meaningful post-game discussion (Kirriemuir 2002). In these different ways they encourage construction of meaning, which is the important process underlying transfer, irrespective of 'whether such meaning is constructed more inductively or more deductively' (Greenfield *et al.* 1994, page 81). Further, outstanding gaming expertise is linked to 'expert' behaviours such as self-monitoring, pattern recognition, problem solving, principled decision-making, qualitative thinking and superior short-term and long-term memory (VanDeventer and White 2002).

There are opportunities with new and emerging technologies for providing effective coaching in an adventure games environment. For example, the player can experience a role or roles in a near real-life setting and at the same time learn about the setting itself, developing intuitive skills at coping in that environment (Khan 2002). When connected to an intranet, learners can interact simultaneously with other users as well as with the environment itself (Lee 2000). Increasing use of mobile devices and of handheld games consoles such as the Game Boy Advance offers opportunities for developing educational software to support blended learning, for example classroom-based learning linked to learning online and/or outdoor activities such as museum visits and field trips (Kirriemuir 2002).

There are, however, some educational considerations. For example, for skills to be enhanced by game playing, players must possess them to some degree already (Subrahmanyam *et al.* 2001). Teacher bias towards a particular learning method and teacher input into debriefing can affect the effectiveness of games in encouraging learning (Randel *et al.* 1992). A number of risk factors can impact negatively on encouraging learning via computer games. For example, learning objectives may not be congruent with game objectives, games can distract from learning as players concentrate on completing, scoring and winning, and games require suspension of belief – it may be difficult to retain learning acquired in that state (Clark 2003). What seems like a game to someone will feel like work to another; hence, it is argued the intention should be enlightenment, not entertainment. There is also an opportunity cost of learning via computers: time spent in front of a screen could instead be spent, for example, in social or sport activity (Stoll 1999).

8.3 How have computer games been used for learning?

Computer games have been used to serve a variety of functions in training and educational environments, for example:

> *Tutoring, amusing, helping to explore new skills, promoting self-esteem, practicing skills, or seeking to change attitudes.*
>
> (Dempsey *et al.* 1994, page 1)

Even simple types of game have been used to address specific learning outcomes such as recall of factual content or providing the basis for discussion (Dempsey *et al.* 1996), while complex games, in particular, have been seen to support cognitive processing and the development of strategic skills, increasing learning and recollection capabilities (Blake and Goodman 1999), and promoting computer literacy skills (Natale 2002).

8.4 What are young people's experiences and preferences in using computer games for learning and for leisure? And what are the implications for designers of educational software?

The reasons for playing games appear to be gender-related – males can focus on winning a game, whereas females can focus on completion. Either way, struggle is a key factor in motivating learners. Struggle is also important in supporting cognitive learning, but there should be a satisfactory end to each game, to reflect an element of progress. Context is also key: it must be meaningful and relevant to target audiences. There is a strong case for games to incorporate creative tools, giving the learner control. This can extend to allowing them to enhance the game or create new games. It is true that few learners may want or feel able to take up such options and that even if they do so the results may be unsatisfactory. Nevertheless, it is vital to encourage aspiration in learning, with at risk students in particular. It would be beneficial for the game to afford opportunities for players to personalise the medium, thereby allowing them to key into their lifelong learning experience. This is important because games should not just relate to curriculum, but also to youth culture and learning styles.

The implications for the planning and design of educational computer games include the issue of the cognitive style changes associated with a generation growing up in the age of digital computer games. If complex games support the development of 'expert behaviours' such as pattern recognition, strategic decision-making, superior memory skills and self-monitoring, students having honed such skills may become disenchanted with learning games if there is little opportunity to deploy those skills. Educational games should therefore engage and stretch players in learning at different levels, from the straightforward to the sophisticated.

This review has indicated that producing educational games that are true games is a worthwhile activity. Indeed, it is a necessary development if we are to reach out to current and future generations in ways that cater for their needs and expectations. Educators and industry experts must work together to research the computer culture, to ensure that innovations are capable of engaging and sustaining interest. Designers should not only explore ways of combining new technologies such as mobile networking, context-aware computing and sensor-based computing but should also ensure the new generation of edugames builds on the principles of successful commercial games such as risk–reward structures.

