Serious Games and Gaming

Terry Bossomaier

Abstract This chapter studies serious games, games for education and training. First, the nature of what makes a game is discussed and a distinction drawn between games and simulation. Games are considered at multiple levels. At one level, there are games which focus on developing a physical skill, such as learning to fly a plane or carry out a surgical procedure. At other levels are games which develop high-level social skills and gamification, the addition of game-like elements to add motivation. The progress in developing games for mathematics education is described, along with a general perspective on the state of evaluation of serious games.

Keywords Collateral Learning · Culture · Play · Applied Drama · Gamification · Simulation · assessment · lusory attitude · affinity space · practice · Role Distance · Magic Circle · Mantle of the Expert · Quest-to-learn · AMP (Autonomy, Mastery Purpose) · complex systems · relativity

> Truth is lived, not taught.—The Glass Bead Game (Hesse 1943)

Introduction

The commercial game industry has grown enormously, alongside increases in computing power over the last few decades (Cross 2011). By a variety of metrics it now surpasses the movie industry. Where at first games might have been developed from successful movies, now the reverse commonly occurs (Tomb Raider, Final Fantasy…). The development cost of games for game consoles, such as the Sony Playstation, which have traditionally captured a large slice of the market, has also

T. Bossomaier (✉)
Charles Sturt University, Bathurst, Australia
e-mail: tbossomaier@csu.edu.au

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risen. A top, so-called AAA title can cost upwards of $20 million to produce, with aggregate teams of 100 people or more. In September 2013, Grand Theft Auto 5 was launched. It was the most expensive game ever, at £170 million. But in the first day of sales, it set another record, boasting *£0.5 billion* in its first day, higher than any movie or game in history.

Serious games attempt to harness this massive interest in games for entertainment, for educational or training purposes. We shall look at the various objectives and the evidence, if any, of how well serious games go towards achieving them. Writing a textbook, particularly if it gets syndicated in the US, can be very lucrative. But such a book will be the work of one, or just a few people, with maybe some secretarial or graphics support. On the other hand, supplying a serious game to the same market has a gigantic upfront cost if the design and production quality are to meet the same standards seen in the entertainment world.

Cost limitations have meant many games for educational and training purposes have been feeble imitations of their entertainment equivalents. But this dire situation may be changing. The mobile game market has exploded alongside the rapid growth in smartphone technology. The smaller screen, reduced processing power and simpler interface (no joysticks, elaborate controllers) mean that game design has to assume a larger part of the overall budget, which, in turn, can be quite a lot smaller. In the film industry over the last decade we have seen movies, such as *Blair Witch Project* and *Saw*, made on miniscule budgets, go on to achieve major box office success. Here a novel idea transcended the massive movie budgets of traditional blockbusters.

The Economist argues that education has much to learn from games (Laibson 2013) and, in June 2013, reports that technology is really starting to deliver major outcomes in education, and large sums of money are changing hands. Major academic publisher Pearson has spent $880 million in technological acquisitions since 2011, while News Corp spent $340 million on acquiring Wireless Generation for its Amplify education arm (Economist-Anonymous 2013). Meanwhile Apple sold 3 million iPads for educational use in 2012. GSV Advisors (Global Silicon Valley Advisors) claimed educational technology investment reached $1.1 billion in 2012.

This chapter asks whether serious games work in delivering education and training and in supporting learning, and whether they are effective in their use of time and, by implication, whether they are cost effective. The approach here is very general and we spend some time at the beginning looking at the variety of games genres and opportunities that they offer. As Hickey and Zuiker (2012) point out, some national assessment exercises may impede deep learning. Our goal here, then, is to look at a bigger picture than national curricula and achievement targets. In the realm of school education alone, we have gamification to make repetitive, simple tasks doable on the one hand and, on the other, entire school programs built around such games, such as Katie Salen's Quest2Learn (Q2L) initiative.

At first there seems to be a paucity of thorough scientific studies with suitable controls. In a recent review, Hays (2005) from the Naval Air Warfare Center in Florida, asserts that "The empirical research on the instructional effectiveness of games is fragmented, filled with ill defined terms, and plagued with methodological flaws". But there are subtleties missed by too narrow a focus on very specific outcomes. In their profound and influential book *Rules of Play*, Salen and Zimmerman (2004) develop three aspects of games: rules, play and culture. These three categories turn out to be a useful lens for effectiveness and how to measure it. We shall discuss in more detail how the **rules** define sets of procedures and are in some sense *closed*, such as learning the laws of physics or mathematics. **Play** is more divergent, embodying broader issues of interests and identity. **Culture** takes us beyond the educational goals to the broader context of what the knowledge is for, why it is useful and its integration with the rest of life.

To these categories we will add a fourth, which has only recently achieved prominence. Since it arises from action video games, which frequently have a military context, we shall coin the phrase *collateral learning*. Unlike the collateral damage sustained in military action, collateral learning is an expected beneficial side effect of such games. Thus the prevailing view is shifting, from one where little Freddie is wasting away his youth playing video games, to one where Freddie is acquiring skills that will help him get his future dream job as a consultant radiologist.

As we move across these categories, the validation requirements and methodologies shift. They also extend into the broader issues of lifelong preparation through mathematics training (Clements and Samara 2011) and the risk to emotional development of poor educational practices (Shonkoff 2011). This broader, life-long picture necessitates the wide-ranging perspective of this chapter. The structure is as follows:

- We examine a broader context of games and simulation and how they integrate with the study of their domain. Computer simulation has been of enormous benefit to teaching, especially in the STEM disciplines, but it is intrinsically passive. Games involve agency, thus fostering *active* learning. The best game may go beyond the game to foster additional study of their domain, something we call *practising* to play.
- We discuss genres and dimensions of serious games along the lines discussed above, starting with highly focused maths games and zooming out to games in society. Beyond developing core skills in the early days of school, the student needs some understanding of what, to paraphrase Thomas Nagel, it's like to be a bat, a mathematician or a physicist (Nagel 1974). This idea takes us from homework problems in statistics, to assessing risk in lifelike situations, to the *mantle of the expert* (Heathcote and Bolton 1995).
- We look at the new fast-growing area of gamification. The evidence is that this is building a wave in education, training and the corporate world. But its merit within a deep learning framework is questionable in light of research on motivation.
- Serious games, of course, have to embody assessment and here we find a curate's egg: on the one hand, we have unprecedented opportunity for cost-effective adaptive learning, using online computer games and big data; and, on the other, politically charged issues of summative versus formative assessment.
- We conclude with the future outlook for serious games.

Games in Context

> I had tasted the bait and knew that there was nothing more attractive and more subtle on earth than the Game. I had also observed fairly early that this enchanting Game demanded more than naive amateur players, that it took total possession of the man who had succumbed to its magic.—The Glass Bead Game

Surprising though it may seem, the definition of a game has generated a lot of discussion, from Huizinga's Homo Ludens (1986) to Suits' Grasshopper dialogues (Suits and Hurka 2005) even before the computer game revolution. We touch on the definition of a game below, but a more detailed discussion is outside the scope of this chapter.

In this section we just want to put the idea of game into some context. The first issue is the distinction between simulation and games. The second issue is what we will call *meta-game* activity, activity beyond the game, but directed towards improving gameplay mentioned below.

Games versus Simulation

Three terms in common use—play, games and simulation—have attracted a lot of discussion since they overlap but are not identical. When we consider serious games, a further complication arises because the player has a learning objective outside the game.

Games frequently involve simulation of some sort of virtual world, but there are numerous discussions of simulation and games. The boundary is at times blurred. Our concern in this chapter is specifically with games, so we need to clarify the difference and put simulation to one side.

The ideas of play and games go way back in history, with eighteenth-century writer Friedrich Schiller[1], stressing the essential element of play to being human (Schiller 1794):

> der Mensch spielt nur, wo er in voller Bedeutung des Worts Mensch ist, und er ist nur da ganz Mensch, wo er spielt (to be fully human is to play)—*Friedrich Schiller, Über die ästhetische Erziehung des Menschen, in einer Reihe von Briefen, 15th Brief*

But one of the earliest and most influential writers on games was Johan Huizinga, born in the late nineteenth century. His influential book, *Homo Ludens* (Huizinga 1986) is still in print today! He looks at play in different domains, art, war, poetry and others, and popularised the celebrated term *The Magic Circle*, but the idea goes far back in history, at least to the Indian epic, the Mahabharata. A prominent theme therein is a game of dice, but this is played in a special, carefully laid out circle. The players are not allowed to leave the circle until the game is complete (Huizinga 1986). (Note, however, some complications discussed below).

