Framing the Adoption of Serious Games in Formal Education

Sylvester Arnab¹, Riccardo Berta², Jeffrey Earp³, Sara de Freitas¹, Maria Popescu⁴, Margarida Romero⁵, Ioana Stanescu⁴, Mireia Usart⁵

¹Serious Games Institute, University of Coventry, UK
²University of Genova, Italy
³Institute for Educational Technology, Italian National Research Council, Genova, Italy
⁴Carol I National Defence University, Bucharest, Romania
⁵Escuela Superior de Administración y Dirección de Empresas (ESADE), Barcelona, Spain

Abstract: Nowadays formal education systems are under increasing pressure to respond and adapt to rapid technological innovation and associated changes in the way we work and live. As well as accommodation of technology in its ever-diversifying forms, there is a fundamental need to enhance learning processes through evolution in pedagogical approaches, so as to make learning in formal education more engaging and, it is hoped, more effective. One opportunity attracting particularly close attention is Serious Games (SG), which offer considerable potential for facilitating both informal and formal learning. SG appear to offer the chance to “hook” today’s (largely) digital-native generation of young learners, who are at risk of falling into an ever-widening gap between “networked” lifestyles and the relative stagnant environment they experience in school and university. However, there are a number of inhibitors preventing wider SG take-up in mainstream education. This paper investigates SG in formal education, initially by concentrating on pedagogical issues from two different but complementary perspectives, game design and deployment. It then goes on to examine game based practice in formal settings and focuses on the pivotal role of the educator within the emerging panorama. This is followed by a brief look at some specific implementation strategies, collaboration and game building, which are opening up new possibilities. Finally some points for further consideration are offered.

Keywords/Key Phrases: serious games, game-based learning, pedagogical issues, formal learning, teacher’s role, collaboration

1. Introduction

Over recent years considerable interest has been devoted to the pursuit of learning through, and with, digital games and particularly so-called Serious Games (SG). The latter are defined and interpreted from a range of different viewpoints: Zyda (2005) sees them as “a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives”. More broadly, Michael & Chen (2005) see SG as “a computer based game with a primary purpose other than entertainment”. Egenfeldt-Nielsen and colleagues (2008) shift the focus from game artefact to game process - from serious game to serious gaming - by stating that “any video game can be perceived as a serious game depending on its actual use and the player’s perception of the game experience”. Stone emphasises the learning dimension within this broader framework, describing SG as “games that support learning in its broadest sense” (Stone 2008). It is in the latter senses that the terms Serious Games (SG) and Game Based Learning (GBL) are used hereafter.

Many studies point to the positive qualities of SG, such as their persuasiveness and motivational appeal, which can support immersive, situated and learner-centred learning experiences (David & Watson 2011; Gee 2003; Aldrich 2009; Gibson 2006). Proponents of SG see them as a means for active construction, rather than passive reception, of knowledge and as prime opportunities to practice key soft skills like problem solving, decision making, inquiry, multitasking, collaboration and creativity. While some remain sceptical (Foster, Mishra & Kohler 2010), most agree SG have strong
potential for learning. That said, inhibitors to uptake need to be recognised and addressed if the potential is to be realised in formal education (Williamson 2009; Sandford et al. 2006). 

Gaining a better understanding of the potentials SG present for learning and how best they can be leveraged to enhance learning processes is one of the main objectives of partners in the Games and Learning Alliance (GALA), an EC-funded Network of Excellence on SG (see http://www.galanoe.eu/). These aspects are of particular concern to GALA’s pedagogy sub-group, whose joint reflections are encapsulated in the following discussions. These begin with examination of pedagogical issues from two different but complementary perspectives, game design and game deployment. Subsequently, game-based practice in formal settings is explored, focusing on the pivotal role of the educator within the emerging panorama. This is followed by a brief look at some specific implementation strategies, collaboration and game building, which are opening up new possibilities. Finally some points for further consideration are offered.

1.1 Approaching pedagogy from a game oriented perspective

Investigating the potential of digital games for enhancing learning, many proponents have focused in the first instance on the nature and design of the game artefact. Some authors have taken a close look at popular video games (Bopp 2006; Becker 2006; Gee 2003; Prensky 2007), noting how these “guide” players towards understanding of the game-world and how they support acquisition of the knowledge and skills needed for successful gameplay, i.e. winning. These efforts have led to frameworks of design-based “learning principles” that, taken together, form a kind of video games pedagogy. The authors also advocate the adoption of such principles for the design of Serious Games, whose intrinsic vocation is to support learning processes, possibly by leveraging rather than eclipsing the fun factor. Some emphasise the need for SG design to be pedagogically informed and based on instructional design principles (Van Eck 2010).

An alternative, more “bottom-up” approach examines the learning dimension of games from the viewpoint of problem solving, i.e. game situations that the player has to tackle by applying problem-solving skills. These are seen by some authors as intrinsic and elemental to gameplay (Gee 2007; Kiili 2007; Van Eck & Hung 2010). The last of these authors proposes a problem-type taxonomy and posits the deconstruction of game problem-events into atomic units of minimal granularity as a foundation for systematically analysing (and also tackling) game design; the thinking is that in this way “instructional designers and game developers have a better idea of what types of gameplay will most appropriately afford given learning goals and objectives”.

A slightly looser, more open-ended approach towards gaining that same understanding is through educational game design patterns, which are defined by Kiili (2010) as “semiformal interdependent descriptions of commonly reoccurring parts of the design of an educational game that concern and optimize gameplay from an educational perspective focusing on the integration of engagement and learning objectives”. These text-based descriptions are proposed as methodological blueprints for analysing and tackling different aspects of game design, including those related to the learning dimension.

Hirumi and Stapleton (2009) assume a slightly different vantage point that concentrates on development processes, equating the fields of game development on the one hand with instructional design on the other. They identify a number of key parallels and intersections between the two that call for coordinated effort in order to maximise the potential for enhancing learning opportunities and reaching objectives. They stress that game design should start with a suitable pedagogical approach, which is “critical for determining the nature of the learning environment and guiding the overall design and sequencing of critical learning interactions and gameplay… by basing the early entertainment development on pedagogy, any subsequent artistic choices will most always enhance, rather than obstruct achievement of the learning objectives.” On this premise, the authors investigate how a given pedagogical approach might be reified within the game design process, positing the adoption of a general framework based on grounded instructional events associated with learning outcomes of different kinds. Similar efforts have been made to shed light on learning with Serious Games by mapping identifiable steps or events in game interaction against general learning activity frameworks. One reference adopted for interpreting game pedagogy is Gagné (1977), particularly his “nine events of instruction” (Van Eck 2010). But other models are referred to as well (Kickmeier-Rust et al., 2006), including the 8LEM model (Verpoorten et al. 2007) and Bloom’s (revised) taxonomy (Krathwohl 2002). In the literature, Serious Games are often mentioned in conjunction with a set of pedagogical paradigms and approaches that are generally considered to be innovative, at least when set against
what is still considered established practice in much mainstream formal education, namely teacher-driven knowledge transmission of the "chalk and talk" kind. This set of "innovative" paradigms includes the likes of situated cognition/situated learning, learning-by-doing, discovery learning, problem-based learning, constructivist learning, among others. While the basis for such attributions can sometimes be sketchy, some serious efforts have been made to provide a systematic analysis. One such was carried out by Kebritchi and Hirumi (2008), who examined a broad set of Serious Games and sought to align these with recognized teaching/learning paradigms that the games are held to reify – or at least strongly resonate with. The basis for associating each game with a given paradigm was deduced from game designers' declarations and standpoints regarding the "pedagogical foundations" underpinning design decisions and strategies. The study grouped the vast majority of the 50 games considered under the chief pedagogical headings of situated cognition, experiential learning, discovery learning and constructivist learning (some games remaining unclassified). These four main categories are further sub-divided into sub-categories. For example, experiential learning (the most prevalent paradigm) is considered to comprise learning-by-doing, guided experiential learning, case-method teaching and experiential/inquiry-based learning. A high-level theoretical framework of this kind is quite evidently open to (re)interpretation and alternative arrangements, nonetheless the attempt at a pedagogical analysis, and classification, of a substantial set of SG grounded on an empirical study represents a useful reference point for further investigation. Indeed, some of the authors of the present paper are currently seeking to extend and enrich this pedagogical survey by adding further paradigms and more examples from the literature; this effort is an undertaking of the GEL Theme Team (see http://www.teleurope.eu/pg/groups/81989/gel-game-enhanced-learning/), an initiative supported by the STELLAR Network of Excellence (see www.stellarnoe.eu), co-funded by the EC under the Seventh Framework Programme.

1.2 Approaching pedagogy from a context oriented perspective

Thus far the discussion has concentrated on the inherent nature and features of games adopted for learning purposes. However, efforts to enhance formal education with serious games are influenced to a large degree by the particular learning context in which a game is deployed and – crucially – by how the educator adopts a game to address particular objectives and learning goals (Egenfeldt-Nielsen 2006). Specifically, a pivotal role is played by (a) the attitude educators assume to SG and game based learning environments, (b) the activity plans and scenarios they devise, (c) the roles, strategies and pedagogical approaches they assume when enacting those plans (Hanghøj & Brund 2010; Chattergee et al. 2011). These factors are discussed in greater detail in Section 2.1. An important starting point is for educators to have an awareness of the particular approach that a particular game lends itself to. In an ideal world they would have access to a wide range of games that differ not just according to subject matter, target group addressed etc. but also in terms of the approach to learning that the game embodies (or might be suitable for), as discussed in Section 1.1. Informed choice on this last aspect is central to the educator's (a) preparedness for the dynamics actuated through interaction with the learning environment, and hence (b) the capacity to guide learning processes effectively towards predetermined learning goals.

Some recent field studies have sought to quantify the impact of context and pedagogical approach on learning outcomes generated within game based learning processes. For example, Chattergee and colleagues (2011) compared the learning outcomes of different student groups who played the same set of SG under different circumstances, i.e. with or without peer collaboration and facilitator support, or with both/neither of these. Although the scope of the tests was admittedly limited, careful statistical analysis of the outcomes confirmed that peer collaboration and facilitator support are factors that are "effective in promoting learning through game-play". It should be noted that 'collaboration' is intended here as students conversing and helping one another out during game sessions, rather than assuming collaborative roles within the games themselves. The authors note that their findings on collaboration substantiate earlier studies carried out by Ke (2008) amongst others, while the outcomes regarding facilitator support confirm the finding of Garris and colleagues (2002). In addition, their results are congruent with the findings of a field study by Leemkuil & Hoog (2005), which revealed that some forms of game-embedded support actually have no positive impact on learning outcomes (indeed they may even have a detrimental "crutch" effect), while player cooperation and facilitator-initiated briefing/debriefing sessions prove to be effective support mechanisms.

As mentioned above, pedagogical context is considered another important factor influencing how – and how effectively – games are used for learning. To investigate this, Barendregt & Bekker (2011) conducted a field study comparing the expectations, attitudes and actual use of an educational game
by children attending schools of three fundamentally different types. The three settings presented children respectively with three distinct levels of freedom for choosing and pursuing learning activities (gameplay in this case), i.e. free choice, limited choice, and no choice. The authors monitored gameplay in both formal (school) and informal (free time) contexts in an effort to determine whether the three types of pedagogical setting impacted on students’ informal game uptake – a key indicator of intrinsic motivation. Results showed that the strongest and most sustained engagement across both the formal/informal contexts was generated in the limited choice setting; in the free choice setting interest proved weaker in both contexts, while no choice (perhaps predictably) generated strong engagement exclusively in the formal context, which however was summarily truncated when the allotted class-time ‘expired’. Once again the authors point to (a) the critical role of the educator in positioning gameplay within structured learning activities, guiding the unfolding of those activities, and facilitating learners, and (b) the importance of players’ socialisation of game-play not just to lower the entry threshold for non-players but also to maintain engagement and enhance learning. These key aspects are discussed further in Section 2.

1.3 Towards multi-perspective frameworks and curriculum integration

The multiplicity of vantage points assumed for investigating learning with SG, exemplified by the efforts discussed thus far, suggests the need for high-level, overarching models and frameworks to provide both conceptual and practical support. Examples of such models include the four dimensional framework (de Freitas & Oliver 2006), the exploratory learning model (de Freitas & Neumann 2009), multimodal interface architecture model (White et al. 2007; Arnab et al. in submission) and the game-based learning framework (Van Staalduinen & de Freitas 2010).

In particular the four dimensional framework (fig 1) advocates the use of pedagogy, an emphasis on learner modelling, the required amounts of fidelity, interactivity and immersion in the representation of the game, and consideration of the context within which learning takes place (Rebolledo-Mendez et al. 2009; de Freitas & Jarvis 2008).

![Figure 1: the Four Dimensional Framework](image)

Each of these four dimensions encompasses aspects that are essential not only for game design and evaluation but also for effective adoption in educational processes. Learning specification involves elicitation of the characteristics defining the learner population so that the intervention can be tailored to meet requirements and optimise outcomes. Representation regards key attributes of SG such as immersion and interactivity which, when successfully implemented, can open the way to the sorts of flow-driven learning experiences recognised as being among the chief potentials of game based learning (Csikszentmihalyi 1990). Context is a key consideration in technology enhanced learning.
generally, as discussed in the following section, it plays a particularly important role in shaping learner expectations as far as SG are concerned. Pedagogical considerations represent the cornerstone of any instructional intervention, encompassing models and approaches (e.g. associative, cognitive, situative) adopted in pursuit of learning objectives.

Research has yet to present educators with clear guidelines to help them incorporate games in practice in such a way as to ensure a smooth continuum from theory/planning to deployment and evaluation. So as well as informing research into SG, conceptual frameworks such as the one above can also represent a useful bridge to support transfer and exchange among those involved in different capacities and at different levels in the SG ecosystem. This is also true for those concerned with curriculum innovation, in this case via integration of SG into curriculum frameworks.

The curriculum is an embodiment of an educational system, be it school (K12), Higher Education or company training. It is a complex and evolving set of rules, experiences and documents, a complex pedagogical project that contains design, practice and assessment stages, guidelines on practice and the competences to be formed, along with assessment types.

The so-called 21st century curriculum is competency based, centred on what students know and can do. It is a curriculum focused on the upper levels of Bloom’s taxonomy - analysing, evaluating, creating (Krathwohl 2002). It is research driven and based on active learning processes whereby the student is no longer spoon-fed, but is encouraged to engage actively with appropriate levels of guidance and scaffolding. It is a curriculum connected to students’ interests, experience and talent, and relates to the real world. It allows students a certain degree of freedom in selecting what, when and how to learn, according to their cognitive and metacognitive abilities. Given that the educational value of games has already been recognised (Gredler 1996), considerable benefit would be gained from aligning games with the curriculum. However, introducing SG into the curriculum requires careful consideration by decision-making bodies and teachers alike.

2. Game based learning in formal settings

The most fundamental distinction that can be made with regard to the context of SG use is between formal and informal settings. To date much of the attention dedicated to SG has regarded their design for, and use in, informal settings, i.e. “daily work-related, family or leisure activities” in which learning is largely unintentional on the part of those involved (Tissot 2004). In this light, it is truly safe to say that, where SGs are concerned, “the game’s the thing”. By the same token, however, players may not necessarily be adverse to playing games with a fairly explicit educational agenda. This is borne out by a recent wide-scale survey of students in which the majority of those questioned stated that they did not mind using games with overtly educational objectives in an informal setting (Dunwell et al. 2011). Evidently what counts first and foremost is the expectation of playing a game that features good playability and offers a rich and engaging gaming experience, irrespective of whether there are overtly educational objectives or not. Indeed, the question of expectation is an important one both for SG design and deployment.

While the initial spotlight has been trained mostly on informal contexts, a growing body of experience is being accrued in the deployment of SGs within formal education settings as well. Games are becoming increasingly pervasive in a whole range of contexts, particularly in the lives of young people, and this trend is encouraging education policy makers and practitioners to seriously consider game use in classes. Strong impetus in this direction is already coming from the recognised need to (re)engage disaffected learners, and game based learning is seen as a potentially effective response. As a result, we are more likely to see serious gaming become an integral part of curricula over the coming years. As will be discussed in Section 3, there are issues regarding practitioners’ positioning with respect to SG, nonetheless game based learning represents an opportunity for more creative approaches that could have a significant and positive impact on teaching practices.

Many experiences of game deployment in educational settings carried out to date have concerned commercial off-the-shelf games, also known as COTS. By contrast, digital games purposely designed to pursue a more overtly educational agenda, related in some way to curriculum (or cross-curriculum) concerns, have figured to a somewhat lesser degree. A number of factors might be behind this: the range and ready availability of COTS, greater student (and teacher) familiarity with these games and their formats, the perception that they represent a refreshingly engaging alternative to entrenched
subject-based teaching (Sandford et al. 2006). Another consideration, which was alluded to at the beginning of Section 1, is that these commercially successful video games often embody sound game design, generating compelling gameplay experiences. In this sense COTS may well be seen as “quality” game environments that resonate with: (a) Malone’s idea (Malone 1981) of intrinsically motivation fostered through challenge, fantasy and curiosity; (b) Csikszentmihalyi’s idea of flow (Csikszentmihalyi 1990). Educational/Serious Games conceived explicitly in response to educational requirements are not always seen in the same positive light.

A number of successful deployments of COTS in formal education settings have been documented. One example is Blunt’s adoption of COTS management simulation videogames (Industry Giant II, Zapitalism and Virtual U) for business studies (Blunt 2007). Other COTS games already being used in the classroom include Civilization (history), Age of Empires II (history), CSI (forensics and criminal justice), The Sims 2 (making complex social relationships), Rollercoaster Tycoon (engineering and business management), and SimCity 4 (civil engineering and government). For some of these there is a clear match between the game’s explicit content and classroom subject; for others, a match is sought between the aims and skills involved in the course of study and the game’s underlying strategies and gameplay. Other noteworthy initiatives that have used these and other COTS include Learning & Teaching Scotland’s Consolarium, the Institute of Play’s Quest to Learn Middle School in New York, North West Learning Grid’s DiDa program in England (Derryberry 2007) and Futurelab’s Teaching with Games project (Sandford et al. 2006).

While such experiences indicate that games have strong potential for enhancing learning, there is still a relative lack of solid and reliable research findings about integration of SGs into teaching and learning. This leaves questions unanswered and as a result the potential remains largely untapped in mainstream formal education. In order to understand how games can best be exploited within a formally structured educational context, we need to look not just at the nature of the game as such but also at how the game and its characteristics can be adopted and leveraged to enhance learning within the structural, organisational and cultural constraints of institutional education (Johnston & Whitehead 2008). This entails broad consideration of ICT-supported innovation in formal education, which is informed and driven by a multiplicity of interrelated factors like new tools and pedagogies, as well as the new organisational roles and relationships that are shaped by learner-centred and collaborative approaches to the learning process.