However, there are budgetary implications in following this route. The modest profits thus far gained from educational games pale into insignificance against the huge profits to be made from commercial games. As the required investment is correspondingly large, the endeavour requires collaboration between educationalists and industry and the commitment of policy-makers and funding bodies.

8.5 Suggested areas for further research

A number of issues have been highlighted in previous literature reviews/ meta-analyses about the use of computer and video games for learning; namely, the literature base is relatively sparse, findings often conflict in their outcomes, there is a lack of studies regarding educational games use by adolescents, some studies have methodological problems, and longitudinal studies are needed.

Further, in reviewing the literature, a number of authors have suggested particular areas of investigation. The examples below are from Subrahmanyam *et al*. (2001).

- The 'cognitive and social effects of the newer generation of video games and other software, especially the multi-user games now available on the Internet … [exploring] more fully the relation between violent games and children's aggression, particularly whether repeated game playing can desensitise children to the impact of violent behavior' (Subrahmanyam *et al*. 2001, page 26).
- The long-term cumulative impact of interactive games on cognition and academic achievement (Subrahmanyam *et al*. 2001, page 26). This concern was also expressed by Griffiths and Davies (2002).
- 'The increasing dominance of simulated worlds (vs real-world experiences) in children's daily experiences and their impact on children's and adolescents' developing identities and sense of reality are topics meriting serious attention' (Subrahmanyam *et al*. 2001, pages 26–27).

These are areas that appear to be relevant to the social and educational development of the m-learning target audience. Other relevant issues include:

- investigating how the aura of a computer game (background colour, sound etc) may affect cognitive and physiological responses (Wolfson and Case 2000)
- identifying and testing strategies for intentional transfer and also seeking knowledge and insights on how expertise is acquired by different learners (VanDeventer and White 2002)
- identifying '…whether the (un)intentional learning that occurs during formal instruction – semantic-based knowledge of simple cognitive structures during early school years – may be considered a form of incidental learning … and, if so, what its relation is to implicit knowledge and how it can be used more adequately as a valuable instructional tool (e.g. through the use of video games)' (Rosas *et al*. 2003, page 77)

and, crucially, from the m-learning project point of view:

- investigating 'the usefulness of games for students with marginal skills or marginal motivation' (Randel *et al*. 1992, page 272).

Finally, the authors would like to reiterate the main conclusion of this review. This is that to date there has been a lack of studies undertaken with young adults using computer and video games who may have literacy, numeracy or other basic skill needs and also little reporting of social and behavioural issues in this age range relating to education of young adults.

Appendix Method used for finding research studies about learning with computer and video games

The aim of the review was to identify, analyse and synthesise the relevant world literature about the use of computer and video games for learning, principally by young adults. Because of the scope of the m-learning project, the literature base encompassed a number of different areas, including:

- the use of information technology (IT) and information and communications technology (ICT)
- the acquisition of basic skills (including literacy and numeracy)
- post-compulsory education
- youth issues
- learning difficulties/disabilities (with a focus on the physical impairments of blindness or deafness).

Such literature was accessed by searching academic journals, general citation indexes, electronic databases and gateways, literature abstracts, internet sites (including research and government sites), papers given at research conferences and newspapers. The searching was undertaken in two stages, first during June 2002, when the bulk of the studies were found, and then updated in January 2003 (and incrementally thereafter).

Keywords used

The keywords used for searching the literature base were agreed by the m-learning partner organisations as follows:

- computer games
- video games.

Inclusion/exclusion criteria applied

The inclusion criteria applied to identifying studies was that the study was undertaken since 1990, thus using a 13-year search base, where most literature was expected to be situated. Any studies which were written in a language other than English were excluded.

Literature searches undertaken

Academic journals and internet sites searched are listed below, grouped by their focus.

Note: for some journals listed in the Appendix it was not possible to access all issues as some were missing from the library or unavailable online etc – these have been marked with a ▷.

Use of information technology (IT), information and communications technology (ICT), and computer and video games

Active Learning (1994+)
(This journal began in 1994, and so the search base relates to literature 1994–2003. This notation (+) is used further below.)

Alt-J (Association for Learning Technology Journal) (1993+)

British Journal of Educational Technology

Computer Assisted Language Learning

Computer Education ▷

Computers & Education

Computers in the Schools
(formerly called Information Technology and Learning)

E.Learning Age (2001+)

Education and Information Technologies (1996+)

Education, Communication and Information (2001+) ▷

Educational Computing and Technology ▷
(formerly called Educational Computing)

Educational Technology

Educational Technology Research and Development
(formerly called Education Communications and Technology)

Information, Communication and Society

Information Technology and Learning (ceased in 1993)
(This journal ceased in 1993, and so the search base relates to literature 1992–1993. This notation (ceased) is used further below.)