[1] Widely known through his words used by Beethoven in his 9th symphony, which provided the music for the European Anthem.

The central concept of Huizinga's book is play, but games appear strongly too. In fact, he sketches out the framework for defining a game, given by McGonigal (2011), which we discuss below. Another influential book, Bernard Suits' *Grasshopper: Games, Life and Utopia* (1990), takes inspiration from the Aesop fable of the ant and the grasshopper. The ant works all summer and survives the winter. The grasshopper plays and dies. The book is a sort of Socratic dialogue between the grasshopper and his acolytes.

Suits' definition is neat, maybe a little unexpected:

> …To play a game is to engage in activity directed towards bringing about a specific state of affairs, using only means permitted by rules, where the rules prohibit more efficient in favour of less efficient means, and where such rules are accepted just because they make possible such activity.

This acceptance of the rules of game, Suits describes as the *Lusory Attitude* and goes on to put games central to the ideal of existence, a somewhat similar position to Hermann Hesse's Glass Bead Game (1943).

Jane McGonigal (2011) offers four defining characteristics of a game, in part derived from work by Suits (1990) and Salen and Zimmerman (2004):

1. **Goals** are essential and are one clear differentiation from simulation. Thus we might have a computer simulation of the effect of greenhouse gases on climate change. We could *play* with parameters and look at, say the effect of rising sea levels, bleaching of coral reefs or increasingly violent weather. But for our purposes this would *not* be a game. It could easily be made a game by creating goals, such as keeping the sea out of Sydney.
2. **Rules** define games from the earliest board examples, Chess 1500 years ago, and Go perhaps at least 3000. For a game to become widely played over time, the rules have to be reasonably constant. For these ancient board games, only occasional changes to the rules have occurred throughout their long history.
3. **Feedback** is a sophisticated feature of many computer games, with a variety of rewards and penalties as skill within the game develops. From an educational perspective, ongoing feedback as the game progresses, as opposed to a simple win/lose is desirable. We come to the idea of *stealth assessment* (Shute 2011) below.
4. **Voluntary participation** is subtle, since some people may be obligated to play a game, such as soldiers in a military war game. The idea here is that everybody accepts the rules and the game for what it is. An important corollary of voluntary participation is that the game should not be harmful, an issue we touch on in discussing applied drama below.

Unlike simulations, the goals of computer games usually have a carefully graduated series of levels, usually more sophisticated than a simple point system. The Nintendo Brain Training Workshop uses graphics of walking, cycling, driving, trains, planes and rockets to illustrate increasing levels of attainment. This *levelling up* is a key part of the engrossing and enduring nature of games and a building block of *gamification*. Klabbers (2009) has written extensively on simulation and games and their differences. He makes the distinction between design sciences (games) and analytical sciences (more tending towards simulation). Design sciences are holistic and have different means of evaluation—in the way one appreciates a picture in its entirety rather than, or as well as, the quality of individual brush strokes. This may hold for the evaluation of a game or simulation, but in the serious games domain we need to evaluate along a third dimension. This third dimension stretches from practice to context.

Klabbers (2009) and Salen and Zimmerman (2004) make much of complex systems theory in games. Complex systems are those for which no simple rules predict how they behave in any given circumstances. The simplest, well-known complex systems are exemplified in John Conway's Game of Life (Gardner 1970). Using very simple rules on a 2D grid, it generates bewildering patterns of behaviour, creating higher level dynamics structures of diverse kinds.

Complexity in a game ensures a richness and longevity, and encourages creativity and analytical depth. This may not always be required for a serious game, where a direct relationship between problem and learning outcome might be essential. But there are exciting opportunities for training in the handling of real-life complex systems, such as crisis management, international politics, long-term strategic planning and so on. The issue of meaningful assessment arises again in the Assessment Section.

Practising to Play

There is a somewhat complementary aspect to using games to teach and learn directly. Players of highly competitive cognitive games—Bridge, Chess, Go—actually spend a lot of time *away from the game*, studying and practising specific elements, just as, say, a tennis player may spend hours practising her backhand; Chess players spend hours studying openings; Bridge players spend hours studying bidding systems, conventions and play techniques. In the computer games world, first-person shooter enthusiasts will spend hours perfecting the use of some weapon.

Closely allied to practise for the game, are affinity spaces (Gee 2003, 2005) and fan culture (Jenkins 2006) (below). Thus perhaps we should envisage a second tier of serious gaming, *the motivation to study to be good at the game*, what we shall call the *meta-game*. In Relativistic Asteroids (Carr and Bossomaier 2011), discussed further below, players gain an intuitive understanding of relativistic dynamics to be able to respond fast and fluently away from the Newtonian world. They need to take into account time dilation, length contraction and mass increase to shoot asteroids and avoid being destroyed. This intuitive understanding is a foundational requirement for more formal knowledge. We live in a mostly Newtonian world (i.e., relativistic effects are not normally apparent) and so the understanding of Newtonian dynamics is something with which we grow up. Games can make comprehensible non-intuitive domains, of which we have no direct experience, such as relativity and quantum mechanics below. The rewards in the game are tightly integrated with relativistic skill, an issue which will crop up repeatedly.

But just as being able to hit a spinning cricket ball, a difficult computation even today does not allow us to write down and manipulate the equations for the Coriolis force. Thus second-generation, asteroid-type games need to integrate the physics and mathematics. The excitement and challenge of the game should encourage deeper study. So, in a relativistic space game, there might be advanced levels which enable the player to design a weapon. But to do so would require being able to solve relativistic equations and calculate their implications on a computer. This *meta-game* experience becomes more and more significant as we proceed through the four categories, which frame this article.

The game/meta-game issues present difficulties for classroom use. McFarlane et al. (2002, p. 205) in the TEEM report on educational use of computers presented results from a range of schools in the UK, obtaining 700 responses. Big successes of the games were in team work and communication. From a real-world, after school education, these are undoubtedly important skills. Yet teachers expressed reservations about the games taking up classroom time away from the core syllabus (from which these social outcomes were excluded).

There are two ways to deal with this criticism: one is to focus more and more tightly on the curriculum outcomes, as in Asteroids and Supercharged discussed below, but with some reservations on assessment agendas. The other is to embrace some of the philosophy of Ken Robinson, described in *The Element* (2009), and move towards a more flexible concept of educational outcomes, a debate outside the scope of this chapter:

> One of the essential problems for education is that most countries subject their schools to the fast-food model of quality assurance when they should be adopting the Michelin model instead. The future for education is not in standardizing but in customizing; not in promoting groupthink and deindividuation but in cultivating the real depth and dynamism of human abilities of every sort.

Dimensions and Genres of Serious Games

> If only there were a dogma to believe in. Everything is contradictory, everything tangential; there are no certainties anywhere. Everything can be interpreted one way and then again interpreted in the opposite sense.—The Glass Bead Game

This section considers the types of serious games, following along the lines of Salen and Zimmerman (2004), examining them through the ever-widening lens angle above: the sandbox; affinity spaces; culture; and collateral learning. An increasing amount of effort is going into the building of serious games, with multiple conferences being held annually and numerous studies of use in schools and elsewhere. Novelty alone is likely to generate improvements and the numerous tricks of game design are going to hold attention and create involvement. Thus it requires very careful work to entangle these effects from improved learning in a given timeframe. In a recent meta-study, Girard et al. (2013) found that, although there were numerous studies, they rarely had control groups. Thus the outcomes were not as forceful as one would hope. There are *definitely positive* results, but the overall picture is somewhat murky. In general, we are likely to find differences between goals and genres, so we shall consider several areas in the following sections.

Building Sandcastles

Computer scientists have adopted the idea of a sandbox as a place to play, using the metaphor of sand not getting out, to safely experiment with new ideas. The first kind of serious game is essentially played in a sandbox—it ignores broader social or cultural issues and is not even particularly focused on other gamers. Such games, of which there are many, teach skills, ideas or theories. Many maths games, discussed elsewhere in this volume, fall into this category. Games which teach manual skills, from car mechanics to surgery are effective and very easy to assess.

Closely linked to games that develop technical skill are games for the quantitative STEM (Science, Technology, Engineering, Maths) disciplines. The interest in games for teaching them arises in part from an awareness of declining performance in schools in this domain—worse in 1986 than in 1970, with little improvement through the 1990s and 2000s (Echeverri and Sadler 2011).

Flight Simulators and 3D Skill Training

Long before Pong, arguably the first video game, appeared in 1972, flight simulators were already in widespread use. Real cockpits, built into huge moveable containers, became the norm for pilot training. Flight simulators have been part of the computer games genre for a long time and have gotten steadily better and more realistic as computer power has increased.