2.3 The educator within the emerging panorama

The educational panorama presently defined as “new” by most researchers (Ala-Mutka et al. 2008) has been (and still is) deeply influenced by the availability of new ICT tools, and learners are now more adept at using these tools. As stated above, SG can play a major role here in instilling innovation in learning processes: they present immersive educational worlds (de Freitas & Neumann 2009) where students can be more deeply and actively involved in educational activities. As proposed by Ott (2011), figure 2 contrasts the traditional learning situation in many formal educational contexts (left) with that (right) typified by the new learning community.

*Figure 2:* Traditional relationship between teachers-learners (left) vs. the new learning community (right)

In the former, teachers mainly act as the information providers and students the recipients, with a prevalingly unidirectional information flow between the two groups. In addition, the two groups are
strictly separate and their respective members (teachers/learners) are depicted as being similar / identical to each other (teachers-squares; students-circles) since the (reductive) nature of the information transmission-reception paradigm attributes little real value to the actors’ individual characteristics.

By contrast, the second picture represents a vision that is both learner centred and based on dynamic collaboration among all the actors involved. Here learners are represented by different shapes, encapsulating the value of their individual differences. They assume the central position, are peer linked (work together, cooperate, network) and have reciprocal, frequent interactions with teachers, who also work in a team and not in isolation.

Facilitating educational processes with technology is a multi-faceted process, one that often places particularly high demands on the educator. In order to fully exploit the potential on offer, educators are called on to possess a range of qualities, attitudes and competencies, and to assume a variety of (sometimes challenging) roles. Beyond possessing subject matter and technological expertise, they need to be (amongst other things) competent instructional designers, strong team-players, critical self-analysts, confident risk-takers, and path-finding innovators pedagogically open to new ways of approaching the curriculum and tailoring classes assisted by technology (Midoro 1995; UNESCO 2011).

When it comes to SG, successful adoption does entail practical steps like identifying a suitable game for a given subject and gaining familiarity with that game. But it also calls for broader know-how that includes awareness of what subjects and skills can benefit from a games-based approach, when and how a SG is best deployed, what stage of the learning path is most appropriate, and how to account for and manage contextual factors.

Hanghøj & Brund (2010) argue that, with some notable exceptions, research in the field of educational games has been dominated by a determinist, game-as-learning-machine view which has largely overshadowed consideration for the teacher’s role. They postulate that “game-based teaching can be understood as a complex series of pedagogical choices, practices and meaning-making processes, which can be analysed through the complimentary notions of teacher roles, game modalities, and positionings”. To a certain degree this teacher-centred standpoint can be seen as an alternative, or complementary, take on the four dimensional model presented in Fig.1. Drawing on field studies in which teachers adopt the Global Conflicts series of Serious Games, the authors identify a repertoire of different, shifting roles that teachers assume through the process, namely that of instructor, playmaker, guide and explorer. These correspond to different phases in the deployment process and can be mapped (fig. 3) onto axes according to the type of knowledge (curricular/game) and perspective (outsider/participant) involved (Hanghøj & Magnussen 2010). The resulting “analytical lens” provides a general framework for gaining a more concrete understanding of game based learning dynamics from the educator’s perspective.

![Figure 3: The relationship between different game-based teaching roles](image_url)
ineffectual role, to the detriment of learning outcomes. This raises a key question: how to embed features in a game environment that support effective deployment in formal education contexts (i.e. that are “teacher sensitive”) without compromising playability. With regard to teachers’ positioning, the authors point to the importance of foregrounding the links between games, curriculum goals and learning outcomes as part of critical planning and enactment of game scenarios.

This study confirms the widely held position that general enthusiasm for SG needs to be matched by critical awareness so as to make the learning experience meaningful for each student. Indeed, not only should teachers know the game well, propose specific learning trajectories and verify effectiveness, they also need to engage in mediation, foster post-game discussions, and encourage reflection (Bellotti et al. 2010; Whitton 2010).

When considering the learning activities to complement and reinforce gameplay, it is important for teachers to “preserve the context (situated cognition) of the game, e.g. by extending the goals and character roles of the game into the classroom” (Van Eck 2006). Once again, this requires solid understanding of the game and means planning appropriate learning paths and monitoring their implementation to ensure effective learning; most importantly it means setting the gaming experience in a sound overall educational framework. This work is all the more important when considering that “games may not always meet the individual requirements of lecturers whose courses are tied to specific learning outcomes” (Rooney et al. 2009).

The transition from learning-by-listening to learning-by-doing generally implied in game based learning brings with it a change in the respective roles of instructors and learners, as illustrated in Fig. 2. Greater emphasis is place on orchestration of the actors on the stage (Garris et al. 2002) by the teacher, who fosters participation and engagement, provides support and feedback, and implements assessment. A key part of this support strategy is pre-game briefing and, perhaps most importantly, post-game debriefing, in which the chance to socialise and reflect on the game experience is key to consolidation of learning gained (Egenfeldt-Nielsen 2006).

3. Two implementation strategies: collaboration and game building

A central thread running through current ideas on education generally and technology enhanced learning in particular is the socialisation of learning processes. This is also reflected in current thinking in the Serious Games field and is generating new scenarios for game based learning in formal education contexts. One direction gaining increasing attention is collaborative gaming, whereby learners interact with one another in competitive/cooperative activities embedded in a multiplayer digital environment. Another approach that is opening the way for increased socialisation of students’ game experience in formal education is learning through game design and building; here, instead of being given a game to play, students have the task of designing, constructing and sharing their own games as part of cross-curricular learning. Some brief discussion and examples of these two approaches are given in this section.

3.1 Focus on collaboration

In the new learning panorama outlined in Section 2, teachers and learners collaborate to achieve learning goals. Interest in collaborative learning has grown in recent decades, supported by studies showing how peers really learn while performing group activities. Learners can build on each other’s knowledge and provide mutual feedback (Dillenbourg et al. 2009). Advantageous peer interactions such as providing and receiving explanations, co-constructing ideas, and negotiating meaning can be found in collaborative learning environments.

In the world of SG, new technological functionalities have recently emerged that have led to the development of engaging collaborative game environments for learning. Accordingly, collaborative SG should be taken into account as potential multi-sensorial learning tools that combine the benefits of collaborative and game based learning. Following Gee (2005), collaborative games not only allow individuals to participate in the same game, but open up a field for learners to construct understandings by interacting with information, tools and materials as well as collaborating with others. There are still few examples of SG that embed a collaborative pedagogical approach. One is Gersang, a pedagogical adaptation of a commercial Massively Multiplayer Online Role-Playing Game (MMORPG) (Kimet et al. 2009). Deployment of this game in a middle school classroom permitted a
qualitative and economic solution for enhancing students’ social problem-solving abilities through think-aloud and modelling processes. In higher education, Baker and colleagues (2004) designed and tested Programs and Programmers, a dyad game intended to help software engineering students gain better understanding of software development processes through active, collaborative and competitive gaming practices. Mawdesley (2010) studied how the introduction of two different SG could improve the learning experience in an applied construction project management program: the Mug Game and Canal Game case studies revealed significant improvement in the communication and presentation skills between peers that had used those games. Chang and colleagues (2009) developed and implemented SIMPLE, a SG environment for management students designed to raise teaching effectiveness and improve classroom practice. Some interesting results could be seen from collaborative playing experiences; students developed internalized knowledge and appeared more interested in the real world applications of the concepts practiced. Another recent initiative in collaborative SG is MetaVals (Romero et al. 2011).

These experiences showed how deployment of both COTS and SG can help students practice and improve metacognitive processes and lead to more concrete problem-solving behaviours among peers. To make collaborative learning effective in terms of learning outcomes and reduced organizational loads, guidance and a scaffolding process are required (Kreijns et al. 2003). This applies especially to SG, where students’ cognitive load should be devoted to the activities leading to attainment of learning objectives.

An interesting term that shows up when introducing SG in management education is “coopetition”, defined as collaboration within the group and competition between groups (Fu & Yu 2008). Competing while cooperating to win a game can be regarded as a successful learning strategy, as it stimulates different types of knowledge acquisition (Ke & Grabowski 2007). Competitive learning environments encourage students to develop higher analytical skills, while collaborative learning situations prompt students to demonstrate higher synthesis skills. Competition and collaborative pedagogies have proved to be effective techniques for enhancing learning performance in face-to-face learning environments.

3.2 Focus on game building

Over recent years, a general view has permeated education communities worldwide that the entrenched power balance within education systems ought to be redressed. It is held that students should be empowered to take a more proactive role in their own learning and in this way they will become more engaged, and hence more effective, learners. The view is encapsulated schematically in Fig. 2; Lim (2008) – to quote just one source – expresses it thus: “engaged learning is (only likely) to happen when students are empowered to take charge of their own learning by co-designing their learning experiences with teachers and other students.”

As mentioned earlier, one of the chief added values identified with game based learning is the opportunity to bolster learners’ intrinsic motivation and engagement (Ott & Tavella 2010). So combining student-driven and game-based learning could be a positive step. According to Lim, one way (forward) is for students to design their own computer games based on their own interpretations of the school curriculum.

A number of efforts in this direction have already been reported and analysed (Prensky 2008; Games 2009). Prensky offers a vision in which students’ game building not only permeates educational practice but even becomes a force in the SG ecosystem. Beyond the product-centred view, he recognises that the true value of game-making for learning lies in the creation process and attendant meta-learning. Such constructionist-oriented thinking is closely associated with the work of Seymour Papert (Ackermann 2001) and underpins the efforts in the field of Kafai (2006) and others. A key aspect in this regard is supporting socialisation processes and developing students’ creativity by means of collaborative interactions (Ott & Pozzi 2009). Students’ game construction still occupies a relative niche position within game based learning. However, pilot experiences - especially those run in the US (Mawdesley et al. 2011; Li 2010; Kafai 2006) - are indicating that game building activities can support the acquisition of knowledge and skills in a number of areas, not just in game content and procedure but also with regard to key transversal skills (Bates et al. 2008). Established digital authoring tools like GameMaker and Scratch are being joined by an ever-growing number of platforms such as GameStar Mechanic and Kodu, which are helping to lay the foundations for the sort of scenario envisioned by Prensky above.
Building on the growing body of work being carried out in this direction, a group of European researchers is currently investigating ways of supporting students’ collaborative game building. This effort is part of a project called MAGICAL (Making Games in Collaboration for Learning), which is co-funded by the European Commission under the Lifelong Learning Programme. MAGICAL explores collaborative design of educational games as part of learning processes enacted in primary and lower secondary schools; it applies a holistic approach that encompasses education/training of teachers and professionals in inclusion. Indeed, as described in Section 2.1, educators play a pivotal role in enacting and orchestrating game based learning activities in formal education and this is particularly crucial when it comes to dealing with the often complex dynamics of students’ peer collaboration within a constructionist-oriented framework. Moreover, by addressing teacher education/training from a multi-faceted transnational perspective, it is hoped that MAGICAL will build a basis for wider transfer to contexts beyond the project’s immediate confines.

4. Final reflections

This paper has sought to frame the adoption of Serious Games in formal education by discussing some key pedagogically-related aspects that have emerged from discussions within a sub-group of partners in the Games and Learning Alliance (GALA). It is believed that adopting a multifaceted view on the subject is a fruitful way of gaining deeper understanding and yields a range of indications for educators’ SG uptake, thus supporting wider adoption in formal educational settings. It is clear that a number of concrete steps need to be taken in this direction, including: better training for practitioners, simpler tools for authoring educational game activities, dedicated web based communities and resources for practitioners, more institutional support structures, and wide-scale access to pedagogically effective games, use cases and potential game content.

Game-based environments are evolving rapidly, and the game experience is set to become even more immersive, both by way of game design and via the technologies with which players will engage. By the same token, there is a good chance that new developments will emerge that more explicitly address the formal learning sector; these may include new tools for tutors to create personalised learning scenarios, intelligent tutoring environments that allow educators and students to author and choreograph experiences (de Freitas & Neumann 2009), greater learner game creation (Vos, Mejiden & Denesen 2011), integration of tools for supporting metacognition and also for fostering collaborative gameplay. In this light, the issues discussed in this paper are destined to take on even greater significance. Among the key challenges that lie ahead are adoption of SG across cultural contexts and ensuring the inclusion of all learners in game based activities.

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Furthermore, the authors point out that the integration of educational games with real-world contexts can significantly enhance learning outcomes. This approach is further supported by the findings of Kim, B., Park, H., Baek, Y. (2009) in their study on the effectiveness of game-based learning experiences. Their research highlighted the importance of incorporating meta-cognitive strategies to support students in their learning processes.

In summary, the integration of educational games with real-world contexts not only enhances learning outcomes but also supports the development of critical thinking and problem-solving skills. Future research in this area should focus on identifying specific strategies that can be effectively incorporated into educational games to maximize their potential impact on student learning.
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Inferring a Learner’s Cognitive, Motivational and Emotional State in a Digital Educational Game

Michael Bedek, Paul Seitlinger, Simone Kopeinik and Dietrich Albert
Graz University of Technology, Austria
michael.bedek@tugraz.at
paul.seitlinger@tugraz.at
simone.kopeinik@tugraz.at
dietrich.albert@tugraz.at

Abstract: Digital educational games (DEGs) possess the potential of providing an appealing and intrinsically motivating learning context. Usually this potential is either taken for granted or examined through questionnaires or interviews in the course of evaluation studies. However, an adaptive game would increase the probability of a DEG being actually motivating and emotionally appealing. In order to adapt the game to the learner’s motivational and emotional state while engaged with a particular game scenario, an ongoing assessment of these states is required. An explicit assessment, e.g. by questionnaires occurring repeatedly in short time intervals on the screen would probably destroy the learner’s flow experience. Thus, it is necessary to apply an approach that assesses the learner’s current states in a non-invasive way. In the course of this paper we describe such a non-invasive, implicit assessment procedure which is based on the interpretation of behavioral indicators. A set of behavioral indicators has been elaborated whereby some of them are derived from the theory of information foraging (Pirolli and Card, 1999). Values for each behavioral indicator (e.g. amount, frequency, seconds, etc.) are gathered after equally long lasting time slices. After each time slice, these values serve as weighted predictors to multiple regression equations for the dimensions of a motivation model, an emotion model and a construct called clearness. The motivation model is based on the two dimensions of approach and avoidance motivation. The emotion model encompasses the dimensions valence and activation. Clearness is defined as appropriate problem representation. A comparison of the resulting values on these dimensions between the current and previous time slices covers fluctuations of the learner’s states over time. The assessment of such changes forms the prerequisite for providing in-game adaptations which aim to enhance the learner’s state, targeting towards a full exploitation of DEGs’ pedagogical potential.

Keywords: digital educational games, motivation, emotion, problem representation, non-invasive assessment.

1 Background

Advantages offered by modern information and communication technologies, such as rapid information access, flexibility regarding time and location, as well as the possibility to apply constructivist learning approaches have been exploited (Chang, Gütl, Kopeinik and Williams, 2009). Nowadays, Technology-enhanced learning (TEL) applications are broadly used in the field of distance and blended education. One of such TEL applications has been developed in the course of the European research project TARGET (http://www.reachyourtarget.org), funded by the European Commission (7th Framework Programme).

The TARGET project aims to reduce the time-to-competence of knowledge workers in the domains of project management, innovation management and global sustainable manufacturing. TARGET’s main focus is on the intersection between these three learning domains. This intersection represents basically a set of social interaction skills, usually known as soft skills, which are highly associated to the competence to communicate (Greene and Burleson, 2003). One example in the context of TARGET is the competence to negotiate with different stakeholders. In order to reach TARGET’s ambitious aims, a new kind of TEL-platform will be provided. The TARGET platform consists of several tools and software components, designated to support self-directed learning (Schunk and Zimmermann, 2008), critical reflection on the learner’s own results by means of open student modelling (e.g. Bull, 2004), collaborative learning and most important, life-like learning experiences. The very heart of the TARGET platform is a digital educational game (DEG) presented within a 3D virtual environment. This DEG consists of a set of game scenarios, which address critical incidents of the knowledge domains. The theoretical foundation of the scenarios design and their narrative structures is primarily founded on competence-based learning (Cheetham and Chivers, 1999) and problem-based learning approaches (Barrows and Tamblyn, 1980).
2 TARGET’s Digital Educational Game

When entering the DEG of the TARGET platform, the learner is first provided with a description of the game scenario’s background, the description of the aims to achieve and the role descriptions of other game characters, so called non-playable characters (NPCs). The 3D virtual environment consists of an office building and various outdoor locations. In order to finish a game scenario successfully, the learner needs to interact with artefacts and to communicate or negotiate with different NPCs to gather valuable pieces of information. For this, the learner has the opportunity to use several tools, for example a chat tool to communicate with the NPCs, a teleport tool to switch between different locations, an emotion tool enabling to express nonverbal communication (which might influence the NPCs’ behaviour and in consequence, increase or reduce the learner’s probability of success), or a face cam that shows the own avatar’s face to evaluate whether the emotions are expressed as intended by the learner. Figure 1 shows a screen of the 3D virtual environment, an NPC, and some of the tools just mentioned.

In general, TARGET’s game scenarios offer a large set of possible actions to be carried out by the learner and a high amount of alternatives to be chosen from. Speaking in terms of problem solving (Sternberg, 1994), this leads to an extensive problem space, i.e. a large set of problem states or game situations constituting a complex and ill-defined problem. On the one hand, such an extensive problem space has the potential of providing an appealing learning context which is intrinsically motivating and challenging to engage with. It provides life-like learning experiences. On the other hand, it also inherits the risk of overburden the learner. This might particularly happen when an extensive problem space is coupled with a lack of clear guidance and instruction (Kirschner, Sweller and Clark, 2006). A suitable balance between guidance and degrees of freedom (i.e. a medium level of complexity and challenge) is known to be an important factor for motivating games and favours the occurrence of flow experiences (Csikszentmihalyi, 1990).

2.1 Adaptive Digital Educational Games

In most cases, the presence of the motivational potential of DEGs is either taken for granted or examined by means of questionnaires, interviews or behavioural observations in the course of evaluation studies. As indicated in the previous section, a medium complex game scenario - or in
other words: A game scenario which causes a medium level of arousal - is expected to be most promising for being motivating and emotionally appealing. Thus, a game should adapt to the learner’s current competence, motivational or emotional state if necessary. The principles and phases of an adaptive approach are shown in Figure 2.

Figure 2: Principles and phases of an adaptive approach

The first step in providing appropriate adaptations is the valid assessment of the learner’s current state. The assessment results have to be interpreted in terms of “sufficient” or “insufficient” states. Didactical rules or a predefined decision process determine the kind of adaptations or interventions to be provided, taking psycho-pedagogical and situational considerations (e.g. current restrictions on the game side) into account. Since the effect of the adaptation on the learner should be evaluated, the described principles can be considered as an iterative process.