Information Technology, Education and Society (2000+) ▷

InterActive: Managing ICT in Schools (1995+) ▷

Interactive Learning Environments (1995+)

Journal of Computer Assisted Learning

Journal of Educational Computing Research

Journal of Educational Media

Journal of Information Technology for Teacher Education (1992+)

Journal of Interactive Learning Research
(formerly called Journal of Artificial Intelligence in Education)

Journal of Research on Computing in Education

Learning and Leading with Technology
(formerly called Computing Teacher)

Technology and Learning

Association for Learning Technology
www.alt.ac.uk

Becta (British Educational Communications and Technology Agency)
www.Becta.org.uk/index.cfm

British Computer Society
www.bcs.org.uk

Digital Library and Archives
http://scholar.lib.vt.edu

From Now On (The Educational Technology Journal)
www.fno.org

Game Studies
www.gamestudies.org/index.html

International Journal of Technologies for the
Advancement of Knowledge and Learning (TechKnowLogia)
www.techknowlogia.org/welcome.asp

IPCT-J (Interpersonal Computing and Technology Journal)
www.emoderators.com/ipct-j

National Education Computing Archive
www.ultralab.anglia.ac.uk/pages/ultralab/ed_archive/contents.html

National Grid for Learning
www.ngfl.gov.uk

National ICT Research Centre
www.learninglab.org.uk

Tech Learning
www.techlearning.com

The Information Network on Education in Europe (EURYDICE)
www.eurydice.org

Acquisition of basic skills (including literacy and numeracy)

Basic Skills (1995+)

Journal of Adolescent and Adult Literacy

Journal of Literacy Research

Literacy and Learning (1997+) ▷

Literacy Today (1994+)

Numeracy in Focus (1995+) ▷

Written Language and Literacy (1998+) ▷

Basic Skills Agency
www.basic-skills.co.uk

National Learning Network
www.nln.ac.uk

National Literacy Trust (and its research database)
www.literacytrust.org.uk

The Australian Journal of Language and Literacy (2001+) ▷
www.alea.edu.au/pubs.htm#ajll

The post-compulsory education sector

Adults Learning

College Research Journal (1997+)

Journal of Access Studies (to 1997)

Journal of Further and Higher Education

Journal of Vocational Education and Training

Research in Post-Compulsory Education (1996+)

Scottish Journal of Adult and Continuing Education (1994+)

Studies in Continuing Education

Studies in the Education of Adults

Vocational Training

Widening Participation and Lifelong Learning (1999+)

Adult, Career and Vocational Education Clearinghouse (ACVE)
http://ericacve.org/searchinput.asp
(at 14 April 2004 this website is no longer available)

Campaign for Learning
www.campaign-for-learning.org.uk

Further Education Funding Council for Wales (FEFCW)
www.wfc.ac.uk/fefcw/index.html

Further Education Resources for Learning (FERL)
http://ferl.Becta.org.uk

Learning and Skills Council
www.lsc.gov.uk

National Advisory Council for Education and Training Targets (NACETT)
www.countyweb.co.uk/cards/nacett

National Advisory Group for Continuing Education
and Lifelong Learning (NAGCELL)
www.niace.org.uk/Organisation/advocacy/NAGCELL/NAGCELL.htm

National Centre for Vocational Educational Research, Australia (NCVER)
www.ncver.edu.au

National Information and Learning Technologies Association (NILTA)
www.nilta.org.uk

National Institute of Adult Continuing Education (NIACE)
www.niace.org.uk

Planning Exchange (The Information Providers
for Regeneration and Development)
www.planex.co.uk

Scottish Further Education Funding Council (SFEFC)
www.sfefc.ac.uk

Scottish Further Education Unit (SFEU)
www.sfeu.ac.uk

Standing Conference on University Teaching and Research
in the Education of Adults (SCUTREA)
www.scutrea.ac.uk