Such major simulators now exist in all sorts of domains: trains; cranes and port machinery; mines and mine rescue. Computer games are taking over more and more of the roles of physical simulators, being much lower cost, more flexible and, of course, easier to replicate. Thus there is not much argument that these simulators work. In a strange twist of life imitating art, military drones now use game-like interfaces with actual game consoles to control real aircraft operating thousands of miles away, sometimes with deadly effect. 3D skill acquisition through games now extends into surgery, car mechanics and other applications pop up with increasing frequency. But there is one possible problem with serious games for domains, where errors may have serious consequences, such as medicine. The problem is stress. The real situation may be very much more stressful than the game and stress may lead to distorted perceptions (Lupien et al. 2007) and consequent errors.

Intuition Beyond Our Senses

The early days of physics addressed things we could experience directly, the movement of objects under the action of forces, the transformation of the states of matter, from solid to liquid to gas, things for which we have sensory knowledge. As physics and chemistry developed, their theoretical framework became less and less immediately accessible.

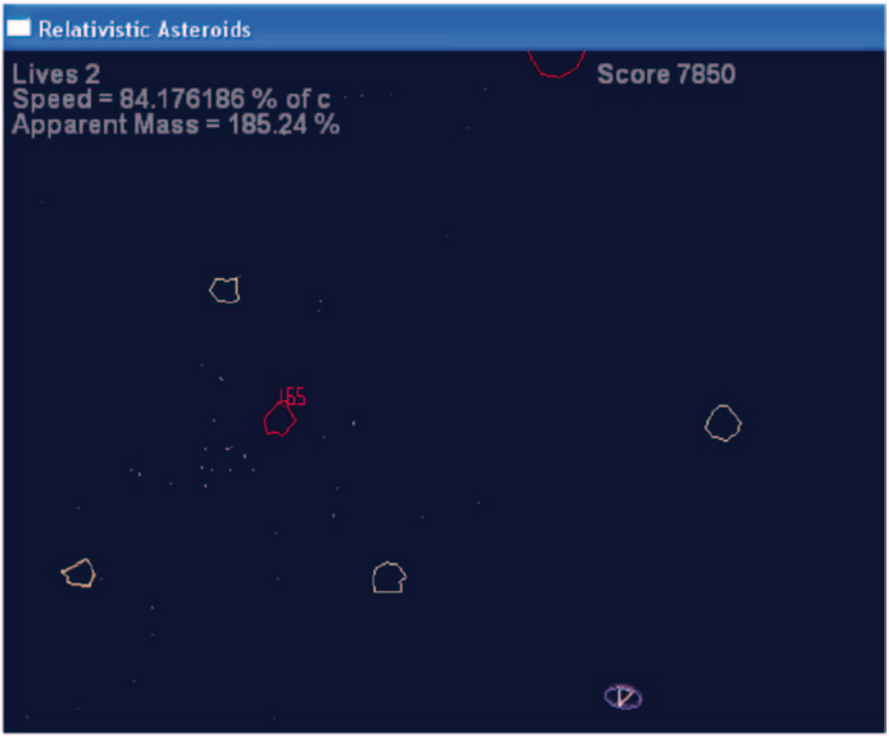

Fig. 1 Relativistic Asteroids (Reprinted from Australasian Journal of Educational Technology)

One of the greatest innovations in physics, Einstein's theory of relativity, brought with it numerous counterintuitive ideas, contrary to everyday experience. By adopting the stance that the speed of light was constant in all inertial reference frames, the increase of mass with speed, the slowing down of time and length contraction followed naturally. But these dynamics are so different from Newtonian mechanics that the equations which describe them have no physical intuition to substantiate them.

In Australia in 2013, special relativity is now part of the school science syllabus. Visualisation and games are powerful tools to make it accessible to school children. Carr and Bossomaier (2011) developed a computer game based around the early computer game of asteroids (Fig. 1). Like Pong and Tetris, these old games are still fun to play. But in relativistic asteroids, asteroids and ships move at close to light speed and therefore move differently on the screen. At close to light speed they change shape, according to the Lorentz contraction. Aiming at an asteroid is different to a normal asteroids game and a time bomb feature introduced the idea of time dilation. This game successfully created a sense of how things moved under relativistic physics. The equations become embedded in practical experience of how things behave close to the speed of light.

However, like the maths examples, actually manipulating the equations is not part of the game, and transferring such manipulations to exciting gameplay remains a challenge. Some of the games in this domain reflect their low-budget origins. But poor eye candy does not substitute for poor design. Some such games are weak because the gameplay is completely decoupled from the learning objective. For example, one might have a series of arithmetic problems and a reward for success being to throw a custard pie at a politician. Fun though this may be it is at best a weak motivator to do some maths exercises. It feels more like the category of gamification (below). This author is of the very strong view that gamification plays no role in school or higher education, since it mitigates the development of interest and intrinsic motivation.

In Supercharged, another space metaphor is used, again, to teach physics intuition. A spaceship's motion is affected by its charge and charge of surrounding objects (Squire et al. 2004; Squire 2006, 2008). Experiments were conducted in a US 8th-grade class comprising a total of 96 students. Both boys and girls improved relative to control groups. Post-session interviews revealed better qualitative understanding of the behaviour of charge and fields, but did not achieve a full understanding across the cohort.

Thus the exercise was a success. It also revealed the problem hinted at the beginning of the chapter. Many kids play commercial computer games and they bring the standards of these highly refined games to educational games. It also transpired that teachers remained essential to encourage reflection on the outcomes of the game and to take learning to a deeper level, another aspect of the meta-game experience.

Exogenous, Endogenous Games and Flow

Not all educational games seem to this author to be particularly good designs because their reward mechanisms are flawed. A number of games exist, for example, for basic accountancy. In the simple Trebuchet game, answering multiple-choice questions in accountancy allows the player to build a catapult (trebuchet) to launch the teacher into orbit. In an American football game (Financial-Football 2013), the graphics are much more sophisticated than in Trebuchet, with 3D representation of the players on the field and sound effects from the play and the crowd. But, the game dynamics are dreadful. Progress up the field is governed by answering accountancy questions. In short, such games decouple the training element from the gameplay. Rieber (1996) describes such games as *exogenous* and they could be considered simple examples of gamification.

We can do better according to Squire (2006). All the games developed therein are *endogenous*, that is, they use gameplay which is intrinsic to the training element (e.g., making financial decisions in the game). The nature of rewards crops up again when we consider gamification.

The best games achieve high player motivation and can result in what Csíkszentmihályi (1990) called *flow*, a state of intense concentration and lack of awareness of outside stimuli. Flow usually requires a careful matching of skill to difficulty level—there must be continual incremental challenge without it appearing insurmountable. Video games are often successful at achieving flow (Holt 2000; Chen 2007). In serious games, stealth assessment, discussed below, has been used to keep the player in a flow through this careful matching of difficulty to skill level (Shute 2011).

Mathematics Games in Schools

As Girard et al. (2013) note, there are a few good studies of the effectiveness of serious games, but there are few in the mathematics domain. The overall outcome is fairly positive, both in terms of engagement and achievement.

Kebritchi et al. (2010) performed a meta-study of 16 papers using computer games for maths teaching. Most outcomes were positive, although the methodologies were varied and often did not include control groups. They then carried out a study with 193 students using a game DimensionM for teaching algebra. 171 students used the game, while 76 students formed the control group. The outcomes were significant, but the effect on motivation as measured was weak.

Lindström et al. (2011) carried out a study in Sweden with children aged from 8 to 10, to help them learn the base-10 number system. The games they used featured not only numerical challenges but also two other pedagogical features: collaborative learning and learning by teaching (similar in some ways to learning by design). The games featured a teachable agent, which the players could train to play the game. Teaching the agent, plus playing against somebody else, lead to successful collaborative learning.

Ke (2013) studied the use of games for teaching mathematics in high school in two different school environments, an urban school and a rural pueblo school for Native Americans. Both studies had a strong qualitative component, seeking attitudes towards game-based tuition. The results, as measured by state examinations, were marginal for the rural school and non-existent for the urban school. The study did not have any sort of control group for comparison.

Ke (2014) then went on to study the use of *designing games* as a learning tool, which he sets in a broader educational framework of *designing to learn*. The idea here is a powerful one: the process of designing a learning tool to teach other people is an excellent use of increasing one's own understanding. The results were positive, albeit, again without a control group.