Since the duration of game scenarios may range from a couple of minutes to several hours, the distinction between macro- and micro-adaptivity has been suggested (Kickmeier-Rust, Hockemeyer, Albert and Augustin, 2008). Macro-adaptivity refers to adaptations of the next game scenario to be played (based on the learner’s performance in the previous one), i.e. macro-adaptive principles are applied between two consecutive game scenarios. Micro-adaptivity refers to adaptations within a single game scenario. An explicit assessment by means of a short questionnaire or ratings via slider scales might be less disturbing when appearing between two game scenarios (i.e. in the context of macro-adaptivity) but it would most likely destroy the learner’s flow experience when appearing in regular time intervals while playing the game scenario (i.e. in the context of micro-adaptivity). Thus, when aiming for applying micro-adaptive principles it is necessary to assess the learner’s state by applying an implicit or non-invasive assessment technique.

2.2 Non-invasive Assessment

The micro-adaptivity approach has been established in the European research project ELEKTRA (http://www.elektra-project.org/). In ELEKTRA, the assessment of the learner’s competence state has been continuously updated based on the interpretation of the learner’s actions and behavioural patterns within game scenarios in terms of underlying competences (Kickmeier-Rust, Hockemeyer, Albert and Augustin, 2008). As an example for a micro-adaptive intervention, an NPC could provide a hint to the learner on how to solve a particular problem within the scenario (Kickmeier-Rust and Albert, 2010). In TARGET, we extend the micro-adaptivity approach by aiming also for the non-invasive assessment of the learner’s motivational and emotional state; in addition to a problem-solving related construct which we call clearness. These constructs are considered as important parts of a holistic view on the individual’s learning process.

The inference of these constructs from the observation of the learner’s actions and behavioural patterns (called Behavioural Indicators in the following) during game-play and the interpretation of the assessment is the main focus of this paper. However, we will also provide a brief overview on applied didactical rules and exemplify one intervention at the end of the paper to cover all three phases of the (micro-) adaptivity approach shown in Figure 2. In the following section, we describe the constructs in more detail and outline their underlying theories, models and dimensions.

3 The constructs of the extended micro-adaptivity approach

3.1 Motivation

In the context of TARGET the emphasis is on achievement motivation as described by McClelland, Atkinson and colleagues (e.g. Atkinson, 1957; McClelland, Atkinson, Clark and Lowell, 1953). According to Elliot and Dweck (2005) achievement motivation should be considered in terms of
competences. It can be distinguished between two forms of achievement motivation (e.g. Elliot and Covington, 2001): Approach motivation and avoidance motivation. Approach motivation is defined as the learner’s motivation to learn in order to become competent and to do justice to her or his own performance standard (e.g. the learner is engaged in a learning activity because she or he is interested in the topic or domain and enjoys the learning material). Avoidance motivation is defined as the motivation to avoid incompetence, or the foreseen consequences of incompetence. For example: A student learns because she or he wants to avoid a bad grade. According to Covington and Omelich (1991), approach and avoidance motivation are two independent dimensions, resulting in a quadripolar model of achievement motivation.

The model assumes that both, high approach and avoidance motivation, respectively, are associated with a similar observable behaviour: The learner will learn (i.e. he or she will approach the situation or the stimuli). To the opposite, the absence of approach motivation and avoidance motivation, respectively, will most likely lead to a withdrawal from the situation or the stimuli.

3.2 Emotion

We follow the approach of Peter and Herbon (2006) and Cai and Lin (2011). According to this approach, emotions are represented by the circumplex model of emotion (e.g. Russell, 1980; Larsen and Diener, 1992). The circumplex model consists of the two continuous dimensions of pleasantness and activation. Pleasantness, also called valence, is considered as a bipolar dimension with the two poles pleasantness and unpleasantness. Activation, also called arousal, is considered as a unipolar dimension with the poles of low and high activation (e.g. Harcourt and Lang, 1995). Each emotional or affective state can be described in terms of these two independent dimensions. For example, the emotional state excitement could be characterized as highly activated and pleasant (Larsen and Diener, 1992). Studies on the effect of emotional states on learning outcomes and efficiency (in particular with respect to valence) have yielded ambiguous results (Bower, 1992). However, with respect to activation, research indicates unambiguously that a medium level of activation leads to a superior learning process in terms of efficiency and sustainability in comparison too high or too low activation levels (Revelle and Loftus, 1992).

3.3 Clearness

In the context of this paper the construct clearness refers to the learner’s appropriate problem representation, i.e. the awareness of the current problem state and the knowledge about the steps to undertake to approach the goal state (or sub-goal states) of the scenario. Problem representation is the mental organization of the known information about a problem. It consists of i) a description of the initial problem state, ii) a description of the problem’s solution state, iii) knowledge on the operators able to manipulate the current problem state in order to get closer to the solution state and iv) knowledge on possible constraints (Ellis and Siegler, 1994).

It is assumed that the absence of clearness leads to the learner being stuck within a scenario not being able to progress. This situation cannot be attributed to missing competences, lack of achievement motivation or to an unfavourable emotional state. In the context of TARGET’s DEG, the construct clearness is considered particularly relevant as the story structure provides a high degree of freedom to the learner. The TARGET game scenarios can be considered as complex and ill-defined problems. Ill-defined problems are characterized by ambiguous goals (solution state) and different possible solution paths, where the obstacles to the solution state have to be overcome by the problem solver (Pretz, Naples and Sternberg, 2003). They can hardly be solved by applying a constrained set of rules.

3.4 Interrelations between the constructs

The underlying models and dimensions of motivation, emotion and clearness suggest that they are not independent from each other but rather highly interrelated. For example, achievement motivation in general is probably related to high activation, whereby such a relation shouldn’t be misinterpreted as a causal statement. Approach motivation is associated with a pleasant emotional state and avoidance motivation is associated with an unpleasant emotional state (Elliot and Covington, 2001). In addition to that, it seems feasible to assume that the absence of clearness for a longer period of time may cause frustration, which is perceived as a highly activated and unpleasant emotional state.
Due to the interrelations between the constructs and their constituting dimensions, it is reasonable to assume that also some of the observable behavioural indicators (BIs) to assess the constructs are interrelated or even similar. Consequently, it is neither possible nor useful or necessary to identify and define BIs that are solely related to a single construct, because a particular indicator may be valid to assess more than one construct or dimension. A suitable framework for elaborating BIs in the context of ill-defined and complex problems in which the problem solver (i.e. the learner) has to gather pieces of information from different sources (e.g. the NPCs and artefacts) is the theory of Information Foraging by Pirolli and Card (1999). In the next section we briefly outline this theory and its most important concepts before describing the set of BIs in more detail.

4 The Theory of Information Foraging

The theory of information foraging (Pirolli & Card, 1999) aims at describing and understanding the strategies that people employ in order to seek for, gather and consume information, for instance during the task of finding relevant information on the Web. Human search behaviour is regarded as adaptive to our environment in order to extract or gain information from external sources effectively and efficiently. External sources are called patches, for example communication partners or on-line documents. Especially in the context of ill-defined problems (e.g. acquiring appropriate knowledge for writing a scientific paper) an ideal information forager maximizes the rate of gaining valuable information by seeking for a balanced ratio of explorative and exploitative search behaviour. In order to acquire knowledge efficiently, available time has to be divided into the search for new sources bearing valuable information (e.g. journal papers) as well as into the elaborate processing of these items to extract relevant information (e.g. at least reading through the abstract, introduction, and discussion). While the time spent on exploration is called Between-Patch processing, the time spent on exploitation is called Within-Patch processing. By solely concentrating on one single patch (e.g. a single paper) valuable information of external resources won’t become available. To the contrary, an excess of exploration (e.g. searching the Web) will lead to ignorance of important details.

The costs and the utility of pieces of information are concretized by the dimension of time within the theory of information foraging. Information that helps to reduce the time to achieve a target is valuable (high utility). If it takes long to gather some kind of information, the costs of the underlying information seeking actions (during within and between patch processing) will be regarded as high. Fu and Gray (2006) propose a U-shaped curve for the relationship between time savings and information foraging actions: A moderate number of information seeking actions will be associated with the most optimal performance. Too much as well as too little information seeking will diminish performance. Even if the theory of information foraging has been initially developed in the context of navigation on the Web, within this research we go a step further and apply the principles by adapting some of the indicators to the area of DEGs because:

i) The learner has to search for and to communicate with several NPCs in order to collect all information necessary to master the game scenarios;

ii) It is assumed that a successful information forager experiences a state of clearness and a positive emotional state more often than an unsuccessful one;

iii) The trade-off between costs and benefits of information-seeking “may not be fully under the person’s cognitive control” (Fu and Gray, 2006: 196). We assume that indicators capturing automatic aspects of a learner’s behaviour (in contrast to controlled cognition) positively contribute to a reliable measurement technique. Behaviour driven by automatic and unconscious cognition is biased by situative factors to a lesser extent and therefore, allows for reliable inferences about a learner’s states, and

iv) Information foraging is built upon the rational analysis of human memory (e.g. Anderson, 1990) that is supposed to adapt to the cost and information structure of the environment and hence, to function rationally.

In the context of information foraging rationality stands for the adoption of an appropriate, i.e. moderate, number of information seeking actions. In order to prevent abstraction from human rationality, proponents of information foraging suggest building upon the concept of bounded rationality, meaning that adaptive behaviour proceeds within the “bounds of limited time, knowledge, and computational power” (Fu and Gray, 2006: 199). Therefore, we assume that a learner’s information seeking during a DEG will reveal her or his cognitive bounds, such as the ability to represent goal states. A learner, who balances well between efficient exploration and exploitation, thereby increasing the rate of information gained, is assumed to be both, aware of a current problem
state and motivated to solve the problem. In the next section it is explained how the concepts of Between- and Within-Patch processing can be applied to the characterization of search behaviour in a DEG.

5 Assessment Procedure

In this section the non-invasive assessment procedure for the constructs, respectively their dimensions, clearness, approach- and avoidance motivation, activation and valence is described. The dimensions are assessed by BIs, which are gathered continuously throughout the game-play. For the ongoing assessment, the overall game-play is divided into consecutive, equally long lasting periods of time, so called time slices. As a starting point (obtained during pilot studies), we set the length of the time slices to 30 seconds. The behavioural indicators’ “raw values” are calculated at the end of each time slice, i.e. they should be considered as values per time slice (i.e. units or frequencies).

We start with the operationalization of the BIs which are considered as the main “building blocks” of the assessment. Then we will exemplify a subset of them, which are based on the principles of the theory of information foraging. The section closes with a description of how to combine the indicators’ raw values to obtain a single value for each dimension.

5.1 Operationalization of Behavioural Indicators

Table 1 lists a set of developed BIs, whereby indicator 1 and indicators 5 to 9 have already been proposed by Linek, Öttl and Albert (2010). The indicators 1 and 2 have been suggested to measure aspects of activation. The indicators 3 to 9 are quite focused on TARGET’s DEG features, characteristics and constrains, and thus, they might not be re-usable for other kinds of DEGs.

<table>
<thead>
<tr>
<th>#</th>
<th>Behavioural Indicator</th>
<th>Operationalization and Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Click rate (cr)</td>
<td>The amount of mouse clicks per time slice</td>
</tr>
<tr>
<td>2</td>
<td>Mouse movements (dRM)</td>
<td>The Euclidian distance between the mouse pointer’s position t and t + Δt is calculated. The sum of all Euclidian distances per time slice is dRM.</td>
</tr>
<tr>
<td>3</td>
<td>Distance of “view” - movements (dVM)</td>
<td>The amount of vertical and horizontal “head movements” of the learner’s avatar; counted in units of visual angle changes. Considered as an indicator for search behaviour in the virtual environment.</td>
</tr>
<tr>
<td>4</td>
<td>Relative exploitation of available tools (p_i)</td>
<td>Number of actually used tools divided by the total number of available tools.</td>
</tr>
<tr>
<td>5</td>
<td>Frequency of tool-usage (of the different available tools) (f_t)</td>
<td>( f_t = \frac{\sum_{i=1}^{n} f_T_i}{n} \cdot \frac{T_W}{T_{ts}} ) Indicator for the average usage frequency of tools. ( \left( \frac{T_W}{T_{ts}} \right) ) acts as a weight so that the indicator takes on a high value only if the learner made use of the tools to gain information through an exhaustive conversation.</td>
</tr>
<tr>
<td>6</td>
<td>Frequency of communication tool-usage (f_c)</td>
<td>Number of chat tool usage</td>
</tr>
<tr>
<td>7</td>
<td>Frequency of interactions with NPCs (f_i)</td>
<td>Number of lines entered in the chat tool</td>
</tr>
<tr>
<td>8</td>
<td>Frequency of expressing positive emotions</td>
<td>Number of function key presses representing positive emotions (e.g. the key F3 leads to the expression of “Joy”)</td>
</tr>
<tr>
<td>9</td>
<td>Frequency of expressing negative emotions</td>
<td>Number of function key presses representing negative emotions (e.g. the key F6 leads to the expression of “Anger”)</td>
</tr>
<tr>
<td>10</td>
<td>Within-patch processing (T_W)</td>
<td>Units of time spent on communicating with NPCs (see section 4.2)</td>
</tr>
<tr>
<td>11</td>
<td>Between-patch Processing (T_B)</td>
<td>Units of time spent for exploring the environment (see section 4.2)</td>
</tr>
<tr>
<td>12</td>
<td>Inactivity (T_a)</td>
<td>Units of time the learner doesn’t press any keys and doesn’t move the mouse.</td>
</tr>
<tr>
<td>13</td>
<td>Extent of NPC-interactions weighted by Within-Patch processing (I_NPC)</td>
<td></td>
</tr>
</tbody>
</table>
# Behavioural Indicator Operationalization and Explanation

\[ I_{NPC} = n_{NPC} \cdot \frac{T_w}{T_{ts}} \]

Number of NPCs contacted by the learner, multiplied by weight \( (T_w/T_{ts}) \). The indicator takes on a high value if NPC-interactions are accompanied by an exhaustive conversation.

14 Information gained (G) \( G = \lambda \cdot T_B \cdot g \) (see equation 1 in section 4.2)

15 Rate of Information Gain (R) \( R = G / (T_B + T_W) \) (see equation 3 in section 4.2)

16 Profitability (\\( \eta \)) \( \eta = g / t_W \) (see equation 4 in section 4.2)

The remaining behavioural indicators 10 to 16 are mainly based on the theory of information foraging. These indicators possess the potential to be re-usable for other kinds of TEL-applications, such as other DEGs or Learning Management Systems. They are further exemplified in the next section.

5.2 Applying the Theory of Information Foraging

The description of the indicators derived from the information foraging theory is embedded into an example of a game scenario in which a learner consecutively talks to two NPCs. As described above, the whole duration of a game-play is split into time slices, whereas the following example extends over the period of one time slice (30 seconds). In the following, the variables \( T_W \) and \( T_B \) represent the number of seconds spent on Within- and Between-Patch processing (see section 3), respectively.

At the beginning of our example the learner may continue with an explorative activity (e.g. searching for an NPC). After three seconds the learner may find the targeted NPC telling the learner to look for a new contact person, an NPC designed to practise negotiation skills. It takes the learner eight seconds to receive this instruction, i.e. to conduct this exploitive activity. Then, after three seconds of inactivity, in which the learner doesn’t move the mouse or doesn’t click any keys, the search for the assigned contact person starts and lasts only five seconds due to a very clear instruction. Afterwards the conversation with the next NPC starts, lasting until the end of the time-slice (i.e. 11 seconds). In this example, \( T_B \) sums up to eight seconds: three seconds for the first, and five seconds for the second period of exploration. \( T_W \) amounts to 19 seconds because the learner has spent eight seconds on the first and 11 seconds on the second period of exploitation.

Besides \( T_B \) and \( T_W \), additional variables that are taken from Pirolli & Card (1999) have to be gathered to obtain an indicator for the rate of valuable information. For that, \( G \) has to be computed, which represents the total amount of information gained and is given by equation (1),

\[ G = \lambda \cdot T_B \cdot g \]

where \( \lambda \) is the prevalence, the average rate of encountering patches (i.e. NPCs) and \( g \) is the average gain per patch. \( \lambda \) is simply given by equation (2),

\[ \lambda = 1/t_b \]

where \( t_b \) represents the average time in seconds between processing patches. Referring to the example above, where the learner spent three seconds on searching for NPC 1 and another five seconds on looking for NPC 2, the value for \( t_b \) is four seconds \( (= (3+5) / 2) \) and therefore, \( \lambda \) is 0.25 \( (= 1 / 4) \). The higher the value of \( t_b \) the lower is \( \lambda \), the rate of encountering NPCs, either reflecting low clearness or low motivation. Finally, as previously described, \( g \) represents the average gain per patch (i.e. during the conversation with an NPC), which is in our case the number of relevant propositions extracted during the conversation. To simplify the assessment process, the number of propositions may be equated with the number of relevant content words used by an NPC. Relevant content words are terms (nouns, adjectives and verbs) referring to topics that have to be addressed by the learner in order to succeed in the negotiation process. By means of WordNet (http://wordnet.princeton.edu/), a psycho-linguistic database, a list of such content words can be arranged beforehand. To continue our example, let’s suppose that the conversation with NPC 2 during the second half of the time-slice
encompasses 15 words, whereby ten words were uttered by NPC 2. Furthermore, let’s suppose that four of the ten words are content words that belong to the semantic field of project management. At that point, G can be computed, since empirical values for all variables (λ, T_B and g) are available. In this example G would be 8 (= 0.25 * 8 * 4).

Finally, R, the rate of valuable information gained per time-slice can be obtained. It is given by

\[ R = \frac{G}{(T_B + T_W)} \] (3)

When inserting the corresponding values from above, R amounts to 0.307 [= 8 / (8 + 19)]. The more information is extracted during conversations and the less time is needed for this information gain, the higher the value of R.

Finally, the so called Profitability π can easily be calculated. It is the ratio of gain per patch to the cost of within-patch processing and is given by

\[ \pi = \frac{g}{t_w} \] (4)

The variable \(t_w\) is the average time in seconds spent on within-patch processing and is computed by simply dividing \(T_w\) by the number of phases in which within-patch processing took place. Hence, in case of TARGET’s DEG, \(\pi\) stands for the efficiency of a learner’s search behaviour. It represents the amount of valuable information (s)he actually extracts from conversations, taking into account the amount of time needed for this process.