The Universities Association for Continuing Education (UACE)
www.uace.org.uk

Youth issues

Children and Society

Childright

Health Education Journal

International Journal of Adolescence and Youth

Journal of Adolescence

Journal of Youth and Adolescence

Journal of Youth Studies

Young People Now

Youth Action

Youth and Policy, the Journal of Critical Analysis

Youth & Society

British Youth Council
www.byc.org.uk

Disability/Exceptionality Links Library
www.asri.edu/CFSP/brochure/library.htm

National Youth Agency
www.nya.org.uk

Pro Youth International (funded by the European Commission)
www.alli.fi/euro

Scottish Youth Issues Journal ▷
www.communitylearning.org/syij.asp

The Foyer Federation
www.foyer.net

The Prince's Trust
www.princes-trust.org.uk

Wales Youth Agency
www.wya.org.uk

YouthNet UK
www.youthnet.org.uk

Youth Work on the Internet
www.youth.org.uk
(at 14 April 2004 this site was temporarily closed)

Learning difficulties/disabilities (where the focus is on the physical impairments of blindness or deafness)

Australian Journal of Education of the Deaf ▷
(formerly called Australian Teacher of the Deaf)

British Journal of Learning Disabilities

British Journal of Special Education

British Journal of Visual Impairment

Canadian Teacher of the Deaf

Deafness and Education
(formerly called Journal of the British Association of Teachers of the Deaf)

Deafness and Education International
(formerly called Deafness and Education)

European Journal of Special Needs Education

Insight
(formerly called Teacher of the Blind)

International Journal of Inclusive Education (1997+)

International Journal of Speech Technology (1995+)

Journal of Deaf Studies and Deaf Education (1996+)

Journal of Learning Disabilities

Journal of Research in Special Educational Needs (2001+)

Journal of Visual Impairment and Blindness

Learning Disabilities Research and Practice

Teaching English to the Deaf ▷

Technology Update (by the Sensory Aids Foundation) ▷

The New Zealand Journal for Teachers of the Deaf

AbilityNet
www.abilitynet.co.uk

Blindness Resource Centre
www.nyise.org/deaf.htm

British Computer Association of the Blind
www.bcab.org.uk

British Deaf Association
www.britishdeafassociation.org.uk

Computer Games for the Blind
www.gamesfortheblind.com

Disability/Exceptionality Web Resource Library
www.asri.edu/CFSP/brochure/library.htm
(at 14 April 2004 this website is no longer active)

National Bureau for Students with Disabilities (SKILL)
www.skill.org.uk

Royal National Institute for Deaf People
www.rnid.org.uk

Royal National Institute for the Blind
(including publications Eye Contact and Visability) ▷
www.rnib.org.uk

Scope
www.scope.org.uk

Technology for Disabilities Information Centre
www.techdis.ac.uk

The Canadian National Institute for the Blind Library
www.cnib.ca/library

The Deaf Resource Library
www.deaflibrary.org

The following are the general citation indexes, electronic databases and gateways which were searched:

Arts and Humanities Citation Index

British Education Index (BEI)
www.leeds.ac.uk/bei

British Humanities Index (BHI Net)

Educational Resources Information Center (ERIC)
www.eric.ed.gov

Joint Information Systems Committee (JISC)
www.jisc.ac.uk

National Information Services and Systems (NISS)
www.hero.ac.uk/index.cfm

Periodicals Contents Index (PCI)

Social Science Information Gateway (SOSIG)
http://sosig.ac.uk

The British Library Electronic Table of Contents Online (ZETOC)
http://zetoc.mimas.ac.uk/index.html

The following are the literature abstracts which were searched:

Contents Pages in Education

Educational Research Abstracts

Educational Technology Abstracts

Special Educational Needs Abstracts

The following are other UK research/governmental/miscellaneous organisations which were searched:

DENI (Department for Education, Northern Ireland)
www.deni.gov.uk

DfES (Department for Education and Skills)
www.dfes.gov.uk/index.htm

Learning and Skills Development Agency's library database
www.LSDA.org.uk

National Assembly for Wales
www.wales.gov.uk

National Foundation for Educational Research (NFER)
www.nfer.ac.uk

Scottish Executive Education Department (SEED)
www.scotland.gov.uk

Scottish Executive Enterprise, Transport
and Lifelong Learning Department (ETLLD)
www.scotland.gov.uk

University for Industry (Ufi)/Learndirect
www.ufi.com

The following are European organisations which were searched:

European Association for Research on Learning and Instruction
www.earli.eu.org

European Centre for the Development of Vocational Training) (CEDEFOP)
www.cedefop.eu.int

European Commission – Community Research
and Development Information Service (CORDIS)
www.cordis.lu/en/home.html

Organisation for Economic Co-operation and Development (OECD)
www.oecd.org

United Nations Educational, Scientific and Cultural Organization (UNESCO)
www.unesco.org

The following are research bodies which were searched (principally for papers presented at annual research conferences):

American Educational Research Association
www.aera.net

Association for Learning Technology (Alt-C)
www.shef.ac.uk/alt

Australian Association for Research in Education
www.aare.edu.au/index.htm

British Educational Research Association
www.bera.ac.uk

European Educational Research Association
www.eera.ac.uk

European Information Society Technologies' Conferences
www.cordis.lu/ist
(link with European Commission CORDIS website
at www.cordis.lu noted above under 'European organisations')

Online Educa
www.online-educa.com

Scottish Council for Research in Education
www.scre.ac.uk

The New Zealand Council for Educational Research
www.nzcer.org.nz/search/Searchsite.htm

The following are online newspapers which were searched:

British Newspaper Index (BNI) (1995+)

Times Educational Supplement
www.tes.co.uk

Times Higher Educational Supplement
www.thes.co.uk

The following are internet search engines which were used to search for 'grey' literature
(ie literature produced by academics, business and industry in print and electronic formats, but not controlled by commercial publishers, eg on the internet) where the main emphasis is on finding research studies noting young people's experiences of computer and video games:

Altavista	Google	Yahoo
www.uk.altavista.com	www.google.com/search	www.yahoo.com

Glossary

Arcade games
These are distinct from console and computer games because they are machines in which players must put coins in order to play a game.

Artificial intelligence (AI)
…the science and engineering of making intelligent machines, especially intelligent computer programs … The ultimate effort is to make computer programs that can solve problems and achieve goals in the world as well as humans. However, many people involved in particular research areas are much less ambitious…

(McCarthy 2003, pages 2 and 5)

Blended learning
Blended learning is learning which uses a combination of face-to-face (ie taught) and online media. This form of learning is increasingly used at universities, and the presence of both types of learning distinguish blended from wholly online and wholly classroom methods of learning.

Console
A dedicated video games machine such as the Sony PlayStation.

Game Boy/Game Boy Advance
Game Boy was the original handheld games machine sold by Nintendo Inc, which played games from ROM-based media cartridges. Tetris was the most successful game on this machine. The Game Boy Advance is an updated model, featuring a colour screen, larger memory and the ability to play Game Boy Advance games on a television (see GameCube).

GameCube
A games console launched in 2001 in Japan by Nintendo Inc. The GameCube allows users to play Game Boy Advance games on a television through the use of a Game Boy player connecting straight to the GameCube. The system is a direct competitor to the PlayStation and Xbox.

Microportal (or m-portal)
The interface on a mobile device through which users can access programs (the m-portal in the m-learning project is being designed by Ultralab – more information can be found at www.m-learning.org).

Mobile phones (or cellphones)
Handheld mobile radiotelephones for use in an area divided into small sections (cells), each with its own short-range transmitter/receiver, which uses digital technology.

MUDs
Multi-user domains, multi-user dimensions or multi-user dungeons are interactive, adventure-type environments where there is a specific goal, and social areas where the purpose is to wander, enter into personal relationships and participate in a community.

Personal digital assistant (PDA)
A small, handheld computer typically providing calendar, contacts address list and note-taking applications. It may also include other applications, (eg a web browser and a media player). The most common ways of inputting data are small keyboards and pen-based systems.

PlayStation
A family of games consoles from Sony Corporation consisting of the original PlayStation (PS1) and the PlayStation 2 (PS2). The basic PlayStations consist of a small box containing the processor and a DVD (Digital Versatile Disc) reader, with video outputs to connect to a television, sockets for two game controllers, and a socket for one or two memory cards. The PS2 also has USB (Universal Serial Bus) sockets.

Plug-in
A hardware or software module that adds a specific feature or service to a larger system. For example, there are a number of plug-ins for internet browsers (such as Microsoft Internet Explorer) which enable them to display different types of audio or video messages.

Xbox
The games console launched in November 2001 by Microsoft, designed using the industry-standard personal computer (PC) architecture.

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