Castro et al. (2014) developed a range of games to help children with Dyscalculia (mathematical learning disabilities). With such children, there is not only the challenge of finding ways to help them learn, but also the challenge of developing motivation. Success generates enthusiasm, seemingly insurmountable difficulties rarely do. A family of a dozen or so games was created, each targeting a component of elementary maths.

This was a strong study, beginning with an initial cohort of 300 children aged 7–10, from which 26 children with Dyscalculia were selected after a pre-test and consultation with teachers. They were divided into experimental and control groups, the experimental group showing greater improvement in the post-test over the control group. It was also significant that the children enjoyed playing the games, even asking for more time to continue playing.

Most applications of serious games in mathematics have focused on these early years. As we move to senior grades and university level, tools such as Mathematics^{TM}, Matlab^{TM} and Maple^{TM} have made teaching higher maths much easier, through visualisation and facilitation of algebra. There are plenty of opportunities for serious games and, perhaps especially, learning by design in this tertiary space.

Play: Fuzzy Edges to the Magic Circle

When we talk about playing Chess, creativity and exploration are an intrinsic part of the game. In this section, we want to move beyond creativity within the game, within the magic circle, to the extensive divergent activity that goes on about the game. Henry Jenkins promoted the idea of fan culture (Jenkins 2006), exploring popular genres across television, film and games. Fans contribute huge amounts of discussion about the content and their personal reactions to it.

Since Jenkins began his seminal work on fans, the domain of supporting material, mostly on the web, has exploded. Gee (2005) coined the term *affinity spaces* for this external structure of games, with a special interest in serious games. Gee wants to distinguish between a community (which requires all sorts of definitions of membership, etc.) and a space where people interact over some shared interest. The issue of community or communities is moot. There may be antagonism and fractures within such a space.

Players discuss many different aspects of game and gameplay, but also use the affinity space to help with the design of new levels. This leads to the idea of *User-Generated Content*, now a study area in its own right (Lastowka 2013), redolent of the learning by design adopted by Ke (2014) for maths games. Adding extensions to games goes back a long way, with Quakebut now spread to extension systems which require no programming skill. One such example is Little Big Planet, and its affinity space Little Big Planet Central. It now advertises 8 million user-generated levels (Central LBP 2013).

Culture

> The Glass Bead Game is thus a mode of playing with the total contents and values of our culture … is capable of reproducing in the Game the entire intellectual content of the universe. —The Glass Bead Game

The fan culture around games extends the game to discussion of its rules, strategy, design, experience and all the things gamers talk about. But the great games go further and impact culture itself. It has always been so, from rites of passage to the ancient board games.

Applied Drama

Serious games are sometimes referred to as *epistemic games* (Shaffer 2004, 2006), which focus on the player's experience and identity within a real-world setting. Closely related to this is the body of work by Heathcote (1991); Heathcote and Bolton (1995); and Heathcote (2002) on *mantle of the expert.* These frameworks drive *Applied Drama*, a training methodology used in Communication and domains such as Public Relations (Carroll et al. 2006). It comprises playing out of scenarios under the supervision of a *Drama Master.* But unlike an ordinary thespian activity it has several distinct features:

- *The players are the audience.* They play a role but watch their role in its interaction with others.
- The idea of *role distance* (Carroll and Cameron 2005) is crucial.
- The Drama Master *dynamically controls the unfolding of the scenario*.

Dramatic enactments are not as harmless as they may seem! Some, maybe many, people cannot partition emotionally charged mindsets, such as trust, into a game environment and the real-world. Unless properly designed and supervised, a betrayal *within* the enactment becomes emotionally damaging *outside* the game. To avoid this role, distance, where people avoid real-life emotional involvement in the drama, is essential. The Drama Master achieves it through being able to stop the enactment at any point, encourage feedback and discussion and then resume the scenario, perhaps where it left off or at some other point dependent upon the discussion. This *in-role, out-role* dynamic minimises the risk of emotional harm.

To bring applied drama into the online world, a game engine, CADGE, was developed to deliver applied drama online, in the first instance to train people in crisis communication (Coombs 2007; Heath and Millar 2004). As recent major disasters, such as Hurricane Katrina or the BP oil spill in the Gulf of Mexico, have convincingly demonstrated, communication is a crucial element of successful crisis management. Apart from the dissemination of information rapidly and effectively, without overload, it has to deal with numerous, often conflicting stakeholder concerns. Organisations may be economical with the truth in order to minimise legal liability, perhaps at the cost of rapid resolution or containment.

CADGE is built around the notion of media resources, such as film clips, specially constructed or taken from real news footage. A large set of these forms a core part of the game; their selection is dynamic, being dependent upon the direction the scenario takes. They are the sort of media feeds which might come through during a crisis, such as a flood, and allow the generation of media artefacts in response. Players represent various stakeholders, government, journalists and corporations, and have to assume the *mantle of the expert* (Heathcote and Bolton 1995) appropriate to these roles.

As noted above, developing AAA computer games is expensive. Thus a key design element was a *Domain-Specific Language* CRASL, with which a domain expert, as opposed to computer expert, could construct a new scenario to run within the game engine. This generalisability is an important cost issue for serious games since it amortises the development cost over multiple games.

Evaluation with undergraduate students in Communication showed the game to give a real meta-game experience, with focus group comments such as:

> It was difficult for me to know exactly what angle to take and what information to include or leave out. At one point I had five paragraphs jotted down, all able to be the lead para in a story. I assume that is what separates the good journalists from the great ones. The great ones have the ability to attain the vital information the fastest and compile a relevant news story in a short amount of time. For me this is still difficult…

and

> The flood simulation highlighted the role of different media forms in communicating all the relevant information. The exercise was intense, stressful but beneficial in that it encouraged a more interactive approach to accessing information. It helped in getting the information more quickly and efficiently, which is always welcome in the face of deadlines and the competitive pressures of the job.

The evaluation of learning in a social communication domain such as this is fraught with difficulties. The assessment is inevitably somewhat subjective, thus creating suitable control groups is difficult. So far, we know that motivation is enhanced and the *mantle of the expert* projected, but the degree of learning is an area for future research.

The future looks good, however. The integration of applied drama with real computer simulations of a crisis unfolding in real-time provides feedback of how effective decisions taken actually were. So, running the enactment, without drama master intervention, can measure learning. Then as with the Go studies, it is possible to titrate decisions taken against best practice, or the most successful players and teams in a given scenario.

Creating new scenarios, using a tool such as CRASL or other authoring mechanism, allows learning by design, already known to be effective elsewhere (Ke 2014).

Collateral Learning

Our thinking so far has been around designing a game to teach some field of knowledge. But there is an entire cottage industry in games designed to have a direct effect, either on the mental state of the player or on their cognitive or perceptual skills. Bio-feedback games, such as Bio-Ball, and a family of similar games, use muscle *relaxation* to control a ball (NASA 1997). There is not much evidence that such games actually work as intended, so we will devote little attention to them here.

More recently, there has been numerous brain training games, such as Nintendo's Brain Training Workshop. Many of these are only loosely based on neuroscientific data, but there have been some significant advances, as we now discuss.

Learning How to Learn

Research in expertise over the last half-century emphasises how specific expertise is to a domain. Top Chess players have to start all over again to become top Go

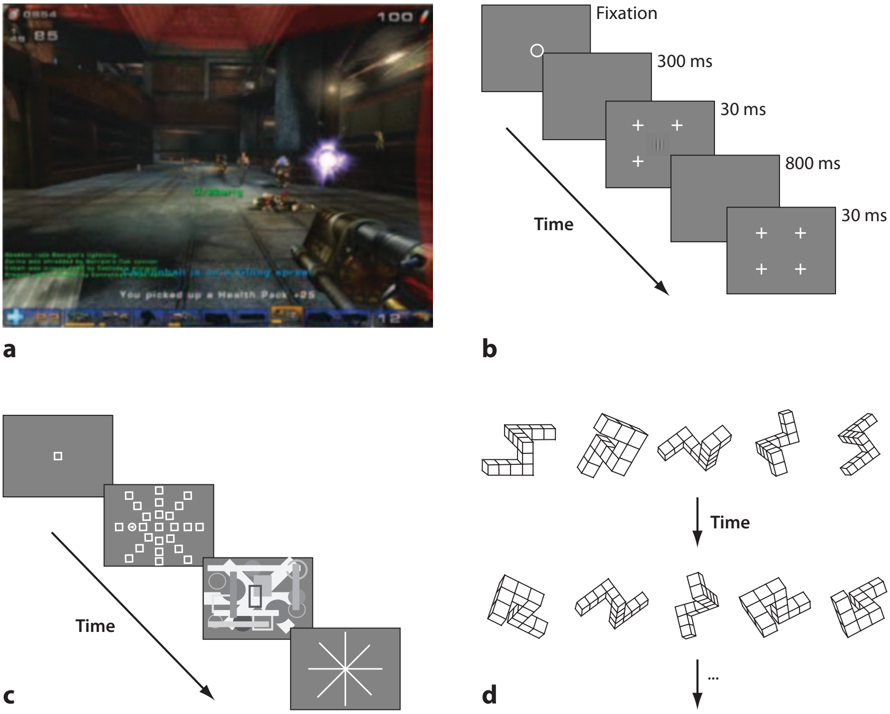

Fig. 2 Training on action computer games as at the top left, creates improvements in visual search, mental rotation and contrast detection (Reprinted from Bavelier et al. (2012) with permission) (see text)

players. Expertise does not transfer because it relies on the accumulation of a very large number of patterns over time (Gobet and Simon 2000; Simon 1959; Groot and Gobet 1996). Thus it was surprising and very interesting to find that some of the skills acquired in computer games *are* transferable.