5.3 Combining Behavioural Indicator’s Values

After gathering the raw values of all BIs at the end of each time slice, they have to be combined to get a single value \(x_i\) for each of the five dimensions \(i\) (Clearness, Approach Motivation, Avoidance Motivation, Valence and Activation). For the combination, we apply a multiple regression model. This is in line with the suggestion from Margolis and Clause (2006). The indicators, respectively their raw values \(BI_j\) serve as predictors in the multiple regression equations. A linear combination is preferred over a multiplicative one in order to allow small values on a particular indicator to be compensated by higher values on other indicators.

For each dimension \(i\) we apply one regression equation, initially consisting of the following input-variables: i) a constant intercept \(d_i\), ii) the 16 predictors, and finally, iii) the 16 predictors’ weights \(w_{ji}\). This leads to the following equation (5):

\[ x_i = d_i + w_{i1} * BI_1 + ... + w_{ij} * BI_j + ... + w_{i16} * BI_{16i} \] (5)

At the time of writing, the realization of validation studies is in progress. However, as a starting point, the weight of each BI for each regression equation has been estimated a-priori, based on expert ratings in the field of cognitive psychology. Independent from each other, two experts evaluated the predictive validity of the BIs (i.e. their weights) for each dimension by a 3 point rating scale. The scale comprised the values 0 (“low validity”), 1 (intermediately validity) and 2 (“high validity”). In addition to that, the experts had to evaluate the direction of the relationships between the particular indicator and the dimension (i.e. positive vs. negative correlation). For the overall ratings presented in Table 2 we decided to take the lower value in case of divergent ratings and the mean value otherwise. For instance, referring to indicator 1, the Click rate is regarded highly predictive for the learner’s activation (as indicated by the value 2), intermediately predictive for approach- and avoidance motivation (value 1) and not predictive for the remaining two dimensions of valence and clearness (value 0).

The actual weight of each indicator and potential redundancies between the indicators will be analysed by a validation study which is briefly outlined in section 6. Those indicators that turn out to be highly correlated with other indicators and which do not contribute substantially to an additional explanation of variance will be dropped. This ensures an economic assessment of the dimensions since the amount of predictors constituting the regression equations will be kept as small as possible.
Table 2: Behavioural indicators and assumed relations to psycho-pedagogical constructs

<table>
<thead>
<tr>
<th>#</th>
<th>Behavioural Indicator</th>
<th>Motivation</th>
<th>Emotion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Approach</td>
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<td>Distance of “view” - movements</td>
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<td>4</td>
<td>Relative exploitation of available tools</td>
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<td>5</td>
<td>Frequency of tool-usage</td>
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<td>Frequency of communication tool-usage</td>
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<td>7</td>
<td>Frequency of interactions with NPCs</td>
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<td>8</td>
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<tr>
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<td>Between-Patch Processing</td>
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<tr>
<td>16</td>
<td>Profitability</td>
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6 Interpretation procedure

The interpretation of a learner’s current state with respect to a particular dimension, as indicated by
the dimension’s initial values $x_i$, depends on the comparison with a baseline. The baseline can be
obtained either by the learner’s values in previous time slices of the same game scenario
(intrapersonal comparison) or by the values of other learners (interpersonal comparison). The latter
approach is feasible when an extensive database of a large number of individuals is available.
However, we prefer an intrapersonal comparison which takes the learner’s gaming history into
account since individual learner’s baselines may differ to a great extent. Thus, the results of the
multiple regression equations, $x_i$, are transformed into $z$-scores for the sake of comparability. The $z$-
transformation is done by the following equation:

$$z_i = \frac{x_i - M_i}{SD_i}$$

(6)

Whereas $z_i$ and $x_i$ represent the standardized and the raw values of the dimension $i$. The average
value of the dimension $i$, represented by $M_i$, is computed by averaging the raw values of all previous
time slices. Thus, $M_i$ does not incorporate the current state. The variability of the dimension $i$
is represented by the standard deviation $SD_i$. Since the reliability of the assessment increases with the
amount of incorporated data, the deviation of the current from the average state in terms of standard
deviations is not taken into account until the fourth time slice has passed. Hence, the computation of
the standardized values of the dimension begins at the earliest 120 seconds after the learner starts to
play the game scenario.

The five values $z_i$ for each dimension and each time slice (from the 4th time slice on) represent the
individual learner’s deviation from the current time slice to the previous ones in terms of standard
deviations. We consider open student modelling not only for the competence and skills assessment
but also for the constructs the extended micro-adaptivity approach in TARGET. In this case, the $z_i$
values might not be easy to interpret for learners who are not familiar to think in terms of standard
deviations. Therefore, we aim to provide manifestations of a continuous variable, with values ranging
between 0 and 1.

This aim can be reached by inserting the standardized values $z_i$ into the following logistic function:
\[ p(z_i) = \frac{1}{1 + e^{-z_i}} \]  

(7)

With \( p(z) \) representing the final value of the dimension \( i \). Besides the obvious advantage of these \( p(z) \) values for the purpose of open student modelling, the second advantage is that the logistic function is positively accelerated and differentiates primarily in a range between -3 and +3 standard deviations. In other words, the logistic function leads to a higher differentiation of initially small differences in the standardized values \( z_i \).

7 Current work and Outlook

The content of this final section is twofold: First we outline how the behavioural indicators described in section 4 will be evaluated, aiming to determine their weights for each of the five multiple regression equation. Finally, we will provide a glimpse on the didactical rules and exemplify one intervention targeting to influence the learner’s current level of activation.

7.1 Validation of Behavioural Indicators

For the evaluation of the indicators’ validity we adopt approaches suggested by Insko (2003) and Van Reekum et al. (2004) in order to conduct a non-invasive measurement procedure and to elicit the subjective experience of the participants. The subjective experience is part of the emotional trinity comprising physiological, expressive and subjective components and is used as an external criterion to be compared with the BIs.

The subjective experience is measured by self-report that will be gathered by a pop-up screen intermittently occurring during game play. These pop-ups present small sets of items that are extracted from standardized state scales and ask for the current emotional, motivational or problem-solving related state. Similar to Cai & Lin (2011) we will apply the Self-Assessment Manikin (SAM; Lang, 1980) to measure both dimensions of the emotional model (activation and valence). To assess participants’ motivational states we will present items from the revised 10-Item version of the Achievement Motives Scale (Lang and Fries, 2006). Since standardized questionnaires on the construct clearness do not exist, we will develop items giving information on a participant’s current problem representation. All items will be rated through slider scales: by moving the position of a slider between two poles of a graphical intensity-dimensional, the learner indicates the extent to which (s)he agrees or disagrees on a particular item. The items will cover different aspects of the cognitive, emotional and motivational dimensions and will be selected randomly for presentation.

Finally, a regression analysis will be conducted to determine the nature and significance of the relationship between the indicators and the self-report. Standardized Beta-Coefficients will support the identification of valid indicators as well as their weights for equation (5). A linear model would be the simplest case; however, we will evaluate whether statistical requirements, such as linearity of the variables’ relationship, are met by the data-pattern. Additionally, we will try to find out if other functions, e.g., modelling non-linear relationships, provide a better data-fit. The Generalized Linear Model is able to incorporate non-linear covariates in the coefficients.

7.2 Didactical Rules

The value \( p(z) \) of each continuous dimension (emotion, motivation and clearness), ranging between 0 and 1, has to be broken up into categories indicating a sufficient, medium or insufficient state for an efficient and sustainable learning process. For that, we introduced the two threshold values 0.50 and 0.80 to assign \( p(z_i) \) to “insufficient” (if \( p(z) < 0.50 \)), “medium” (if \( 0.50 \leq p(z) \leq 0.80 \)) and “good” (if \( p(z) > 0.80 \)). The combination of these categorizations across the three dimensions represents the learner’s current psycho-pedagogical state. We draw on a set of didactical rules that trigger particular classes of interventions (motivational, emotional and clarifications to increase the learner’s problem representation) in response to the current psycho-pedagogical state. We designed three didactical rules for the provision of appropriate interventions: i) Priority ranking of intervention-classes, ii) Selection of intervention-instances, and iii) Stopping Rule.

Based on the learner’s psycho-pedagogical state, the priority ranking defines in which order the different classes of interventions should be provided. Our priority ranking is based on the following
considerations: If the learner’s clearness state is insufficient, i.e. if he or she simply doesn’t know how to progress within the game scenario, it is impossible to establish and reflect upon self-regulating goals (Elliot and Harackiewicz, 1996). Goals are an obligatory part for self-regulated learning, and highly related to the construct of (achievement-) motivation (Schunk and Zimmermann, 2008). Therefore, a sufficient (“good”) clearness state is seen as prerequisite for a desirable motivational state and for avoiding an undesirable emotional state (e.g. frustration). Thus, interventions aiming to enhance the learner’s clearness state (i.e. clarifications) do have the highest priority. Emotional and motivational interventions share the second highest priority.

Once it has been decided which class of interventions should be provided, a concrete instantiation of this class needs to be selected. It is necessary to consider that some concrete interventions may have been already provided but without reaching the intended outcome, while other interventions may not be appropriate in the current game context (e.g. activating office noise when the learner’s avatar is outside the office building).

The Stopping Rule defines which values of the different psycho-pedagogical constructs are sufficient for an efficient and sustainable learning process, i.e. under which circumstances (i.e. current psycho-pedagogical state) the introduction of interventions should be stopped. As a rule of thumb, interventions should be provided as seldom as possible and as often as necessary. Applying this simple principle should avoid that the learner’s game-flow (Csikszentmihalyi, 1990) is disturbed. As a starting point we take a medium value for the emotional and the motivational state of the learner as sufficient into account. This means that further interventions won’t be provided if the learner’s values remain at least equal compared to the previous time slice. However, for the construct of clearness, only a “good” value seems to be sufficient since less (or non-existent) clearness can be seen as prerequisite for interventions of other classes to be efficaciously.

7.3 Interventions

Within this subsection an example of an intervention-instantiation is presented. We selected an intervention called field records. In a DEG that is based on a 3D virtual environment like TARGET, the introduction of field records is assumed to be beneficial out of two main reasons. First, natural background noises increase the perceived level of reality within a game scenario. And second, specifically selected and designed noises can be systematically applied to beneficially affect the learner’s psycho-pedagogical state; in particular his or her emotional and motivational state. The term field records describes sounds naturally occurring in our environment, for instance the chirping of birds, the clicking of a keyboard or the ringing of a phone in an office environment. Most of the time, we would not even notice their appearance. Nevertheless, well-founded psychological research suggests that external stimuli do not have to be processed consciously in order to influence our state of mind. To the contrary, it is known that stimuli which are processed unconsciously can activate our implicit motive system (Bargh et al., 2001), which in turn may lead to affective reactions. Intending to use these effects, we adopt field-records to unleash a non-intrusive, acoustic atmosphere influencing the learner’s motivational and emotional state. To allocate appropriate sound samples we make use of the International Affective Digitized Sounds (http://csea.phpp.ufl.edu/media/iadsmessage.html) initiated by Bradely and Lang (1999). This psychological database of sound-tracks is characterized with respect to the dimensions activation and valence. By that, it is possible to select and provide sounds during the game play that stimulate the emotional state of the learner and are mainly congruent with her or his current state. The provision of sounds that are in accordance with the learner’s emotional state should avoid unpleasant feelings of dissonance (Gembris, 1990). In case of low values on the activation and valence dimensions, the learner should not be confronted with sounds characterized by high activation or very positive valence. In order to improve her or his state in a gentle way, sounds should be selected that are described as moderate with respect to both dimensions. However, a learner with intermediate or even high valence and activation values may be stimulated by activating and happy sounds.

Acknowledgements

This paper is part of the EC-Project TARGET funded by the 7th Framework Programme of the European Commission’s IST-Programme (contract no. 231717). The authors are solely responsible for the content of this paper. It does not represent the opinion of the European Community, and the
European Community is not responsible for any use that might be made of data appearing therein. A initial version of this paper has been presented at the 5th European Conference on Games Based Learning (Bedek, Seitlinger, Kopeinik and Albert 2011).

References


Becoming Chemists through Game-based Inquiry Learning: The Case of Legends of Alkhimia

Yam San Chee and Kim Chwee Daniel Tan
Nanyang Technological University, Singapore
yamsan.chee@nie.edu.sg
daniel.tan@nie.edu.sg

Abstract: Traditional modes of chemistry education in schools focus on imparting chemistry knowledge to students via instruction. Consequently, students often acquire the mistaken understanding that scientific knowledge comprises a fixed body of "proven" facts. They fail to comprehend that the construction of scientific understanding is a human and social endeavor. Consequently, there can be alternative and conflicting views and theories.

To provide students access to an enhanced learning curriculum, Legends of Alkhimia was designed and developed as an educational game for 13 to 14-year-olds to foster the learning of chemistry through inquiry. The multiplayer game supports four concurrent players. It is played on personal computers connected via a local area network. The game embeds students in problem solving challenges related to the use of chemistry in realistic contexts. In attempting to solve these problems, students must engage in individual laboratory work using an in-game virtual chemistry lab. The game levels take students through a narrative arc that provides coherence to the entire gameplay experience. Legends of Alkhimia, together with its associated curricular materials, instantiates classroom learning based on performance pedagogy: a pedagogy that constructs learning through the lens of performance theory. Leveraging the immersive affordances of 3D game environments, the learning experience is designed to engage students in the dialectic interplay between learning in the first person, based on playing the game, and learning in the third person, based on the Bakhtinian notion of dialog. The learning process follows a developmental trajectory of becoming a chemist.

Enacting performance pedagogy in the classroom requires a shift in traditional classroom culture toward that of a professional practice community. We report on an empirical study of a game-based learning classroom intervention where students in the Alkhimia learning program participated in an 8-week curriculum sequence involving six levels of game play. We compared pre- and posttest survey responses from a class of 40 students who learned chemistry using the Alkhimia curriculum. We also compared learning outcomes of students in the said intervention class with a control class of 38 students who learned chemistry through traditional classroom instruction. All students in our study were 13-year-olds from a typical government secondary school. We noted significant shifts in intervention students’ perceptions of their identity, their epistemological beliefs, their dispositions toward science inquiry, and of classroom culture. Students’ understanding of chemistry was evaluated through a common assessment that comprised a complex separation task involving mixtures, solutes, and immiscible liquids. Two evaluation criteria were used: (1) effectiveness of separation, and (2) demonstration of conceptual understanding of chemistry. We found that the Alkhimia students significantly outperformed the control students when assessed on the extent to which effective separation was achieved in the students’ proposed solution (t(75) = 2.56, p = .026) and when assessed with respect to conceptual understanding of chemistry in the separation task (t(75) = 3.41, p = .002). We discuss, from a theoretical perspective, how and why learning with the Alkhimia curriculum is efficacious. Our findings are significant in that they suggest how inquiry learning can be successfully enacted in a chemistry game-based learning curriculum, and they underscore the efficacy of approaching game-based learning in terms of performance.

Keywords: performance, play, dialog, inquiry, chemistry, identity, epistemological beliefs, classroom culture

1. Introduction

Traditional modes of chemistry education in schools focus on imparting chemistry knowledge to students via instruction. The work of professional scientists, including chemists, is embedded within a classroom discourse of scientific discovery (Langley et al., 1987, Popper, 2002). Adoption of a discovery metaphor leads students to believe that there exists a body of indisputable and eternally true facts about the natural world that are just waiting to be uncovered by smart scientists. Through the process of classroom instruction, students unwittingly imbibe an objectivist epistemology of science. This situation is exacerbated by science textbooks that reinforce the common rhetoric of science revolving around assertions of fact, scientific discovery, and certainty. Heyworth (2002), for example claims: “Atoms are so small that nobody has ever seen a single atom. But scientists are certain they exist” (p. 26, italics added). Relying on authorial privilege and laying claim to scientific
expertise, the author boldly asserts that, despite being humans themselves, scientists somehow are completely certain that atoms exist although no one, including the scientists themselves, has ever seen an atom. Such a claim stretches the author's credibility. In a culture of schooling and high stakes testing, however, challenging such claims is simply not entertained.

Consequently, contrary to Popper's theoretical position that scientific theories can only be falsified and never proven, students develop an understanding of scientific knowledge as statements of truth arising from a body of "proven facts." They fail to comprehend that the construction of scientific knowledge is a human and social endeavor involving peer review, critique, justification, argumentation, and rebuttal, based on the citation of evidence and provision of warrants for claims. They do not realize that theorizing is an intellectual creative act to imagine and construct explanations and models of phenomena (Schwartz and Lederman, 2002). The outcome is that students derive a badly misrepresented characterization of the nature of science making in practice.

In our attempt to improve science education in the domain of chemistry, we have endeavored to shift students' understanding of science based on the metaphor of discovery to one based on the practice of scientific inquiry (Dewey, 1938/1991, Hickman, 1998), befitting the process that scientists pre-occupy themselves with. We do so via the Alkhimia learning program, a game-based learning curriculum for lower secondary chemistry. This paper explicates the learning program and its underlying theoretical bases, and reports findings from a classroom empirical study.

In Section 2, we explain the constructs employed to achieve a shift in classroom culture through game-based inquiry learning: namely, performance, play, and dialog. Section 3 concretizes the Alkhimia curriculum through an example. Section 4 describes the research method, and Section 5 reports the data analysis and findings. Section 6 discusses the implications of our findings. We then conclude the paper.

2. Changing classroom culture through performance, play, and dialog

To the extent that digital games are used at all in everyday classrooms, such games typically adhere to what we refer to as an "educational resource model". Games of this type have restricted scope and purpose. While students may play them several times within a 10–15 minute interval within a classroom period of 40–50 minutes, their purpose is served once the lesson is over, and students do not encounter the same game again. These games effectively play the role of a technology resource to enhance the basic classroom lesson. Often, the game is simply a form of drill-and-practice embedded within a more attractive and engaging digital form.

We wish to advance the idea of game-based learning in the literal sense of the term: that is, the objective is the enaction of a coherently designed learning curriculum where a single, substantial digital game is used to help students learn a complete curriculum or curricular unit. For such learning to take place successfully, a transformation in classroom culture is needed: one that is centered on learning rather than instruction. We argue that inquiry learning is a strong candidate for achieving learning centrality based on the associated theoretical constructs of performance, play, and dialog.

2.1 Learning as performance

Computer and video games constitute a unique digital medium that supports first-person immersive learning. However, traditional teaching and learning, especially as it is commonly practiced in schools, emphasizes third-person learning. Given the orientation toward fostering subject content mastery, teachers expend a great deal of time and effort telling students about domain content. They engage in telling to achieve the first level of knowledge in Bloom's taxonomy of thinking skills in the cognitive domain. They hope that students will also comprehend what they are told and thereby advance their thinking ability to the second level in Bloom's taxonomy. To the extent that anything needs to be done by students, teachers then assign students a task and instruct them to apply what they have learned, to advance student thinking to the third level in Bloom's taxonomy. For real world tasks, which naturally tend to be somewhat complex, this instructional approach tends to lead quickly to breakdown. To illustrate, consider a child learning to swim for the first time. Suppose that the swimming instructor delivers a series of outstanding lectures about swimming. He then tests the child's "comprehension" of swimming using multiple-choice questions. Suppose further that the child
attains a high score on the test. The instructor then instructs the child to “apply” what she has learned by swimming three lengths of the pool. Is the child likely to succeed?