Bavelier et al. (2012) review a range of studies showing how basic perceptual skills improve and *show long-lasting effects in other non-game tests*. Figures 2 and 3 show three tasks which players of video games perform better than control subjects:

Mental Rotation: is commonly found in intelligence tests

Visual Search: looking for things in crowded environments

Contrast Detection: seeing a faint object in the background

The panel at the side of Fig. 3 shows how performance on these tasks holds up months afterwards. As one might anticipate for improvements in perceptual processing, the games used here were fast action games.

This collateral gain is no barrier to developing games specifically for brain training. Two examples stand out. They are important because, although designed for

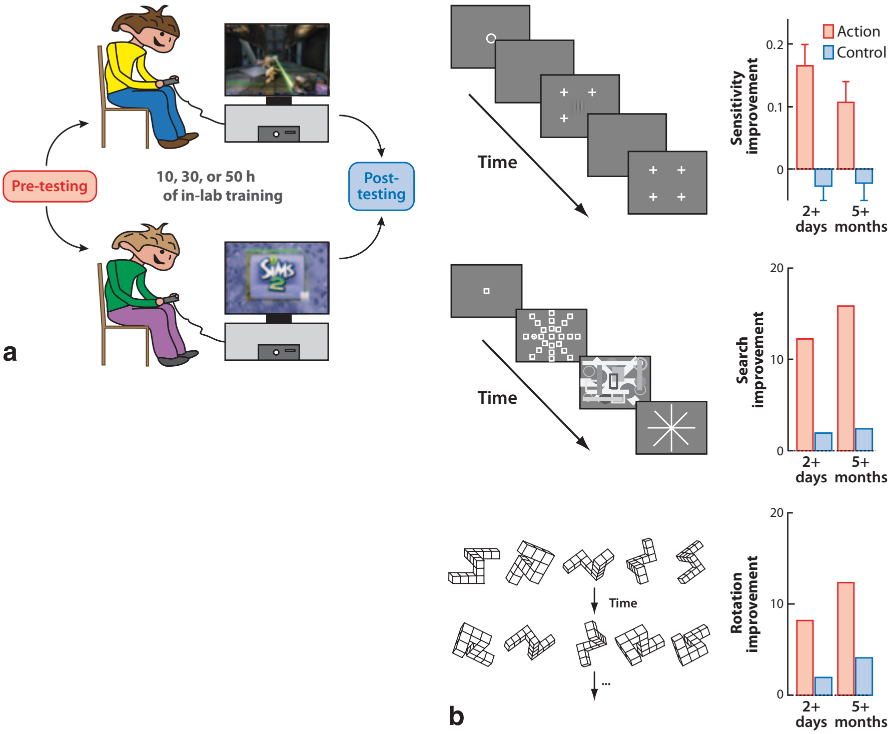

Fig. 3 Longevity of improvements in search, contrast detection and mental rotation obtained with video game training

cognitive training, they have demonstrated generalisation to domains outside the game.

Jaeggi et al. (2008) made quite a stir when they showed that a simple video game could improve working memory[2]. This was surprising because the prevailing view was that working memory was something set very early in life, which deteriorated gradually with age. Even more surprising that the gains in working memory on the game tasks generalised to other working memory tasks and, in particular, led to an increase in general intelligence (as measured by IQ-like tests).

Strobach et al. (2012) show that action games also enhance multitasking and now, at the time of writing in mid-2014, another study on brain plasticity has appeared, this time showing gains for people aged 60 and older. Anguera et al. (2013) developed a game, Neuroracer, which is a driving game with added distractors. The players have to respond as quickly as possible to the distractors without going off the road. A few hours per week show dramatic gains in working memory and multitasking, which transfer to other domains and persist for at least 6 months afterwards.

[2] Working memory is closely related to short-term memory. It is essentially the things you hold in your mind at one time for analysis and manipulation.

Unlike many other studies, which have made claims for brain training sometimes not standing up to intense scrutiny, Anguera et al. (2013) back up their behavioural results with comprehensive brain imaging and a coherent neuroscientific model.

This fascinating area is still rapidly developing. Although the gains are clear in the work so far, there is another recent result, which suggests that design details may be critical. This was not a game study, but a test of the capacity for multitasking. Almost all folklore and a lot of experimentation conforms to the *practice makes perfect* dictum. Not so for multitasking! Ophir et al. (2009) showed that chronic multitaskers, people reading social media, answering the phone, watching the screen, while pushing the cat off the keyboard, perform *worse* on tests of multitasking ability. Perhaps related to this is an earlier study by Koechlin and Hyafil (2007) which found that we can handle at most two independent tasks without interference.

We conclude this section with a note of caution. Exciting though all these results are, the experiments are very difficult. Sometimes subtle biases may occur, as suggested by Boot et al. (2008), weakening the results. But the overarching outlook is very encouraging.

Gamification

> All the tasks are in themselves small, but each one has to be carried out at its proper hour, and the day has far more tasks than hours. —The Glass Bead Game

Gaming, for non-entertainment purposes, pervades many new areas in the form of *gamification.* From a neat idea and a community website, *gamification.org*, Badgeville has now acquired the use of the term on major social media, notably Twitter, Facebook and YouTube (Perez 2012). A recent start-up, they have now raised $40 million in funding and have an international presence across many large companies.

Creating a game out of mundane things, cleaning the bathroom in the case of Jane McGonigal's household (McGonigal 2011), attempts to add motivation and excitement to chores which would otherwise not get done or get done less often or less thoroughly, than might be desirable.

Gamification is a rising phenomenon of some sort. The Gartner Group 2012 Hype Cycle (Pettey and van der Meulen 2012) has it on the rise, peaking in 5–10 years. At a simple level the meaning of the term is obvious—making non-game things into a game but, somewhat surprisingly, a lot of discussion has centred around the definition. Deterding et al. (2011) propose:

> the use of games design elements in non-game contexts

and this has become quite common. Houtari and Hamari (2012) go for a more specialist definition for service marketing:

> a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation.

Despite this very recent activity in finding a definition, the *game mechanisms* used boil down to just four things: points, badges, leader boards and levels—all pretty self-explanatory. But if we forget computer games, these motivators have been around for a long time. One might even argue that the Olympiads of Ancient Greece nearly 3000 years ago were a form of gamification: the prizes were made of olive leaves, but the agendas were large-scale politics.

Badges are a prominent feature of the Boy Scout and Girl Guide movements, which were formed over a century ago. Points and leader boards are featured in everything from amateur sport to sales force motivation. Levels appear frequently; learned societies, for example, run through various levels of members to fellowship; loyalty programs, from airlines to hotel chains, have different levels, with George Clooney reaching the 10 million mile club in the film *Up in the Air*.

So, what is new seems to comprise firstly the use of computer tools to add game elements to any activity with relative ease and, secondly, the rapid spread to so many domains which have not previously had the full gamut of game features. A 2011 Gartner report suggests gamification will spread widely through the commercial world, with 50 % of organisations involved in innovation gamifying some of their processes by 2015. Brian Burke at Gartner (Gartner 2011) states that:

> Gamification describes the broad trend of employing game mechanics to non-game environments such as innovation, marketing, training, employee performance, health and social change. Enterprise architects, CIOs and IT planners must be aware of, and lead, the business trend of gamification, educate their business counterparts and collaborate in the evaluation of opportunities within the organization.

The Pew Research Center carried out an extensive survey of diverse experts on the future of gamification (Anderson and Rainie 2012). They formulated a series of tension pairs, two propositions with opposing outcomes in 2020. Around 1000 people participated, with an opt-in and therefore not random selection. An example of one such pair is *Gaming is double-edged: it can be fun, useful increasing engagement and personal improvement; it can also be manipulative, insidious*. The overall expectation was an ongoing increase to 2020, but with mixed feelings about how desirable and effective it would be, as hinted in the tension pair example. Some of the respondents hark back to the point made earlier: gamification is a new wrapper for techniques which have been around a long time viz.

> Gamification is an overblown term for old-school marketing. Yes it works, No, it's no game changer (pun intended). —Paul Jones (Anderson and Rainie 2012)

The idea of cognitive manipulation cropped up repeatedly with its good and bad connotations.

One of the four game elements above, the awarding of badges, has taken on a life of its own. Mozilla, which makes the popular Firefox browser, has introduced the Open Badges (Mozilla 2014), a comprehensive framework for creating badges which includes: the image; URLs which encode details of what the badge is for, how it is earned and how it is validated; and tools for maintaining collections, called knapsacks, of badges, displaying them and so on.

Badges are particularly effective at influencing user behaviour. Anderson et al. (2013) developed a model for how users respond to badges and find it predicts a *steering effect* and validate it against the popular website Stack Overflow. Essentially, users devote more and more time towards the badge the closer they get to it. This in turn shifts their distribution of activity. In the education context we will come to shortly, this steering effect has to be carefully balanced.

British company Hide & Seek, operates in a similar space of gamification of everyday things and collaborative/community engagement, i.e., the spin-off is the goal. Complementing the Olympics in London was the 2012 London Showtime Festival, which featured a huge range of community activities. Amongst them were 99 Tiny Games, across all the 33 London boroughs. Tiny Games was funded through Kickstarter (Kickstarter 2013), one of the first and biggest crowd-sourcing activities.

Of the many such applications springing up everywhere, we now want to look at the increasing activity in, and the relevance to, education and training. Of the variety of applications, we can distinguish two broad categories: increased participation and increased performance levels.

Perhaps because of the pervasiveness of online and multiplayer games, increased participation seems to be achievable through gamification. Fitz-Walter et al. (2011) developed *Orientation Passport* to engage new students in the variety of activities offered in orientation week and at the beginning of semester. Although it was moderately successful, it highlighted a freakonomics hazard (Levitt and Dubner 2005): so, if points were awarded for attending up to three events, students might attend just three.

College students also respond to gamification. At the US Air Force Academy, de Freitas and de Freitas (2013) developed a gamification tool, *Classroom Live*, to enhance participation, what they refer to as *classroom gamification.* Survey results after the first 3 months of use are generally positive.

Hakulinen et al. (2013) carried out a more quantitative study of students studying online data structures and algorithms, aspects of computer science. Badges were awarded for a range of good study practices, as well as performance *per se.* The sample size was 281, but only a small fraction showed behaviour change as a result of earning badges. But this highlights an important feature of the design. The badges were meant to be motivators in their own right. Getting badges had no impact on the final grades.

The need to divorce game rewards from course outcomes or requirements is stressed by Landers and Callan (2011). They examine the psychology of gamification using a series of tests in psychology courses embedded within a purpose-built social network site. The tests were for training only and were not included in any grade assessment. The participation was around 30 % of about 600 students. Likert tests (scale of 5) showed a strong bias of (high) scores of 3–5 on questions relating to fun, enjoyable and rewarding.

At the school level, classroom gamification gets a great deal of attention. Studies are too numerous to consider here, so we will consider just two examples: Mathland and Buzzmath. Both blend skill development with participation.

Franelli (Ross 2010) developed Mathland to enhance classroom maths teaching in Canton, near Detroit. Each student gets an avatar on a leader board which the whole class can see. As they progress through various proficiency tests their avatar moves up the board. Although each pupil tracks their own progress on the board, they can also see how others are doing. Although there is no control study, the class improvements were significant: 13 % increase in attendance in 2 years and 22 % increase in statewide assessment in 3 years.

Buzzmath (2014) makes use of the Mozilla Open Badges system discussed above, with badges for many different skills in basic numeracy. Developed by a multidisciplinary team of teachers and designers, it is a commercial product but is used in North American schools. Although controlled evaluation does not yet seem to be available, the engagement seems strong and support has been received from the prestigious MacArthur Foundation.

There are some issues with gamification, though, highlighted by Scott Nicholson of the *Because Play Matters* lab at Syracuse University (Nicholson 2012). The lowest level of gamification is simply a point collecting system, which well-known game polemicist, Ian Bogost, has attacked vociferously (Bogost 2008, 2011). Gamification needs to go beyond this to more meaningful play dynamics and can include mechanisms such as people setting their own goals. Deci (1971) argued that extrinsic rewards weaken internal motivation and extensive follow-up work reinforces these conclusions across many different domains of learning (Deci and Ryan 2008). But where intrinsic motivation is weak, gamification with external rewards, can still be a productive way of getting things done.

More recently, Grant (2011) at the Wharton Business School, summarised a wide range of studies, showing external motivation, such as financial incentives, leads at best to lower performance and at worst exaggeration and unethical practices. One prominent voice, cited therein is Daniel (Pink 2011), whose TED talk is highly recommended. He advocates the trilogy of *Autonomy, Mastery and Purpose* (AMP) as the key to superior performance.

So, where does this leave gamification? Pink (2011) makes the point that AMP is crucial to creative work, finding divergent and novel solutions, which are absolutely essential to the modern world. Gamification, though, still seems to have a place in dealing with concrete tasks, where novel solutions are not (one assumes) required and where intrinsic motivation is hard to find. It seems to have a strong role in remedial or school classes where motivation and/or attendance is low for whatever reason. Whether it belongs in tertiary education is a moot point, to which this author is in the negative camp.

But even for very young children, the best mathematical games or interventions, dig deep into research in the development of cognition. Two highly successful programs, Number Worlds and Building Blocks do precisely this with carefully constructed *learning trajectories: a goal; a developmental progression; and a set of instructional activities* (Clements and Samara 2011). Given the hive of activity in gamification of elementary numeracy, the concluding remarks by Clements and Samara (2011) are worth remembering, that we want to get deep into mathematics:

> There is much to gain, and little to lose, by engaging young children in mathematical experiences. Mathematics is cognitively foundational…. Evidence supports interventions that provide foundational and mathematical experiences in number, space, geometry, measurement, and the processes of mathematical thinking.

Assessment

With the increasing use of technology in schools, the amount of data available for analysis is vast. Companies such as Knewton specialise in the collection and analysis of such data, making it possible to adapt learning to each and every individual (Economist-Anonymous 2013). It also becomes possible to measure performance *in situ* as opposed to more conventional means, so-called *stealth assessment*.

Although games are played for fun, for and in themselves, players nevertheless like to keep league tables, master ranking systems, national trophies, the Olympics writ small from checkers to chess, from snap to bridge. These are the grist of gamification and obviously we would like to harvest such competitive data to serve as assessment.

Most serious games are oriented towards beginners, or players with not much more than minimal experience. But mastery takes a long time. The commonly accepted view, which originates with Nobel Laureate Herbert Simon, but has since been developed by people such as Fernand Gobet and Karl-Anders Ericsson, is that deep expertise takes time: 10,000 h of focused experience, or the acquisition of 200,000 pattern fragments or chunks.

That would be a lot of time spent playing a game, unless of course the game was an end in itself, such as becoming a grand master at Chess. But the glory of the great games of history, such as Chess and Go, is that beginners and masters play the same rules on the same board. This opens up the potential to assess players from the moves they make. It turns out not only to be possible to do this, but an unexpected finding pops out—tipping points in the acquisition of expertise. We elaborate on these findings and explore the implications for assessment generally later in the section.

Tipping Points in the Acquisition of Expertise

Archimedes' Eureka moment transmitted a word directly from ancient Greek to modern English. We have all had the experience of a sudden flash of insight. But it is also a common experience to see, often quite suddenly, how all the pieces of a domain of knowledge fit together. Until now it has been difficult to do little more than conjecture how this might work, or even how true it is. It is hardly feasible to do experiments lasting 10,000 h. But asking experts how things progressed for them is a notoriously unreliable methodology.

The advent of big data—very large volumes of data online—has enabled an entirely new method. We can now look at what people do, beginner or expert, over thousands of decisions, maybe millions of decisions in the near future.