The example above illustrates that knowing is distinct from knowing about. There is no easy way to translate information narrated in third-person terms to the capacity to act in first-person terms. Knowing in a linguistic, conceptual, and third-person sense, is a very different phenomenon from knowing in an embodied, enactive, and first-person sense (Gibbs, 2005, Johnson, 1987). To assume that people learn to do by being told is a common fallacy. We are not suggesting that being told is necessarily unhelpful to the process. Rather, we wish to suggest that learning to do, that is, performative mastery, can only be attained by direct engagement in doing. Classical epistemology commits the error of assuming a knower who exists independently of that which is known. However, as Dewey and Bentley (Dewey, 1949/1991) argue in their essay “Knowing and the Known”, there is no such possibility because every knower is always already situated in and part of the world. Coming to know, therefore, requires a process of direct engagement with the phenomenon of interest in the world. It mandates that learners be engaged in the performance of meaningful tasks that allow the development of enactive capacities pertinent to valued social practices.

In the context of education, the philosophy of pragmatism stakes the claim that learning outcomes must make a practical difference to students’ lives by developing their capacity for effective action. On this account, learning necessarily takes place in situated action (Coulter, 1989, Wertsch, 1998). We propose the construct of performance as a productive basis for understanding learning through the theoretical lens of being and becoming (Chee et al., 2009, Semetsky, 2006). The construct of performance is drawn from performance theory and performance studies (Bell, 2008, Schechner, 2006). According to Bell (2008), performance has three key characteristics. First, it is constitutive; that is, it is established, created, and given form through enactment. Second, performance is epistemic: that is, performance is a way through which human actors come to know themselves, know others, and know the world. Third, performance is critical; that is, it provides a means for actors to stake claims about knowledge and the creation of knowledge. Performance is also deeply constitutive of identity (Benwell and Stokoe, 2006). Implicit and explicit claims about that which is valued by human actors, as well as how these actors as members of a group ought to act, are manifested through performance. Because game play involves being a person on a developmental trajectory of becoming within a fictional game world, it inherently entails players constructing a sense of who they are and the kind of person they want to become—their identity—through the very act of game play.

Aligned with Dewey’s pragmatic stance (Bernstein, 1960), performance entails living, experiencing, and acting in the here-and-now. Through performance, performers wrestle with human experience as a lived and always dynamic process. They develop participatory and embodied ways of knowing and being. Experience is made available for contemplation, thereby providing opportunities to think and to think differently; in short, to learn in an experientially grounded way.

2.2 Performance–Play–Dialog: The pedagogical model

The pedagogy underlying the design of the Legends of Alkhimia curriculum is that of learning as inquiry, in the spirit of Dewey (1938/1991). Dewey argues that the origin of thinking arises in a feeling of perplexity or doubt in the non-cognitive background of embodied experience. Inquiry begins in doubt and concludes when the stimulus of doubt is removed. In the activation of thinking, the qualitative immediacy of experience is transformed from the level of feeling to a level where possibilities and connections are recognized. Such possibilities and connections are exploited at the cognitive level for use as ideas and plans of action. Even as cognitive events transpire, substantial portions of the non-cognitive dimensions of experience are retained, and they serve to regulate the thinking experience. On Dewey’s account, thinking represents the emergence of a new organization of experience (Holder, 1995). Educational aims must be translatable into teaching methods that fit the activities of those receiving instruction, and education administrators must foster the kind of environments required to liberate and to organize the thinking capacities of students. Figure 1 depicts the Performance–Play–Dialog model of game-based learning designed to achieve these goals.
As shown, the primary thrust of learning is driven by performance that encompasses the development of understanding in the subject domain and the construction of self-identity with respect to that domain. Through performance, students develop new ways of seeing and understanding the world and of understanding themselves in relation to that world. The construction of an expansive yet coherent worldview, coupled with the agency to act, is central to learning that is developmental and empowering. Figure 1 shows this future-oriented pathway of a learner as a trajectory of becoming through which the learner develops understanding in and practice of a professional domain. Performance itself is realized through the sub-constructs of play and dialog.

Students’ learning is mediated by engagement in play via a material, digital game world. The space of play is experiential, and learning actions are transactional (Dewey, 1925/1988). The player’s experience is embodied, by virtue of being represented in the game world by his avatar, and the player is embedded, or immersed, in the virtual space of the game world. In the design of our learning curriculum, students play multiple levels of the game. Game levels build incrementally on one another to help them develop the dispositions and habits of mind related to professional practice in the domain of chemistry.

Dialogism, a key Bakhtinian (1981) idea, is central to our pedagogical design of the curriculum. For Bakhtin, dialog is not constituted merely by words or by talking. Dialog is also ontological: it is a way of life. In the context of the classroom, dialog is intended to help students achieve comprehension rather than to provide explanation. Dialogism generates internally persuasive discourse that is open, allowing students to construct new ways to mean. Fostering dialog in the classroom creates a more open yet more critical disposition toward discourse and the knowledge construction process. As ideas collide and are interrogated, students learn that the practice of science is itself a process of sense making, and, hence, a dialogically constituted activity. Consistent with pragmatism, they learn that scientific “facts” are warranted assertions and hence tentative in nature rather than eternally “proven” claims. Dialogism thus sustains inquiry as an open process and allows students to participate in the social construction of reality (Berger and Luckmann, 1966). The construct of dialog builds upon and extends the common concern amongst science educators that students develop the skills of scientific argumentation and understand that knowledge claims are socially negotiated. Consequently, there may not be complete agreement on the validity of any particular theory. Based on the model, play and dialog stand in dialectic relation to each other. Play sustains dialog, and dialog informs play.
3. The Alkhimia learning program

The Alkhimia learning program is an eight-session chemistry curriculum for lower secondary school science. The curriculum is game-based. It centers on students playing the multiplayer game, *Legends of Alkhimia*, as well as participating in learning activities that embed game play. As used in the study reported in this paper, *Legends of Alkhimia* comprises six levels of game play. The game was designed and developed by our research lab. In-house development allowed us to exercise fine control over the interweaving of game design and pedagogic intent so as to achieve a strongly coherent pedagogy in practice. The game is played on PCs over a local area network that is typically located in a school computer laboratory. It supports four concurrent players. Based on the research context within which our classroom-based investigation was carried out, the first and last sessions of the curriculum were devoted to the administration of research surveys and student tests. The intervening six sessions were devoted to students engaging in the game-based learning sessions proper, with each level of game play and associated learning activity comprising one session.

To help readers acquire a concrete feel for the game, we briefly describe Level 5 of *Legends of Alkhimia*. The curriculum focus of this penultimate game level concerns the separation of miscible and immiscible liquids. At the commencement of the level, and following the narrative arc of the game at the close of Level 4, students find themselves trapped in an underground chemistry lab once used to conduct bizarre experiments that have produced strange creatures the students have been battling with in the ancient town of Alkhimia. Students are positioned by the game as members of a team apprenticed to the Master Chemist, Aurus. As part of the equipment available to them, they each have a weapon to protect themselves with. They find that the ammunition for their weapon, in the form of chemical substances, is of little effect when they fire their weapons at the metallic door preventing their escape from the lab (see Figure 2). To their horror, the air vents of the room begin to exude a toxic gas. The flow of gas increases with the passage of time. An in-game timer begins to count down. The players need to find a way to escape from the lab as quickly as possible. They find samples of liquid mixtures on the lab benches. The samples do not all look the same. A player may try to fill his weapon’s ammunition cartridge with one of the samples and attempt to penetrate the metal door by shooting the substance at it. Her underlying hope would be that the ensuing chemical reaction between the substance and the door will create a hole that she and her team members can wriggle through to safety. The substance chosen is the highlighted topmost item in the selectable ammunition pane on the right side of the screen (see Figure 2). To the player’s dismay, however, the mixture is of very low effectiveness in penetrating the door (indicated by a hit score of -1). Based on gameplay in Levels 1 and 2 where students were engaged in the separation of other kinds of mixtures (for example, sand from acid, and salt from water), students know that they should proceed to the in-game chemistry lab to see if they can separate out pure forms of the substances with a view to testing whether the pure substances are more effective in penetrating the metal door.
Teleporting to the virtual chemistry lab (see Figure 3), the players engage in carrying out separation techniques on their own. Figure 3 shows a player attempting fractional distillation with a mixture of immiscible liquids (indicated by the orange upper layer resting on the lower blue layer). Based on the game design, the simplest method of separating immiscible liquids is by using a separating funnel. The underlying pedagogy of game-based learning employed here, however, explicitly encourages students to experiment with multiple approaches to solving a problem so that they can derive a concrete sense of what works in relation to what does not work and, most importantly, to determine why. At times, there may be more than one functional solution. As curriculum designers, we want students to consider which solution should be regarded as the “better” solution and on what grounds.

There are actually three distinct types of liquid mixtures employed in Level 5 of the game. After students complete their separation techniques in the virtual lab, they return to the in-game chemistry lab shown in Figure 2 and test the effectiveness of their separated liquids on the metal door. Unknown to the students (but known to us as game designers), it is the use of gasoline, separated from water, or ethanol, separated from water, that leads to effective solutions when either of these substances is fired at the door with the weapon’s heating element attached. The challenge facing students at this stage is to speculate what kinds of substances these might be. The heating element ignites the substance and causes the metal to melt when it hits the door. All these events should be understood as taking place within the fictionalized space of gameplay.

After completing gameplay, students transition from the space of gameplay to one of classroom dialog facilitated by the teacher. Following the Performance–Play–Dialog (PPD) Model of game-based learning (Chee, 2011), students step back to reflect on their gameplay experience and to make sense of the chemistry underlying why the different substances that they used in the game and experimented with in the virtual lab behaved in the way that they did. The model provides the conceptual basis for designing a classroom environment where “ideas collide” and find substantiated resolution through the negotiation of meaning. It is also used to enact a learning context where student voices are heard, valued, harnessed, and respected in service of student learning (Alexander, 2004, Michaels, O’Connor, and Resnick, 2007). In addition, the dialogic learning space is used to help students theorize and generalize from their cumulative learning experiences, in and out of the game, so as to be able to articulate knowledge claims in more generalizable and parsimonious terms.
As students participate in one level of the game-based curriculum after another, they enact a trajectory of learning chemistry by doing chemistry (albeit virtually). This trajectory instantiates the learning principle of competence-through-performance (Gee, 2007). The goal here is not merely to learn about chemistry, a third-person perspective on knowledge, but rather to learn chemistry as a performance capacity to engage in doing chemistry, a first-person perspective. This performance orientation entails not only physical behaviors related to doing but also speech acts and discursive moves appropriate to enacting professional practice. In this manner, students do not merely learn about chemistry. Rather, they learn to become chemists by imbibing the dispositions and values of professional chemists. In short, they develop their identity as chemists.

4. Method

The research study reported in this paper examines changes in students’ perceptions of their identity, their epistemological beliefs, their dispositions toward science inquiry, and of classroom culture. It also investigates whether learning lower secondary chemistry is more effective with the inquiry-based Alkhimia curriculum compared to learning chemistry using traditional classroom teaching. It does so by comparing the learning outcomes of an intervention class that enacted the Alkhimia learning program with those of a control class. The learning outcomes are based on a summative test that assessed students’ ability to solve a complex separation task in chemistry. The task was designed to be effective in discriminating how well students understand the properties of substances in the context of separation of mixtures, a key topic in the syllabus. Our work as researchers entailed direct observation of all classroom enactions of the Alkhimia curriculum, administration of pre-intervention and post-intervention research instruments, and the conduct of post-intervention student and teacher interviews.

4.1 Subjects

The subjects in our intervention class comprised 40 students from a high-ability class in the Express academic stream of the school where we conducted our research. 22 students were boys (55%), and 18 students were girls (45%). The average age of students was 13 years old. The control class consisted of 38 students who were also from a high-ability class and in the same ability band as
students belonging to the intervention class. 18 students were boys (47%), and 20 students were girls (53%). Students in the control class were taught chemistry in the traditional way, based on the use of PowerPoint slides and the lecture method. The conduct of hands-on laboratory sessions, as part of executing the standard chemistry curriculum, was common to both groups of students. As is often the case in schools, the lab sessions required students to adhere strictly to predetermined procedures to obtain and verify predetermined results.

4.2 Materials

Students belonging to the intervention class made use of Legends of Alkhimia to play the six levels of the game. During the post gameplay time following each level of gameplay, students engaged in learning activities that helped them to focus on the different stages of the inquiry cycle, prior to the class-level engagement in teacher-facilitated dialog. Each game level targeted one focus. The six foci were: (1) question, (2) hypothesize, (3) investigate, (4) analyze, (5) synthesize and claim, and (6) evaluate. Activity sheets were provided to structure the learning activities. As an example, the first level of gameplay was associated with the questioning phase of the inquiry cycle. The activity sheet took the form of a large poster that invited students to express the questions they wanted to find answers to as a result of playing Level 1 of the game. Students in the control class received as well as took notes on the subject during curriculum time.

An attitudinal survey, comprising 27 items, was administered to the intervention class before the Alkhimia intervention commenced, as well as after it ended. A common summative test, shown in Figure 4, was administered to students in both intervention and control classes. The test was devised by the second author.

Figure 4: The summative chemistry separation posttest

4.3 Procedure

The Alkhimia learning program was conducted twice a week during four weeks of July 2010. Each session lasted 120 minutes. By special prior arrangement with the school administration, the sessions were held as part of the intervention students’ regular science curriculum. The sessions were held on Tuesdays and Thursdays. Tuesday sessions ran from 10.30 a.m. to 12.30 p.m., during normal school hours. Thursday sessions commenced at 12.30 p.m. and ran until 2.30 p.m., an hour past normal school hours. Two schoolteachers participated in the program. Each session began with the lead teacher introducing the session, including the inquiry focus for the day’s session. Students then played a level of the game. The amount of time spent playing a level ranged from 30 to 45 minutes. Due to the school’s inability to support one student to each PC in the computer lab, we ran with a dyad model, with two students sharing one computer. The students of each dyad took turns to control
gameplay. The school decided to use their Macintosh computer lab, with 20 computers, to run the lessons. Consequently, the game was run in Microsoft Windows installed in Boot Camp on the Macintosh.

After the gameplay segment of each session, students were divided into two groups. One group remained in the computer lab with the lead teacher while the other group proceeded to a separate classroom so that both groups could engage in the learning activities and dialogic conversations with a smaller teacher-to-student ratio. This form of organization was intended to facilitate more effective conversations, with each student having greater opportunity to participate in class dialog. After working on the learning activity for the session, teachers helped students to make sense of their gameplay in relation to the chemistry embedded in the particular game level played. They also helped students to deepen their understanding of the inquiry focus for the session. For the session that focused on questions, for example, teachers helped students to interrogate what makes a good scientific question, and they encouraged students to self-evaluate the quality of the questions they proposed to pursue. The sessions culminated in students being invited to propose suitable names for the new substances they encountered in each level of gameplay. This activity was intended to mirror authentic scientific practice in relation to how scientists choose and give names to new elements on the periodic table. Teachers assisted students in interrogating what makes a “good” choice of name in the context of the work of professional chemists. An extended description of this activity can be found in Chee, Tan, Tan, and Jan (in press).

5. Data analysis and results

In this section, we report on the data analysis and results from the attitudinal survey and the summative chemistry posttest.

5.1 Survey data

The intervention class comprised 40 students. However, one student was absent when the survey was administered at the posttest. Consequently, the data analysis, using one-tailed independent samples t-tests, is based on the responses of 39 students. Table 1 shows a summary of the survey findings. Statements 1–7 focus on identity as scientist or student. Statements 8–15 examine student dispositions toward inquiry in science learning. Statements 16–17 focus on affect related to learning in the science classroom. Statements 18–20 examine epistemological beliefs related to textbook knowledge. Statements 21–27 focus on student voice as part of classroom culture. It should be noted that the wording shown in Table 1 follows that of the pretest survey instrument. In the posttest, all references to “a science classroom” were replaced by “the Alkhimia Learning Program” so as to draw a distinction between students’ conception of their typical science class and their experience of an Alkhimia science class.