Because game associations rank players, there is a ready-made metric to relate the decisions they make to their ability. The Game of Go is an ideal game to study. Firstly, it is the oldest game by far listed by Salen and Zimmerman (2004) in their game appendix and is very likely to be the oldest game with any strategic depth. Its complexity, but human tractable complexity, may be one reason it has lasted for 4000 years, with each generation finding new moves and strategies.

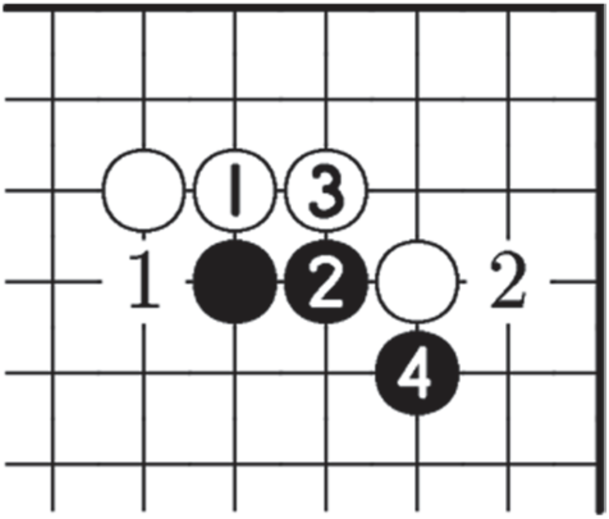

Fig. 4 A fragment of a Go board. If black plays at position 2, then the white stone has only one liberty (free grid point) left and will die if black is allowed to play there too. If white joins this stone up with the stone marked three the stone is safe (for the time being). If white can play at the point marked 1, then black needs to join 2 and 4. If white can occupy this point the two black stones will die

Go is interesting for a couple of other reasons. Firstly, it is extraordinarily simple. There are no pieces with different roles, as say the king, queen and knight in Chess. There are just black and white stones, as shown in Fig. 4. There is no complicated board, like Monopoly, just a simple 19 × 19 grid. It has just a couple of simple rules, from which emerges a game of great subtlety, a quintessential complex system. Lastly, it is still the most difficult of all games for computers. Go bots struggle to reach club level, lending the game an air of mystique as one of the few bastions of human intelligence not yet breached by computers.

Fortunately, there are lots of games recorded online, which means we can compare the move profiles of the top professionals (9-Dan Professional, denoted 9P, effectively equivalent to a Grand Master in Chess) with all the players below. Doing this generated three important findings:

1. It takes a long time before the big picture takes shape.
2. There is a tipping point on the way to 9P.
3. The tipping point occurs through changes at a very early perceptual level.

Salen and Zimmerman (2004) and Klabbers (2009) both stress the importance of complex systems in thinking about games and this notion of pieces self-assembling into larger structures is a canonical theoretical mechanism (Bossomaier and Green 2000). A profoundly important paper by Erdös and Rényi (1960) captures this idea in the notion of random graphs.

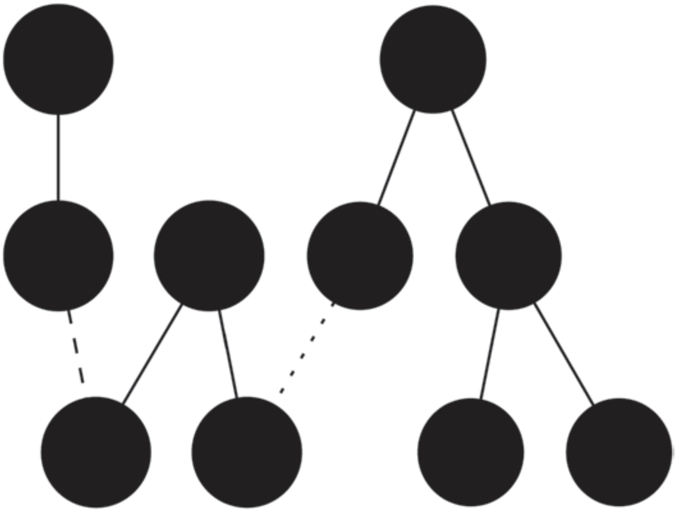

Fig. 5 Erdös Rényi random graph formation. When the dashed edge is added a second five node component is formed. Adding just one more edge, such as the dotted edge, makes the graph fully connected

Figure 5 shows the development of a random graph. We start with a collection of points (*nodes*) and draw lines (*links*) between them at random. As the number of links grows clusters start to appear. Then adding just one extra link can join clusters together, making a much bigger cluster, creating *giant components* and the graph becomes fully connected, where there is a path from every node to every other node. This process is referred to as the connectivity avalanche and is an example of a *phase transition.*

Seeing the Big Picture

It is a common experience, but one difficult to quantify, that we often learn things bottom up. Parts start to fit together and parts ultimately join up until global relationships are clear. The random graph model discussed above shows in a simple abstract way what is happening. When, and how does it occur though, is a largely open question.

For Go, Harré et al. (2011b) determined when the big picture appears. Figure 6 shows what happens. By analysing tens of thousands of decisions from games at different ranks, it was possible to compute how far a player was in strategy from a 9P (the best). The mathematical details are based around Shannon's ideas of Information Theory (Shannon 1948) which can be found in the original paper, but here we just want the qualitative idea. The key result as explained in Fig. 6 is that the global insight does not really develop at all until 1-Dan Amateur. This is a seriously good Go player. It would usually require several years of serious tournament play to get to this level.

The challenge and opportunity for serious games comes in being able to assess, *as people play*, when they reach this understanding of global factors. The challenge lies in that such games have to address the cohort of people well beyond the beginner level.

The Expertise Flashpoint

Turning now to the tipping point in expertise, the flashpoint where everything fits together. Again, we can find this from the analysis of online games. Figure 7 looks at how the strategies from some rank compare with the rank just below. The lower curve in the figure is the comparison with the best, 9P. It falls steadily as we saw in Fig. 6

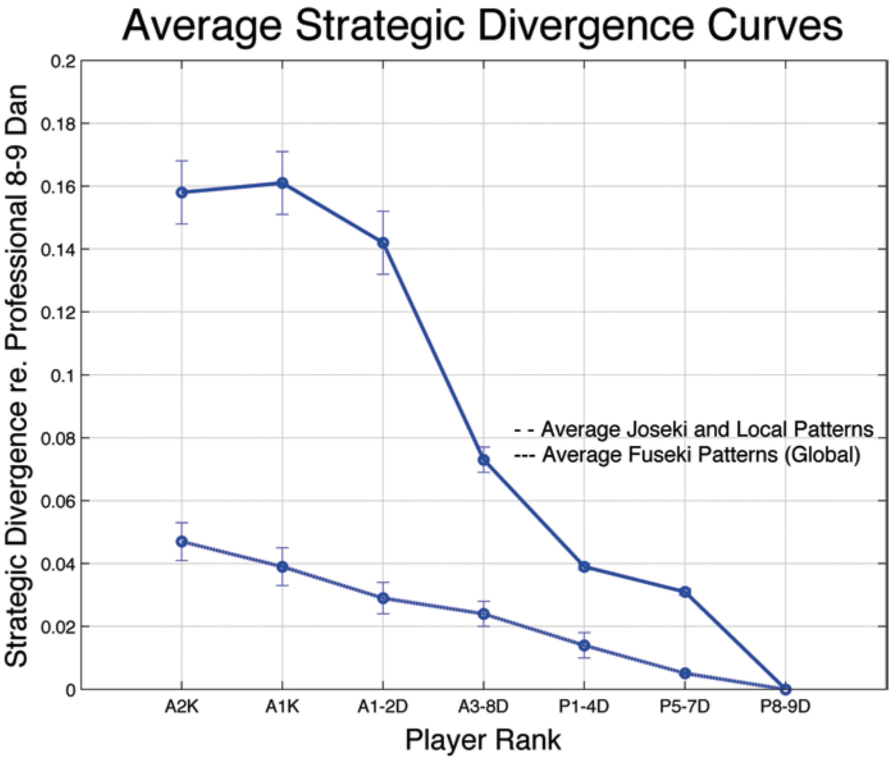

Fig. 6 Illustration of the relative performance on global problems (see text). The bottom line shows the gradual matching of strategy to 9P as a function of rank across diverse problems. The y-axis measures the *difference* from the top experts. The top curve does the same for problems which require *global* understanding. The curve is flat (meaning no improvement) until 1-Dan Amateur (Redrawn from Harré et al. 2011b)

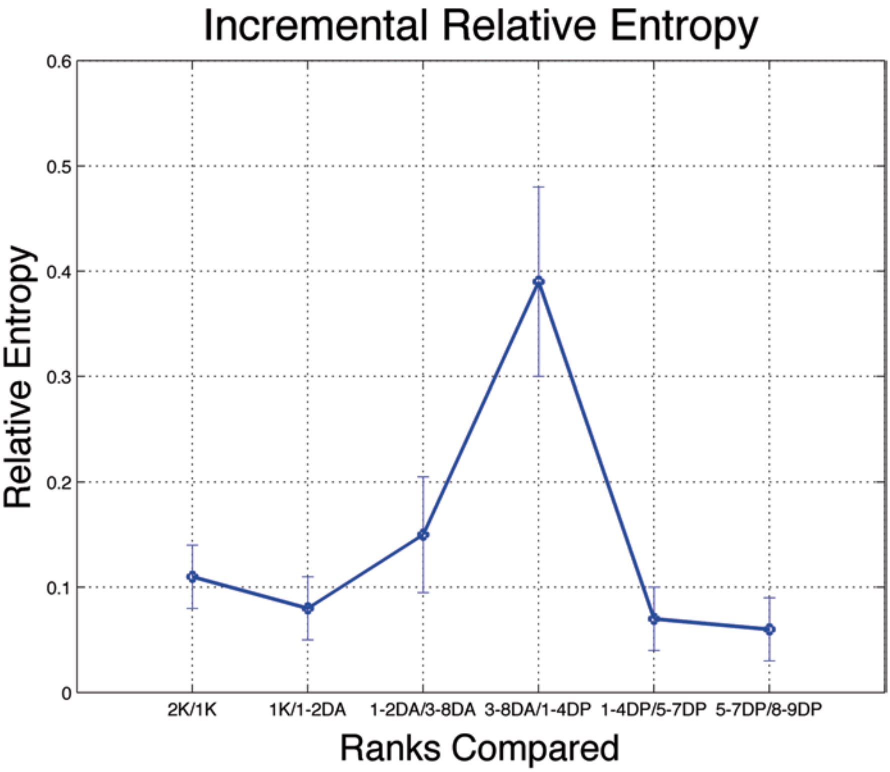

Fig. 7 The expertise flashpoint (Redrawn from Harré et al. 2011b)

on local-global. But comparing adjoining ranks, there is a big peak in difference at the top amateur and low professional ranks. But the overall performance is not changing.

This is more like a rearrangement of how things fit together. Further work established that this was a second-order phase transition by detecting a peak in mutual information (Harré et al. 2011a; Bossomaier et al. 2013).

There is much work to be done, to determine how widespread these transitions are. But the implication for serious games is clear. We want to be able to detect when players have gone through these expertise transitions.

Changing the Building Blocks

The final piece of the story tells us where and what these transitions are. One might assume that they are at very high cognitive levels in the brain. But the reality might be otherwise. Using a technique known as self-organising maps (Kohonen 1982), we determined sets of *perceptual templates*, the low-level primitives by which players group patterns on the board (Harré et al. 2012). It turns out that these templates

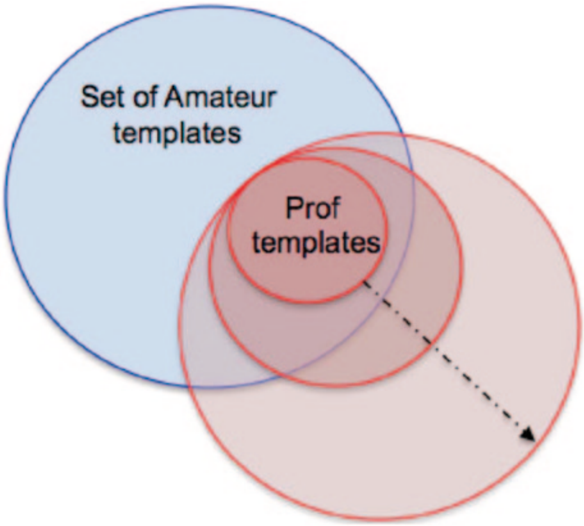

Fig. 8 Amateur and professional templates. As the threshold for frequency of occurrence decreases, more and more professional templates appear which are different from the amateur set. See Harré et al. (2012)

change significantly through the expertise transition. Figure 8 shows the limited overlap of amateur and professional templates.

So, the lowest level filter through which we see the domain changes. It is not so easy to get a feel for this by introspection. But many of the great breakthroughs in science involve a change at the lowest level, quantisation of energy, constancy of the speed of light or realisation that DNA was double helix. But the same happens amongst the great creations in art and humanities, cubism, equal temperament scale or squeezing paint, seemingly at random, but maybe fractally onto giant canvases, a technique made famous by Jackson Pollock.

A potential use of these findings within serious games is to get players to learn the templates of experts much earlier. It is not too difficult to imagine ways this might be done, but it is a completely open area of research. It might be that only through stumbling through some of the blind alleys that the royal road to expertise will become apparent.

Big Brother is Watching: Quiet Assessment

A recent innovation in thinking about learning, especially in the games context, is the idea of watching how people play, and measuring their performance *in situ*. Valerie Shute, who introduced the term in 2005, acknowledges its *sine nomine* use two decades earlier. Webb et al. (2013) prefer the term *quiet assessment*, to avoid the furtive implications of the former.

Knewton (a collection of Knerds) is a data analytics company putting computational teeth into student learning—to study individual learning and make it adaptive. Its founder, Jose Ferreira, points out in his company blog, that there are huge data resources waiting to be tapped:

> Only recently have advances in technology and data science made it possible to unlock these vast data sets. The benefits range from more effective self-paced learning to tools that enable instructors to pinpoint interventions, create productive peer groups, and free up class time for creativity and problem solving. (Ferreira 2013)

Computer games, along with some other digital media, offer tremendous possibilities for watching how we learn, giving us a gentle prod when we go off track, helpful little avatars popping up when we need a hint and a totally new level of personalised tuition. We saw above that if we have records of the decisions people make, we can track their progression from novice to expert.

But here, at the start of the second decade of the twenty-first century, we have hit a serious problem, discussed at length by Hickey and Zuiker (2012). We have entered an era of testing, national testing, even global standards. The US *No Child Left Behind* supported a narrowing of testing, which in turn led to increasing stress on teachers created by these outcomes of these tests, what Webb et al. (2013) describe as *high stakes assessment*. Hickey and Zuiker (2012) point out that the drive for the readily testable and the effectiveness of simple drill-like exercises (and we could suggest that a lot of gamification would fit into this category) interfere or conflict with *assessment for learning*.

We saw something of this dichotomy in the TEEM report above. The rich multi-level feedback, which we could potentially get from computer games, may not fit in with teacher priorities imposed by national curricula. Specifically in maths and English, studies have found that assessment practices were weak (Webb et al. 2013) and even hint that teachers may not be given sufficient opportunity to be involved in assessment design.

At the time of writing (mid-2014) the world is awash with professional failings, driving increased monitoring and accreditation. The work of rogue traders and other crafty operators betting on the collapse of sub-prime mortgages and other shaking financial instruments, created the Global Financial Crisis (GFC) and brought us very, very close to a global economic meltdown. The UK National Health Service, lauded by Danny Boyle in the opening of the London Olympics, is suffering one crisis after another, as one hospital after another fails to meet basic standards.

But these large-scale challenges go beyond conventional training. Some of the people making the decisions which led to the GFC were highly qualified. Serious games have the potential to monitor expertise in a rich, realistic context and provide ongoing updating and measurement of performance amongst established practitioners. This is another open area of research.

Envoi

Video games are a major feature of twentieth century life. They occupy a big chunk of leisure activity and show huge promise for learning and education. They have an established track record in skill development, such as learning to fly, drive or operate something. They show a lot of promise in many areas of the school and university curriculum.

But the real excitement of this growing area of serious games is the complex environment surrounding the game, the meta-game and affinity spaces. This rich, creativity extension of the gaming world offers in-depth, contextualised understanding. One of the huge gains, and possibly, one of the challenges, is integrating these powerful frameworks into conventional courses and educational programs:

> …the symbols and formulas of the Glass Bead Game combined structurally, musically and philosophically within the framework of a universal language, were nourished by all the sciences and arts….—The Glass Bead Game

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Terry Bossomaier is Strategic Research Professor of Computer Systems in the Faculty of Business at Charles Sturt University. He graduated from the Universities of Cambridge and East Anglia and has carried out research in diverse areas, from sensory information processing to parallel computation. He is the author/co-author of four books, co-editor of two more and the author of numerous papers. His most recent centres on using information theory to predict tipping points in complex systems. He has had a long-time interest in games and set up the first computer games degree course in Australia, which has been running successfully for over a decade.