Table 1: Summary of findings from survey administered before and after the Alkhimia intervention

<table>
<thead>
<tr>
<th>Item</th>
<th>Statement^1</th>
<th>n</th>
<th>Pretest</th>
<th>Posttest</th>
<th>t^1(38)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>I feel like a scientist when I am in a science classroom.</td>
<td>39</td>
<td>4.15</td>
<td>4.97</td>
<td>5.28</td>
<td>.000**</td>
</tr>
<tr>
<td>2.</td>
<td>I feel like a student when I am in a science classroom.</td>
<td>39</td>
<td>4.59</td>
<td>4.03</td>
<td>-2.22</td>
<td>.064*</td>
</tr>
<tr>
<td>3.</td>
<td>My teacher sees me as a scientist in a science classroom.</td>
<td>39</td>
<td>3.87</td>
<td>4.49</td>
<td>2.696</td>
<td>.020**</td>
</tr>
<tr>
<td>4.</td>
<td>My teacher sees me as a student in a science classroom.</td>
<td>39</td>
<td>4.72</td>
<td>4.26</td>
<td>-2.04</td>
<td>.096*</td>
</tr>
<tr>
<td>5.</td>
<td>My classmates see me as a scientist in a science classroom.</td>
<td>39</td>
<td>3.21</td>
<td>3.74</td>
<td>2.12</td>
<td>.082*</td>
</tr>
<tr>
<td>6.</td>
<td>My classmates see me as a student in a science classroom.</td>
<td>39</td>
<td>4.72</td>
<td>4.69</td>
<td>-0.12</td>
<td>.999</td>
</tr>
<tr>
<td>7.</td>
<td>I am a good learner in a science classroom.</td>
<td>39</td>
<td>4.67</td>
<td>4.74</td>
<td>0.48</td>
<td>.999</td>
</tr>
<tr>
<td>8.</td>
<td>I ask myself questions when I want to find out more about something in a science class.</td>
<td>39</td>
<td>4.64</td>
<td>4.92</td>
<td>1.97</td>
<td>.108</td>
</tr>
<tr>
<td>9.</td>
<td>I ask others when I want to find out</td>
<td>39</td>
<td>4.79</td>
<td>5.08</td>
<td>1.22</td>
<td>.464</td>
</tr>
<tr>
<td>Item</td>
<td>Statement†</td>
<td>n</td>
<td>Pretest</td>
<td>Posttest</td>
<td>$t_{(38)}$</td>
<td>$p$</td>
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<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>10.</td>
<td>I think to myself what could be possible answers when I have a question in a science class.</td>
<td>39</td>
<td>4.79</td>
<td>0.73</td>
<td>4.87</td>
<td>0.95</td>
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<td></td>
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<td></td>
<td></td>
<td>.44</td>
</tr>
<tr>
<td>11.</td>
<td>In a science class, I take steps to see if the possible answers to my questions are reasonable.</td>
<td>39</td>
<td>4.44</td>
<td>0.91</td>
<td>4.97</td>
<td>0.74</td>
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<td></td>
<td></td>
<td>3.94</td>
</tr>
<tr>
<td>12.</td>
<td>I ask myself to what extent my question is a good question.</td>
<td>39</td>
<td>4.33</td>
<td>1.15</td>
<td>4.56</td>
<td>1.05</td>
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<td></td>
<td></td>
<td>1.12</td>
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<tr>
<td>13.</td>
<td>I ask myself what are the strengths and weaknesses of the questions I ask in a science class.</td>
<td>39</td>
<td>4.15</td>
<td>1.01</td>
<td>4.74</td>
<td>1.07</td>
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<td></td>
<td>2.85</td>
</tr>
<tr>
<td>14.</td>
<td>I can conduct scientific inquiry independently.</td>
<td>39</td>
<td>4.28</td>
<td>0.92</td>
<td>4.77</td>
<td>0.96</td>
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<td></td>
<td></td>
<td>2.31</td>
</tr>
<tr>
<td>15.</td>
<td>I have a good understanding of scientific inquiry.</td>
<td>39</td>
<td>4.23</td>
<td>1.06</td>
<td>4.87</td>
<td>0.83</td>
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<td></td>
<td></td>
<td>3.53</td>
</tr>
<tr>
<td>16.</td>
<td>The way science is learned in the science classroom makes me more curious about science.</td>
<td>39</td>
<td>4.46</td>
<td>1.25</td>
<td>5.03</td>
<td>1.14</td>
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<td></td>
<td></td>
<td>2.64</td>
</tr>
<tr>
<td>17.</td>
<td>The way science is learned in the science classroom makes me enjoy science more.</td>
<td>39</td>
<td>4.79</td>
<td>1.17</td>
<td>5.05</td>
<td>1.21</td>
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<td></td>
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<td></td>
<td></td>
<td>1.40</td>
</tr>
<tr>
<td>18.</td>
<td>Reading textbooks is a good way to learn science.</td>
<td>39</td>
<td>4.03</td>
<td>1.29</td>
<td>3.87</td>
<td>1.28</td>
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<td></td>
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<td></td>
<td></td>
<td>-.81</td>
</tr>
<tr>
<td>19.</td>
<td>Reading textbooks is an efficient way to learn science.</td>
<td>39</td>
<td>3.90</td>
<td>1.41</td>
<td>3.90</td>
<td>1.29</td>
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<td></td>
<td></td>
<td>.00</td>
</tr>
<tr>
<td>20.</td>
<td>Scientific knowledge described in textbooks is always right.</td>
<td>39</td>
<td>3.45</td>
<td>1.13</td>
<td>2.79</td>
<td>1.45</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>-3.12</td>
</tr>
<tr>
<td>21.</td>
<td>In my science classroom, my teachers’ viewpoints about science are often the only viewpoints.</td>
<td>39</td>
<td>3.69</td>
<td>1.22</td>
<td>3.56</td>
<td>1.29</td>
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<td></td>
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<td></td>
<td></td>
<td>-0.57</td>
</tr>
<tr>
<td>22.</td>
<td>In my science classroom, I hear many different viewpoints from my classmates.</td>
<td>39</td>
<td>4.56</td>
<td>1.14</td>
<td>4.90</td>
<td>1.02</td>
</tr>
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<td></td>
<td></td>
<td>1.33</td>
</tr>
<tr>
<td>23.</td>
<td>In my science classroom, I have plenty of opportunities to voice out my opinions.</td>
<td>39</td>
<td>4.36</td>
<td>1.20</td>
<td>5.00</td>
<td>0.79</td>
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<td></td>
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<td></td>
<td></td>
<td>2.81</td>
</tr>
<tr>
<td>24.</td>
<td>I can disagree with what teachers say about science in my science classroom.</td>
<td>39</td>
<td>4.21</td>
<td>1.13</td>
<td>4.31</td>
<td>1.40</td>
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<td></td>
<td></td>
<td>0.50</td>
</tr>
<tr>
<td>25.</td>
<td>It is important to have my own viewpoints about science in my science classroom.</td>
<td>39</td>
<td>4.97</td>
<td>0.90</td>
<td>5.23</td>
<td>0.63</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>1.61</td>
</tr>
<tr>
<td>26.</td>
<td>My opinions are important to other classmates in my science classroom.</td>
<td>39</td>
<td>4.10</td>
<td>0.91</td>
<td>4.67</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.37</td>
</tr>
<tr>
<td>27.</td>
<td>Knowing different viewpoints is important for learning science.</td>
<td>39</td>
<td>5.13</td>
<td>0.98</td>
<td>5.46</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.12</td>
</tr>
</tbody>
</table>

**p<.05;  **p<.10;  p values are for a one-tailed t test

† The statements shown above are based on the pretest questionnaire.

Examining the statistical test outcomes for statements 1–7, we observe that students felt like scientists in the Alkhimia classroom (statement 1), and also perceived being viewed as such by their teachers (statement 3). These outcomes are matched by corresponding shifts (marginally significant) in feeling less like a student (statement 2) and being perceived less as a student by teachers (statement 4). In addition, students also felt they were perceived more like scientists by their classmates (statement 5; marginally significant).

Concerning student dispositions toward inquiry in science learning, students’ responses indicate that they had learned to take steps to examine whether possible answers to their questions were reasonable (statement 11) and to examine their own questions more critically (statement 13). They
also reported having developed a good understanding of scientific inquiry (statement 15) and expressed the ability to conduct scientific inquiry independently (statement 14, marginally significant).

With respect to affect related to learning in the science classroom, students’ responses indicate that, with the Alkhimia program, they became more curious about science (statement 16). For epistemological beliefs related to textbook knowledge, they reported that they no longer believed that scientific knowledge described in textbooks is always right (statement 20; decrease in mean score).

Concerning student voice as part of classroom culture, students’ responses indicate that they had ample opportunity to be heard (statement 23) and that their viewpoints were important to their classmates (statement 26). In addition, they indicate that knowing different viewpoints is important for learning science (statement 27; marginally significant).

5.2 Summative posttest

The second author, a faculty member, and a teaching fellow evaluated students’ written responses to the summative posttest. The faculty member is a science education professor who specializes in chemistry. Each evaluator assessed the responses of one class (intervention or control), and then acted as an independent corroborator for the responses of the other class. Where differences arose, they were discussed and resolved mutually. Students’ responses were scored on two separate criteria: (1) effectiveness of separation achieved and (2) conceptual understanding of chemistry demonstrated in the student’s solution. The maximum separation score attainable was 8, and the maximum concept score attainable was 6, based on the agreed scoring scheme. A one-tailed independent samples t-test was used to test the hypothesis of equal means for students in the intervention class compared to the control class. One student was absent when the posttest was administered to the intervention class. Hence, the statistical test is based on the responses of 39 students.

For the separation score, the mean and standard deviation of the intervention class was $M = 3.28$ and $SD = 2.61$ respectively, while that of the control class was $M = 2.00$ and $SD = 1.71$ respectively. The one-tailed independent samples t-test shows that the hypothesis of equal means is rejected: the intervention students significantly outperformed the control students when assessed on the extent to which effective separation was achieved in the student’s solution ($t_{75} = 2.56, p = .026$). For the conceptual understanding score, the mean and standard deviation of the intervention class was $M = 4.08$ and $SD = 1.84$ respectively, while that of the control class was $M = 2.68$ and $SD = 1.74$ respectively. Again, the one-tailed independent samples t-test shows that the hypothesis of equal means is rejected: the intervention students significantly outperformed the control students when assessed on the criterion of conceptual understanding of chemistry demonstrated in students’ response to the separation task ($t_{75} = 3.41, p = .002$).

6. Discussion

Our findings demonstrate that game-based learning, designed on the model of performance, play, and dialog, has efficacy with respect to changing the culture of traditional instruction-centered classrooms to one that is more centered on student inquiry. As the survey findings indicate, classroom culture is shifted in the direction of a community of inquiry where students feel and identify themselves with the endeavor of science making. They are no longer “regular students” in the eyes of one another and those of their teachers. In this community, they develop the dispositions of critical and interrogative thinking. Students appear to be more self-aware and more self-regulatory in their thinking. They express greater curiosity about science. They are also more critical and discerning about textbook knowledge. These outcomes suggest that students develop a deeper appreciation of science making as a human endeavor and have a more critical disposition toward textbook authority. As part of the desired cultural shift in the classroom, students express their understanding of the importance to speak, to be heard, and to be open to multiple points of view. All these dispositional shifts are of great significance in advancing a classroom culture of “talking science” (Lemke, 1990) and of practicing scientific inquiry.

The Alkhimia curriculum also has efficacy in helping students strengthen their understanding of chemistry, as manifested by the outcomes of the summative assessment. We believe that this outcome arises directly from adopting a performance-oriented pedagogy—embedding embodied learning and enactment of discursive practice appropriate to a professional discipline—such that the
primary instructional goal is not students learning about chemistry but students learning (to do) chemistry. From the perspective of performance pedagogy, what students can articulate of their understanding of chemistry, the so-called “knowledge”, is a derivative of their hard-earned understanding. It is, strictly, a language-based form of knowledge representation, rather than “knowledge” per se. This epistemological positioning is rooted in the process philosophy of Mead (1934, 1938), James (1890/2007), and Dewey (Dewey and Bentley, 1949).

A critical learning affordance provided by Legends of Alkhimia concerns the way in which the virtual chemistry lab allows students to learn by exploration and by generally “messing around with things” in the lab. As evidenced by the entrenched schooling practice of allowing students to only do “what is right” in a real-world chemistry lab, classroom lessons tend to mirror the same ethic: students are drilled to learn and remember only “what is right”—the posited “knowledge” deemed to be “true”. The side effect of students learning in this way is that they never come to an understanding of why “what is right” is indeed “right”. Hence, they lack the justificatory basis for the “rightness” of their answers. Regrettably, students are unable to justify their “right” answers because what is “wrong” is quickly backgrounded into oblivion in the classroom on the premise that it has no educational value. (“Wrong” answers do not earn credit in tests or examinations.) Working in the chemistry lab, however, with unlimited opportunities to reattempt experiments gone wrong, allows students to develop a deep understanding of why “wrong” solutions do not work and, hence, why the “right” answer to the problem is indeed correct. The principle articulated here parallels de Saussure’s (1986) argument that the meaning of signs—their value—can only be understood in relation to the entire signifying system. The relation that creates value is known as difference. Thus, “black” can only be understood in relation to its antithesis “white”. Likewise, “right” can only be (really) understood in relation to “wrong”. Giving students the opportunity to be exposed to “wrong” is thus a vital requirement for developing understanding (not just “knowledge”) of what is “right”. In this sense, giving students access to the “negative space” of play in Legends of Alkhimia is as important as giving them access to the “positive space” of play because meaning making is fundamentally a relational enterprise.

The superior performance of intervention class students with respect to achieving effective separation of the mixture shown in Figure 4, compared to the control class, can be attributed to the virtual chemistry lab representing and constraining the operations with mixtures and substances in a consistent and systematic manner such that students discern a regular pattern of behavior underlying the chemical materials that they work with. This systematicity allows them to construct understandings that are efficacious for performing effective separations of mixtures. The superior performance of these same students in relation to conceptual understanding of chemistry arises from the game’s design and narrative arc creating a need to know chemistry in its canonical form coupled with the implicit embedding of this “need to know” through experiencing the arc of gameplay. These principles are applicable to the effective design of game-based learning in general.

Enacting the Alkhimia curriculum represents shifting to a more student-centered mode of teaching and learning within the context of twenty-first century education and its emphasis on new literacies. Moving away from a psychological construction of literacy to one that is social (Lankshear and Knobel, 2006), the challenge is to help students develop ways of knowing, acting, and speaking that have value in a globalized world. Based on our experience to date, this shift requires accommodation by teachers, students, and education administrators. On their part, teachers need to develop the skills of facilitation necessitated by dialogic learning. In an inquiry-driven spirit of open learning, teachers no longer necessarily know more; neither are they the final arbiters of what is “right.” “Rightness” becomes relative, and the skills of critique and argumentation become more vital. Students also need to develop an understanding of the new “rules of the game.” Whereas effective memorization of facts may have served them well in the past, this well-honed skill no longer delivers the sought after rewards. They now need to develop independent problem solving and critical thinking abilities. Not all students necessarily welcome this development. In addition, education administrators need to shift their thinking away from the model of a school day subdivided into multiple slots of 30 to 45 minutes of curriculum time. Inquiry based learning and learning by doing require substantial stretches of focused time. Students’ short attention span is a valid concern when the classroom activity focuses on information dissemination. When students learn by doing, however, engagement comes quite naturally, and attention span no longer needs to be a determining factor for timetable scheduling.
7. Conclusion

In this paper, we have argued that the prevalent metaphor of scientific discovery does not serve science education well because it leads students to a misrepresented understanding of the nature of science. In its place, we have argued for learning by inquiry. We described the Alkhimia learning program, a chemistry curriculum for lower secondary school science, that instantiates a game-based and inquiry-centered mode of learning, based on the pedagogical model of performance, play, and dialog. Our findings, based on a pre-post survey of student perceptions and a summative chemistry separation task, showed that (1) the Alkhimia learning program effectively fosters a shift in classroom culture toward one of inquiry, and (2) the intervention class outperformed a control class on measures of separation effectiveness and conceptual understanding of chemistry. We discussed the likely reasons for the efficacy of game-based learning, as enacted, and how the learning innovation requires change on the part of teachers, students, and education administrators in order to effectively enact game-based learning in terms of performance.

Acknowledgments

The National Research Foundation, Singapore, provided funding for the research reported in this paper through grant number NRF2007-IDM005-MOE-006CYS. We express our appreciation to Ek Ming Tan and Mingfong Jan who participated in the research. We also thank members of the game design and development team for their contributions: Rahul Nath, Yik Shan Wee, Cher Yee Ong, Won Kit Ho, Simon Yang, Andy Lim, Henry Kang, Ittirat Vayachut, and Aldinny Abdul Gapar.

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Playing in School or at Home? An Exploration of the Effects of Context on Educational Game Experience

Frederik De Grove¹, Jan Van Looy¹, Joyce Neys² and Jeroen Jansz²
¹IBBT-MICT, Ghent University, Belgium
²ERMeCC, Erasmus University Rotterdam, The Netherlands
frederik.degrove@ugent.be
j.vanlooy@ugent.be
neys@eshcc.eur.nl
jansz@eshcc.eur.nl

Abstract: The goal of this study is to gain insight into the effects of context on educational game experience. Using a quasi-experimental setup, it compares the playing and learning experiences of adolescent players of the awareness-raising game PING in a domestic (N=135) and a school (N=121) context. Results indicate that both gaming (identification, enjoyment) and learning experiences are more intense in a home compared to a school context. However, all of the variance in gaming and part of that in learning experience are caused by longer playing times and better computer equipment. Moreover, the overall impact of context on perceived learning is significantly smaller than that of other experiential factors such as identification and enjoyment. Thus context should be considered as a significant yet relatively small determinant of learning experience.

Keywords: context, serious games, game-based learning, situated play, game experience

1 Introduction

The use of digital games for learning has received considerable academic attention in the past decade. Several authors have discussed the opportunities of using games for teaching or training (Michael & Chen, 2006; Prensky, 2003, 2005; Ritterfeld, Cody, & Vorderer, 2009). Others have looked into how the use of game-based learning relates to motivation (Garris, Ahlers, & Driskell, 2002; Miller, Chang, Wang, Beier, & Klisch, 2011; Papastergiou, 2009). Still others have focussed on the design aspect of games and learning and have explored factors that are important when designing game-based learning environments (Gros, 2007; Kliss, 2005). A final strand of research has put forward and assessed potential adoption barriers for using digital games in the classroom (Bourgonjon, Valcke, Soetaert, & Schellens, 2010; Ketelhut & Schifter, 2011; Squire, 2003, 2005). It is clear that educational games cover a broad range of topics featuring different goals and eliciting different types of use. Playing games and learning are, however, context-embedded activities. Hence playing the same game in an educational context tends to be experienced in a different way than in a private setting (Squire, 2005).

Whilst the use of learning games has been studied in educational settings (see e.g. De Grove, Van Looy, Courtois, & De Marez, 2010), little is known about how these games are experienced when being played in other environments and about the experiential differences between differing settings. The aim of this study is to explore whether the playing and learning experiences evoked by an educational game differ between a domestic and an educational context. More particularly, we present a quasi-experimental design in which we compare experience and perceived learning of players of the social awareness raising game Poverty Is Not a Game (PING, GriN Multimedia 2010) who are at home and in school. First, we provide a brief overview of existing literature on the influence of different contexts on game experience. Next, we discuss three experience dimensions related to playing educational awareness-raising games such as PING. Finally, we report on the empirical exploration of how the game is experienced in the different settings.

2 Poverty Is Not a Game (PING)

In order to understand the choice of the theoretical constructs underlying this research, the game used for testing is briefly introduced. Poverty Is Not a Game (PING) is a single-player adventure game that aims to raise awareness concerning poverty and social exclusion in adolescents in a way that relates to their everyday lives (see Appendix A for screenshots of the game). The game takes place in a three-dimensional environment which represents an average Western-European city. Players can choose between a male or a female avatar. Although the decision to play with a certain avatar has an impact on the storyline, the central message the game wishes to convey is the same. It aims to raise
awareness concerning the mechanisms underlying poverty and is specifically aimed at what is sometimes referred to as the fourth world. Each storyline can be finished in approximately forty-five minutes. Previous research into learning and games motivate the inclusion of enjoyment and learning effects in the research design (cf. infra). Moreover, due to the importance of the avatar and its relation with the story, there is also a strong interest in how players identify with their avatar and how this is related to their playing and learning experiences.

3 Background

3.1 Play in context

While digital games mainly take place in a virtual world, they are at the same time being played by individuals in a physical space defined by socio-spatial characteristics. These characteristics, which may include environmental factors, device characteristics, previous occupations, the presence of co-players or even the associations linked with a setting, shape the individual game experience (Mäyrä, 2007). It is therefore surprising that in the literature so little attention has been given to contextual factors in conceptualizations and operationalizations of game experience and in empirically grounded game experience research (De Kort & Ijsselsteijn, 2008). According to Mäyrä (2007), immediate social and personal contexts influence the experience while, on a more abstract level, experiences are influenced by social norms and values, by the contexts of digital game production and by the contexts provided by earlier forms of gaming and play. This model provides us with a first basic understanding of how different types of context influence game experience. At the same time, however, it fails to provide more detailed operationalizations or subcomponents of constructs such as social norms and values. Playing a digital game in a public versus a private place, for example, can be expected to result in a different game experience precisely because the socio-spatial affordances are shaped by the public or private character of those places. To our knowledge no integrated models have been proposed that approach game experience as a contextual phenomenon.

Most research taking into account the role of context focuses on the immediate social relations. De Kort and IJsselsteijn (2008) provide an overview of possible social roles (e.g. spectator, co-player, opponent) and discuss how these roles evoke different experiences. Moreover, a broad range of mostly survey, studies have explored the importance of the social component as a motivator for playing games (Cole & Griffiths, 2007; Griffiths, Davies, & Chappell, 2003; Van Looy, Courtois, & De Vocht, 2010; Yee, 2006; Yee, 2006). Other, experimental studies manipulate social context and then measure how this change affects game experience. Weibel and colleagues (2008) explored the experiences of people when playing online against a human versus a computer-controlled opponent and found higher instances of presence, flow and enjoyment for people who played against another human. Likewise, the differences in several game experience dimensions between virtual, mediated and co-located play have been studied for adolescents (Gajadhar, de Kort, & IJsselsteijn, 2008; Gajadhar, de Kort, & IJsselsteijn, 2008) and elderly people (Gajadhar, Nap, de Kort, & IJsselsteijn, 2010).

While the aforementioned studies provide valuable insights into the effects of different social configurations on the game experience, they do not take into account the broader setting in which these games are played. Educational games, for instance, can be designed for use in a school context. This imposes certain limitations regarding the possible social and spatial configurations in which such games are used. Therefore it is argued that these contexts create different social roles and have different spatial and physical characteristics. Research taking the broader context into account in this manner can mainly be found in research on computer-supported collaborative learning in which the effect of group learning in a computer-mediated environment is examined. A key finding in using collaborative learning environments concerns the necessity of social interaction. If group learning is to be efficient, collaborative learning environments should not prevent or inhibit social interaction between students. Therefore, the teacher serves as a facilitator and the design of the learning environment should be as sociable as possible (Kreijns, Kirschner, & Jochems, 2003; Nastasi & Clements, 1993). These studies only focus on variations in social configuration of the educational context however. No empirical research was found that explores how the educational game experience differs between a school and a domestic context.
3.2 Game experience and digital game-based learning

3.2.1 Enjoyment

While digital games can evoke a broad range of different experiences, most studies focus on what makes them enjoyable. Several approaches exist, however, towards its causes and conceptualizations. Vorderer et al. (2004) identify motivations and user and media characteristics as determining factors leading to enjoyment. Motivations are drawn from a uses and gratifications perspective and include escapism, mood management, achievement and competition. Enjoyment is conceptualized as consisting of three components: one cognitive, one physiological and one affective. Tamborini et al. (2010) approach enjoyment from an interpersonal point of view and conceptualize it as the satisfaction of three needs: autonomy, competence, and relatedness. Relatedness refers to the need to feel connected to others while competence refers to the need to feel competent in the action that is performed and is similar to the concept of self-efficacy in social cognitive theory (Bandura, 1977). Autonomy, finally, refers to the desire to behave according to one’s own will. In the same vein, Sweetser and Wyeth (2005) define game enjoyment in relation to intrinsic motivations and adapt flow theory (Csikszentmihalyi, 1990) to the specificity of digital games. They propose to extend the traditional flow model with the concept of social interaction.

Despite the differences between these approaches, it is remarkable to note that they all take into account the role played by the social dimension of gaming. Vorderer and colleagues do so by means of the user prerequisites and more specifically by integrating parasocial relationships in their model. In self-determination theory, the importance of the social aspect when playing games is represented by the need for relatedness and in the game flow model of Sweetser and Wyeth, social interaction is added in order to take the social aspect of gaming into account. In addition to these theoretical frameworks, empirical studies have found a significant effect of social context on enjoyment (Gajadhar, de Kort, & IJsselsteijn, 2008; Gajadhar, de Kort, & Ijsselsteijn, 2008). Since private and public environments can be considered as different contexts, it is argued that playing in those contexts will significantly impact enjoyment.

H1: The enjoyment evoked by playing an educational game will differ significantly between a school and a domestic context.

3.2.2 Learning effects

Enjoyment is regularly conceptualized as the motivational basis for digital game-based learning (Garris et al., 2002; Michael & Chen, 2006; Squire, 2005). Digital games are perceived as intrinsically motivating because they are enjoyable and it is this trait that is used as a lever to facilitate learning (Chuang, 2007). Authors like Gee (2003, 2005, 2007) and Prensky (2003, 2005) argue that the motivational nature of digital games combined with certain educational content will make learning more effective. Moreover, several models have conceptualized learning as an effect of enjoyment. For instance, Kiili (2005) uses flow and experiential learning theory to construct an experiential gaming model. It is argued that the positive user experiences caused by a flow experience can be brought into service to maximize the impact of educational games. Similarly, Vorderer and colleagues posit that “one the most important of such useful effects of being entertained is comprehension and learning” (Vorderer et al., 2004, p. 403). It is therefore reasonable to assume that the pleasure of playing an awareness-raising game is correlated with its perceived learning effects. The concept of perceived learning aims to explore to what extent participants feel they have learned about the subject matter, in this case about how it is to be poor in a Western country. Employing this construct serves a double purpose. As increased perceived performance capabilities impact motivational outcomes, this construct incorporates an affective outcome (Kraiger, Ford, & Salas, 1993). Yet, by asking to assess their cognitive learning progress, it also serves as a proxy for cognitive learning gains (Pace, 1990).

H2: Perceived learning effects are positively linked with a stronger feeling of enjoyment

However, previous research has shown that different social configurations lead to different learning experiences (Kreijns et al., 2003). As with enjoyment, it is argued that the broader context affects the range of socio-spatial possibilities. It is therefore hypothesised that this will in turn result in different learning experiences.
H3: The learning experiences evoked by playing an educational game will differ significantly between a school and a domestic context.

3.2.3 Identification

Identification is a concept that has been used to explore the attractiveness of media such as television, film and books. Two central concepts are connected to the process of identification with fictional characters: similarity identification and wishful identification. Similarity identification implies that the observer shares certain salient characteristics with the character and hence feels a stronger affinity with it (Feilitzen & Linné, 1975). Wishful identification, on the other hand, refers to the desire to be more like the media character in general or in a specific regard and is related to the idea of vicarious learning (Konijn, Bijvank, & Bushman, 2007).

Digital games have been claimed to differ from traditional media in that the player is given an active role in the fictional world as opposed to just witnessing on-going events (Herz, 1997; Klimmt, 2003; Van Looy, 2010). Klimmt, Heffner and Vorderer (2009) therefore distinguish between a dyadic audience-character relation as it occurs in most media and a monadic player-avatar relation in digital games, whereby the player alters their self-perception into an amalgamation of their avatar and himself. To account for this specific aspect of digital games Van Looy, Courtois, De Vocht and De Marez (in press) introduce embodied presence alongside similarity and wishful identification to measure avatar identification. Embodied presence thereby refers to the feeling of being present in the virtual environment through the body container of the avatar (see also Ducheneaut, Wen, Yee, & Wadley, 2009). This concept thus combines the idea of presence (Lee, 2004; McMahan, 2003; Schubert, Friedmann, & Regenbrecht, 2001) with the fact that experiences in a virtual environment are observably mediated through the avatar, and hence embodied. Regarding learning effects, the concept of identification is closely related to social learning theory (Konijn et al., 2007). As we are dealing with an awareness-raising game that uses the character and storyline to let players experience aspects of what it means to be poor, it is expected that identification will have an effect on perceived learning.

H4a: Perceived learning effects are positively linked with stronger identification with the avatar.

Whereas the effect of (socio-spatial) context on enjoyment and learning experiences has previously been studied, to our knowledge no such research exists for identification with the avatar. Based on the fact that other experience dimensions have been found to be affected by contextual factors, we expect that, apart from the individual situation, the proximity (or absence) of important others influences the feelings of identification. If peers in a classroom make certain remarks regarding the protagonist in PING, for example, these may well affect the feelings of wishful identification of other students. Moreover, the concept of embodied presence entails the idea of ‘being there’. As several authors have noted, social interactions can prevent deep engagement in the game (De Kort & Ijsselsteijn, 2008; Mäyrä, 2007).

H4b: The identification evoked by playing an educational game will differ significantly between a school and a domestic context.

4 Method

4.1 Design and procedure

Poverty Is Not a Game (PING) was launched online on October 20, 2010 and its free availability was advertised on several specialized websites on educational games as well as in the national, regional and specialized presses. Anyone interested in playing the game could go to the game website and play the game directly in the browser or download it and play on their local system. At the same time schools were encouraged to use the game in their lessons related to the European Year of Combating Poverty and Social Exclusion. For several weeks every visitor of the website was invited to take part in a survey for evaluating the game with the possibility of winning a smartphone as incentive. As relatively few respondents turned out to have played the game in a school setting, the game was tested additionally in five different classes. All participants were asked to fill out a questionnaire before and after playing the game.
A quasi-experimental between-subjects design was used with type of context as a factor with two levels: school and domestic context. In the first analysis, dependent variables are enjoyment, identification and perceived learning. The time spent playing and technical performance are used as control variables. In the second analysis, perceived learning is the dependent variable while enjoyment, identification, the time spent playing and technical performance are the independent variables.

4.2 Subjects

In total, 787 participants filled out the questionnaire. As our interest lay with adolescents, participants born before 1990 were excluded from further analysis. After cleaning the data, 264 respondents were retained of which 125 played the game at school and 139 played the game at home. Analysis revealed that there were no significant differences between both groups regarding the number of male ($N_{class}=90$; $N_{home}=88$) and female ($N_{class}=35$; $N_{home}=51$) participants ($\chi^2=2.26$; $df=1; p=0.15$). While the mean age in both groups was statistically different, this difference is considered negligible ($M_{class}=17.3$ $M_{home}=17.8$; $t=-2.5; p<.05$).

4.3 Measures

4.3.1 Enjoyment (Chronbach’s $\alpha=.90$)

To measure enjoyment, a scale based on that by Trepte and Reinecke (2011) was used. Due to the fact that playing during a course is embedded within a certain time frame, it was decided to omit the question "I’m glad the game did not take any longer". Thus the scale consisted of four items rated on a 7-point Likert scale (totally disagree to totally agree). Sample items are “I enjoyed playing PING" and “I found it interesting to play PING”.

4.3.2 Perceived learning (Chronbach’s $\alpha=.90$)

A scale to measure self-reported learning effects in PING was developed based on previous research (De Grove, Van Looy, & Courtois, 2010). This scale explores cognitive as well as attitudinal learning effects. It consists of five items rated on a 7-point Likert scale (totally disagree to totally agree). Sample items are “By playing PING I got a better understanding of the problems poor people face" and "If I were a politician I would now be more able to combat poverty”.

4.3.3 Identification (Chronbach’s $\alpha=.89$)

Identification with the avatar was measured using a short version of the avatar identification component of the player identification scale developed by Van Looy and colleagues (in press). It consists of the first two items of each of the three first-order constructs (similarity identification, wishful identification, and embodied presence), which together constitute the second order construct avatar identification. All items are rated on a 7-point Likert scale (totally disagree to totally agree) and the words “my character” were replaced with the name of the avatar. Sample items are “Jim as a person, resembles me" and “I would like to be more like Jim”.

4.3.4 Time played

As the time that is spent playing the game can influence game and learning experiences, a subjective measure was added asking for how long the participant had played the game (in minutes). A significant difference was found for this variable between both contexts ($M_{class}=27$min; $M_{home}=37$min; $t=-3.99; p<.001$). Playing duration ranged from 10 minutes to 180 minutes.

4.3.5 Technical performance

Previous tests with the game (De Grove et al., 2010) showed that technical problems occasionally occurred during game play due to a slow network connection, limited graphics capabilities or bugs in the software. It was therefore decided to add a subjective measure assessing the technical performance of the game. Participants were asked to rate the technical performance of the game on a scale ranging from 1 (bad) to 10 (excellent). Technical performance differed between contexts. On average, respondents playing at school scored lower than those playing at home ($M_{class}=5.9$; $M_{home}=7$; $t=-5.09; p<.001$).
5 Results

5.1 Game experience in context

In this first analysis, identification, perceived learning and enjoyment are separately analyzed using ANOVA to check whether there are significant differences between contexts. Similar effects are found for all three variables. As shown in Table 1, enjoyment ($M_{\text{class}}=4.03, \text{SD}=1.22$; $M_{\text{home}}=4.43, \text{SD}=1.32$), perceived learning ($M_{\text{class}}=3.24, \text{SD}=1.31$; $M_{\text{home}}=4.26, \text{SD}=1.22$) and identification ($M_{\text{class}}=2.51, \text{SD}=1.13$; $M_{\text{home}}=3.03; \text{SD}=1.21$) all score significantly higher in a domestic compared to a school setting. When the same procedure is repeated using time spent playing and technical performance as covariates, however, only perceived learning scores significantly higher in a domestic setting. There are no longer any differences between contexts for enjoyment and identification (Table 1). The effect of both time played and technological performance is significant for all experience dimensions. When the effect of these covariates is omitted, 14% of the overall variance in perceived learning is explained by differing contexts. When taking these factors into account, 5.4% of the total variance in perceived learning is explained by the difference in context.

Table 1: GLM results with and without covariates (** p<0.01)

<table>
<thead>
<tr>
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<th>F</th>
<th>df</th>
<th>df error</th>
<th>η²</th>
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<td>With covariates</td>
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<td>With covariates</td>
<td>.21</td>
<td>1</td>
<td>260</td>
</tr>
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</table>

5.2 Context effects of identification and enjoyment on perceived learning

The previous analysis explored the differences in game and learning experiences between contexts. These experiences, however, are not unrelated (cf. supra). Learning effects can be evoked by other experience variables such as enjoyment and identification. Testing this model (ANCOVA) explained 56% of the variance in perceived learning. Results show that the score on perceived learning is different between an educational and a domestic context ($F(1, 258)=20.63; p<.001; \text{partial } \eta^2=0.074$) when using enjoyment ($F(1, 258)=49.88; p<.001; \text{partial } \eta^2=0.16$), identification ($F(1, 258)=30.55, p<.001; \text{partial } \eta^2=0.11$), time played ($F(1, 258)=3.81; p=.052; \text{partial } \eta^2=0.015$) and technical performance ($F(1, 258)=4.45; p=0.05; \text{partial } \eta^2=0.017$) as covariates. This tells us that, in accordance with our first analysis, (adjusted) means show that those playing in school reported lower scores on perceived learning than those playing at home ($M_{\text{class}}=3.49, \text{SD}=0.08$; $M_{\text{home}}=4.03, \text{SD}=0.08$, $b=-5.45; t=-4.54, p<.001$). Furthermore, perceived learning is positively associated with enjoyment ($b=.40; t=7.06, p<.001$) and identification ($b=.32; t=5.53, p<.001$) and to a lesser degree with the time played ($b=0.05; t=0.03; p=0.052$) and technical performance ($b=0.077; t=2.11; p<0.05$).

6 Conclusion / discussion

The results of this explorative study suggest that context has an effect on game and learning experiences. Although the effect of context was small to moderate, people playing at home reported significantly higher scores on enjoyment, perceived learning and identification. It is interesting to see that the technical performance of the game and the time played account for these differences regarding enjoyment and identification. This means that if these two covariates were kept constant, there would be no difference in the feelings of enjoyment or identification evoked by playing PING. It should be noted, however, that technical performance and the time that can be spent playing a game are part of the broader context in which an educational game is played. Education in schools is typically embedded within a certain time frame and IT infrastructure which is not always up to date (Squire, 2005). Findings thus suggest that not only socio-spatial characteristics play a significant role in influencing the game experience.

Regarding our hypotheses, our first analysis shows that context has an effect on all three experience dimensions ($H_1, H_3, H_4b$). While it could be expected that a different setting in itself, disregarding playing time and technological performance, would result in differences for enjoyment and
identification, this is not confirmed by our data. Moreover, with the available data it is not possible to say what caused the feelings of enjoyment and identification. Acquiring the same score on enjoyment does not guarantee that the cause of enjoyment is the same for both groups. A part of the score on enjoyment in a school context could stem from lower expectations or the social dynamics while the same score on enjoyment in a domestic setting could be caused by in-game characteristics. The same holds true for identification. While the score on identification is the same in both contexts (when controlled for time played and infrastructure), the processes underlying identification may be different.

For perceived learning, differences remain when accounting for (significant effects of) time played and technical performance. It is remarkable to see that higher learning is reported by people playing in a domestic context which indicates that a domestic setting produces stronger perceived learning effects than an educational one. A possible explanation could be that people playing at home have different expectations than those playing in class. Due to the school context, students may have had higher learning expectations compared to people playing the game at home. Or people playing the game voluntarily at home may have been more interested in the subject matter than those playing it compulsorily in class. Such assumptions, however, cannot be confirmed by the present study.

As learning in the broadest sense of the word is seen as the primary goal of playing or designing an educational game, the second part of our analysis focused on the learning experience and its relation to enjoyment and identification. A model was constructed that explained 56% of the variance in perceived learning. There is a relatively strong association between enjoyment and learning ($H_2$). This is in line with most research on the topic (De Grove et al., 2010; Kiili, 2005). The same goes for identification ($H_{4a}$). A higher degree of identification is related to higher learning effects. Even when controlling for enjoyment, identification, time played and technical performance, a significant effect of context remains (5.4% of total variance in perceived learning).

7 Limitations and future research

Exploring context effects raised several important questions. While, initially, enjoyment and identification differed between contexts, these differences disappeared when time played and technological performance were used as covariates. This points to little or no direct influence of for example social context on these playing experience variables. The question remains, however, as to the antecedents of enjoyment and identification. Future research could explore what causes these experiences and whether these causes differ between contexts. Furthermore, it should be noted that participants playing the game at school did so in a compulsory framework while those playing at home did not. It could be useful to explore how learning is experienced by students playing compulsorily at home as well (e.g., as homework).

Moreover, this study is limited by the consequences of the design. Using a quasi-experimental design allows to test in a naturalistic setting but the flip side of the coin is that there is little control over such a setting or over the participants, which endangers the internal validity. Due to the fact that we had no control over who was allocated to which experimental condition, it is possible that both groups differed in important respects. Although no relevant differences were found between groups on account of gender and age, future research should take into account additional control variables such as participants’ interest in or relatedness to the subject matter and expectations in terms of learning and enjoyment. Another option could be to complement quantitative research with qualitative research such as observations and interviews. In this way, it would have been possible to explore why little or no differences were found between contexts for enjoyment or identification.

Furthermore, there was no control over the setting in which the game was played. Different school settings may have had different social configurations while the same holds true for the domestic settings. Again, observations and interviews could have been valuable complementary techniques to gain additional insight into these questions. Nonetheless, we believe that our findings provide a valuable starting point for further research. As digital games are played within a variety of contexts and not within one contextual layer, it would be interesting for future research to take these broader contexts into account on a theoretical as well as on an empirical level. More specifically, this is supported by the finding that other contextual aspects besides socio-spatial characteristics influence the game experience.
References


**Appendix A – Screenshots of PING**

Jim in Wooters
Sophia talking to her sister
Sustainability Learning through Gaming: An Exploratory Study

Carlo Fabricatore¹ and Ximena López²
¹University of Worcester, UK
²Initium, Rome, Italy
c.fabricatore@worc.ac.uk
ximena.lopez@initium-studios.com

Abstract: This study explored the potential of digital games as learning environments to develop mindsets capable of dealing with complexity in the domain of sustainability. Building sustainable futures requires the ability to deal with the complex dynamics that characterize the world in which we live. As central elements in this system, we must develop the ability of constantly assessing the environment that surrounds us, operating in it and adapting it through a continuous and iterative individual and interpersonal process of revision of our frames of reference. We must focus on our world as a whole, considering both immediate problems and long-term consequences that decision making processes could generate. Educating for sustainability demands learning approaches and environments that require the development of systems thinking and problem-solving, rather than solely the acquisition of factual knowledge. When designed with complexity in mind, digital games present a high potential to facilitate sustainability learning. Digital games can be modelled as ‘complexified’ systems, engaging players in cognitively demanding tasks requiring problem-solving and decision-making skills to deal with ill-structured problems, unpredictable circumstances, emerging system properties and behaviours, and non-linear development of events. Furthermore, games can require players to collectively engage in the pursuit of common goals, promoting remote interactions across large numbers of players. To understand how games are currently used for “learning for sustainability”, we analysed 20 games. In spite of the potential offered by digital games and concrete examples of good practice, we found that sustainability thematic contextualisation and complex system dynamics are not leveraged as much as could be expected. Hence, there seems to be space for improvements oriented at creating game systems requiring players to address sustainability issues from multiple perspectives through: contextualisation integrating the social, economic and environmental dimensions of sustainability; gameplay dynamics integrating non-linearity, emergence, uncertainty, ill-defined problems and social interactions.

Keywords: sustainability, complex systems, game-based learning, digital games

3. Introduction: The focus on sustainability

Over the last 40 years, there has been an increasing interest in supporting sustainable development to manage limited resources in a world facing growing population, industrialization and globalization. Although much work has been done, progress has been slow. In 1972, the international community met for the first time in Stockholm to analyse global environment and development needs. The resulting Stockholm Declaration and Action Plan defined principles for the preservation and enhancement of the natural environment, highlighting the relationship between environmental and developmental issues.

After the Stockholm Conference, the United Nations organised two summits on sustainable development in Rio de Janeiro (1992) and Johannesburg (2002). The concept of sustainability became increasingly popular and used in our common language as well as in important strategies and policies promoting sustainable development.

Although much work has been done since 1972 to define and support sustainable development, progress has been slow. As stated by the Secretary-General of the UN (2002), throughout the years the concept of sustainability ‘(…) has become a pious invocation, rather than the urgent call to concrete action that it should be. And while sustainable development may be the new conventional wisdom, many people have still not grasped its meaning.’ (§ 3). Consequently, there is an urgent need to promote new ways of learning and thinking to help societies shift towards a more sustainable development (Tilbury and Wortman 2004).

This paper presents an exploratory study examining how games are used to educate for sustainability. It constitutes the preliminary phase of a research programme aimed at investigating how the science of complexity can guide game design to leverage the potential of game-based learning for the development of sustainable mindsets.

4. Conceptual framework

4.3 Defining sustainability

Sustainability is a constantly evolving concept (UNESCO 2005), involving multiple fields and perspectives, and related to very diverse phenomena. It is therefore extremely difficult to unify definition of sustainability that is at the same time broad and specific to suit the diversity of contexts sustainability relates to. Consequently, sustainability has been inconsistently interpreted and only partially understood, often leading to inadequate and contradictory policies (Lele, 2002).

The UN World Commission on Environment and Development provided through the Brundtland Report the most widely used definition of sustainability, outlined as ‘(...) development that meets the needs of the present without compromising the ability of future generations to meet their own needs.’ (UNWCED 1987). Albeit criticised for not explicitly mentioning the importance environmental sustainability, this definition is considered an important foundation, as it involves the ethical and intergenerational aspects of sustainability, implicitly addressing the idea of a harmonious development that incorporates not solely the economy but people and ecosystems as well (Gardiner 2002). Accordingly, sustainability is nowadays generally conceptualised in terms of the “Triple Bottom Line” (Elkington 1999), a concept involving three dimensions:

- **Economic**: An economically sustainable system must be able to produce goods and services on a continuing basis, to maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances which damage agricultural or industrial production.

- **Environmental**: An environmentally sustainable system must maintain a stable resource base, avoiding over-exploitation of renewable resource systems or environmental sink functions, and depleting non-renewable resources only to the extent that investment is made in adequate substitutes. This includes maintenance of biodiversity, atmospheric stability, and other ecosystem functions not ordinarily classed as economic resources.

- **Social**: A socially sustainable system must achieve distributional equity, adequate provision of social services including health and education, political accountability and participation.’ (Harris 2000, pp.5-6).

Although individual logics govern each of these dimensions, the three of them are tightly coupled, and their interplay originates global systemic effects that cannot be fully understood or predicted based on local events. This defines the complex nature of sustainability.

4.4 Education and the sustainability mindset

Dealing with the complexity of sustainability requires significant changes in government policies, social and cultural values, and public attitudes and behaviour. These changes are not straightforward, as they call for an important shift in the perspectives that individuals and societies hold in relation to the world and their role in it. In order to foster the changes needed, in 2002 the UN proclaimed the Decade of Education for Sustainable Development, 2005-14, promoting the key role of education for the acquisition of knowledge and the development of skills and attitudes necessary for achieving sustainable development and face present and future challenges. A key postulate of this initiative is that a sustainable future is only possible if we understand the systemic interrelations among environment, economic growth and social development. Therefore, education should help developing our ability of constantly assessing the environment that surrounds us, operating and adapting to it through continuous and iterative individual and interpersonal processes of revision of our frames of reference. We must learn to focus on our world as a whole, considering both immediate problems and long-term consequences that key decisions could generate, through a trans-disciplinary approach, and at both an individual and societal level.

Consequently, it is now understood that in order to deal with and engage in sustainability, more is needed than just knowledge concerning sustainable development (Tilbury 2004; UNESCO 2005). Although domain-specific knowledge is relevant, it is equally important that we, as central actors, develop skills, attitudes and capacities necessary to engage in sustainability with “heads, hearts and hands” (Sipos, Battisti and Grimm 2008). The literature on education for sustainability (Tilbury 2004; Tilbury & Wortman 2004; UNESCO 2005) has identified several characteristics of a sustainable mindset which enable individuals to engage in sustainable behaviours (Figure 1).
Educating for sustainability demands approaches and learning environments promoting and facilitating the development of systems thinking and learning for complexity (intended as the development of mindsets and skills required to deal with essential traits of complexity, such as change, uncertainty, and global phenomena emerging from local dynamics). As Dieleman and Huisingh (2008) emphasise, traditional western education is strongly focused on analysis and deconstruction. We are taught and encouraged to analyse wholes in parts, decomposing complicated systems in an effort to understand them through their elements. This reductionist approach contradicts the very nature of complex systems, which cannot be understood as wholes just by analysing their parts (McDaniel and Driebe 2005; Miller and Page 2007; Patton 2010). Consequently, we are poorly equipped to comprehend elements and interdependencies in complex systems. Dieleman and Huisingh (2008) pinpoint that the lack of cognitive tools appropriate to explore and comprehend systemic complexity lead us to fall back to analysis, being this a more familiar way of knowing and learning. Furthermore, Tilbury and Wortman (2004) indicate that educators are too often provided with resources which address the theory of education for sustainability, but fail to offer relevant examples of tools and approaches that may be used to facilitate the implementation of the theory. Hence, there is an urgent need for tools and educational models fostering systems thinking and facilitating learning for complexity.

Due to their characteristics, digital games can highly benefit learning for complexity. In fact, they can be regarded as excellent educational environments, supporting knowledge and skills learning through fun, in situated and meaningful contexts. Furthermore, digital games can address complexity, requiring players to deal with ill-structured problems, unpredictability, emerging systemic properties and behaviours, and non-linear development of events. Finally, gaming environments can support remote interactions across large numbers of players, requiring collective engagement in the pursuit of common goals. We explore this in more detail in the following sections.

4.4.1 Learning in games

The educational value of digital games and simulations has been theorised and empirically investigated for more than 20 years. Different authors identified numerous reasons why games can be considered educational tools, such as: the intrinsic motivation stimulated in games (Malone & Lepper 1987); the experiential learning occurring while playing (Dieleman and Huisingh 2006); the presence of pedagogic principles in game design (Becker 2007); and the access to shared social practices for the construction of knowledge (Gee 2007; Steinkhueler 2008). In our past research, we have outlined the characteristics shared by good games and good learning environments, and identified the intrinsic connection between fun and learning in games (Fabricatore 2000; Fabricatore and López, 2009; López 2010).
The very same nature of the gaming experience makes digital games valuable tools for learning for sustainability. Most digital games require players to engage in activities organized as a sequence of steps involving different thinking processes, skills and knowledge (Figure 2). First, players identify or define a goal to accomplish in the game. Goals can be partially or completely undefined, thus challenging players to complete their definition through exploration, deduction and inference. Then, players plan how to achieve the set goal, relying on problem-solving, decision-making and creativity. When planning players define one or more suitable courses of action, understand purposes, forecast outcomes, and manage available resources optimising their use. Planning is followed by action, which requires putting into practice the knowledge and skills acquired in the previous stages. Through action players are challenged to develop different types of skills and knowledge depending on the type of game, (e.g. psycho-motor skills; communication and negotiation abilities; attention; memory; rhythm; and timing, among others). While acting, players assess intermediate outcomes and relevant changes in the game state, deciding whether to continue, modify, or abort the current plan. After action is taken, players assess the final outcome. Based on this assessment they set goals for future planning, starting again the cycle. During the game play a spirit of enquiry is needed to explore different scenarios, and reflection and adaptation are required to deal with uncertainty, accept failure and investigate alternate strategies.

Figure 2: Articulation of the game experience (Fabricatore and López 2009)

All these steps are carried out directly in the gaming environment that serves as a frame for meaning making (Gee 2007). Players receive just-in-time feedback, affording a situated and systemic understanding of the consequences of their actions. Furthermore, games foster the collective construction of knowledge, collaboration and sense of belonging by stimulating players to discover and discuss within the gaming community how to tackle game mechanisms, quests, rules and stories that define the game world (Steinkuehler 2008).

The contribution of digital games to education for sustainability also depends on their extraordinary potential to motivate players and emotionally engage them in the game dynamics. Emotional involvement and commitment is essential to engage in sustainability, the same way that motivation and fun are fundamental to engage players in the game. The key principle to motivate and engage players in learning processes is leveraging the intrinsic connection between fun and learning (López 2010). It is known that we learn more and better when we enjoy what we are doing, but the link between learning and fun in games is actually much deeper. In order to play a game, players must learn about elements of the game system such as goals, entities and rules, and develop individual
and social skills required to succeed. Fabricatore (2000, 2007) emphasizes that meaningful learning is not only required in games but is actually a major determinant of motivation. If players do not have anything new to learn, discover, develop or improve they will not feel challenged. Consequently, their motivation will drop and they will stop playing the game. On the contrary, new challenges motivate players to continue playing and engage in further learning, exploring alternatives, increasing their knowledge, discovering mechanisms and improving their performance to progress and develop their mastery. Thus, learning can be considered an essential determinant of the game fun (Fabricatore 2007), engaging players at a cognitive, emotional and conative level. This is precisely what education for sustainability needs.

4.4.2 Games as complex systems

Any digital game can be considered a system, intended as a whole composed of parts which are interconnected and interact so that the system maintains its existence through the mutual interaction of its parts. At any given time the state of a game system is defined by the on-going dynamics and the current state of the system components (Meadows and Wright 2009).

In a game system players play in order to fulfil game aims through the achievement of game goals, interacting with other players and game entities, and engaging in challenges and artificial conflicts resulting in quantifiable outcomes (Salen and Zimmerman 2003). Interactions among players and game entities originate game system dynamics. Game system dynamics can be either triggered by the player or by other game entities, regardless of the decisions of the player (Fabricatore et al. 2002).

Digital games can be merely complicated or properly complex systems. Complicated systems are composed of large numbers of elements and interrelations. Elements maintain a degree of independence from one another, can be fully understood in isolation, and interact based on predefined rules. Hence, complicated systems are knowable, and their behaviour can be predicted examining their parts and the laws that govern interactions among parts, although their study can be challenging (Miller and Page 2007; Quinn Patton 2010).

Complex systems too comprise large numbers of interacting and interconnected elements. What distinguishes them from complicated systems is, first and foremost, the phenomenon of emergence, whereby ‘(…) well-formulated aggregate behavior arises from local behavior.’ (Miller and Page 2007, p.46). Hence, in complex systems interacting elements originate dynamics which cannot be predicted examining the behaviours of individual parts and the laws governing their interactions (Johnson 2001; McDaniel and Driebe 2005).

Elements interacting in a complex system may change their behaviours and properties, co-evolving in order to adapt to each other and to their environment. Consequently, new patterns of organization emerge spontaneously without the intervention of a centralized control, and the system as a whole displays properties of self-organization and adaptation (McDaniel and Driebe 2005; Miller and Page 2007; Quinn Patton, 2010).

Interactions among elements in a complex system are usually non-linear. Depending on the state of the system, a given interaction can: develop according to different patterns; generate different outcomes; and trigger reactions and changes that transcend the initial scope of the interaction (McDaniel and Driebe 2005; Miller and Page 2007; Quinn Patton 2010).

Emergence, adaptation and non-linearity make of unpredictability a further important characteristic of complex systems. Although unpredictability makes processes and related outcomes non-fully-controllable and knowable in advance, it is not synonym of chaos and randomness, since complex systems as wholes tend to change in order to self-organize and adapt (McDaniel and Driebe 2005; Quinn Patton 2010).

From a player-centric perspective digital game systems can display different degrees of complexity. The perceived complexity of a game depends mainly on: the player’s cognitive capacity; mechanistic systemic complicity; proper systemic complexity.

The cognitive capacity of the player is defined by subjective skills and objective limits on human capacity for gathering and processing information. Subjective skill limitations can prevent players from
finding and gathering information actually available in the game (e.g. limited exploratory skills may lead to missing pieces of information in a virtual crime scene). However skilled they are, players are constrained by the objectively limited capacity of the human working memory (Miller, 1994) (e.g. a game of chess appears to be complex, unpredictable and non-fully-controllable mainly because players cannot remember all the possible sequences of chessboard configurations). Ignorance originates from these issues, leading players to wrongly perceive complexity where there is simple complicacy, or even simplicity (Miller and Page, 2007).

Perceived complexity can also result from mechanistic design decisions, which allow designers to define the mechanics of the game events based on causal and stochastic rules, thus controlling the development of sequences of events based on predefined scripts. Through mechanistic complicacy designers can deliberately hide information, gradually revealing or changing aspects of the game system (e.g. new entities and behaviours, or unknown properties of already-known entities) depending on the fulfillment of predefined conditions or probabilistic events. Mechanistic complicacy could lead players to believe that global phenomena spontaneously emerge from local interactions of entities through uncertain and non-linear dynamics, whereas everything actually unfolds based on predefined criteria.

Finally, games can be designed as proper complex systems when interactions among players and system entities can result in consequences of a higher order. These consequences: change the state and behaviour of the game; lead to new discernible and rational organizations of the game system as a whole; and are not planned or even predicted by the game designers (Sweetser 2007). In this case, ‘A modest number of rules applied again and again to a limited collection of objects leads to variety, novelty, and surprise. One can describe all the rules, but not necessarily all the products of the rules (…) which may arise from evolution.’ (Campbell 1983, p. 127).

Mechanistic design decisions can involve the player in dynamics perceived as non-linear, requiring to deal with what Sweetser (2007) calls first and second order emergence. Even when a game unfolds based on predefined causal mechanics and scripts, local interactions could have effects on both the game elements immediately involved and nearby elements in the game world (first order emergence). Furthermore, preconceived causal mechanics can allow players to use basic elements of the game system to create strategies and solve problems in alternate ways (second order emergence). Finally, mechanistic decisions can allow for non-linear developments of game events, through non-linear game progression (e.g. multiple possible progression paths through different stages of a game). Hence, mechanistic design can generate dynamics requiring the player to face uncertainty, emergence and adapt to the unfolding of game events, almost as if the game were a proper complex system.

Systemic complexity is the only quality in a game that can require players to engage with what Sweetser (2007) calls third order emergence: changes on a global scale arising from dynamics happening at a local scale. Third order emergence can change salient traits of the game system as a whole, requiring players and other entities to change and adapt through repeated processes of self-organization (e.g. in a gaming world populated by intelligent agents organized in social systems, a sudden flooding could change the value of resources and social relationships, triggering processes of adaptation at both a local and global scale, and ultimately changing the winning strategies). In this case players have to deal with uncertainty, frequent change and ill-defined problems, and mastery and success are defined by the ability to adapt to change and facilitate the emergence of new favourable system organizations.

5. The study

5.3 Rationale

The challenging nature of sustainability is defined by the complex system dynamics originating from the interplay of the economic, environmental and social dimensions of our world (Elkington, 1999). Given its aims and nature, sustainability learning can be generally regarded as learning to cope with complexity in a specific domain and with specific aims (Tilbury 2004; Davis and Sumara 2006; Sipos, Battisti and Grimm 2008). Furthermore, educational research suggests that learning for complexity, intended as the ability to cope with complex systems, emerges as an adaptive response from the active and passive involvement of individuals in complex system dynamics (Figure 3).
Consequently, we aimed this study at exploring how broadly available sustainability games facilitate
the development of sustainable mindsets. In order to fulfil this aim we investigated game system
aspects defining complex dynamics related to the development of properties of the sustainability
mindset.

Our inquiry was driven by the following guiding questions:
- What types of games are being created?
- What is the target public?
- To what extent are sustainability-related topics addressed?
- To what extent are complex system dynamics leveraged by games?

We consequently investigated the following five categories of game aspects:
- Product profile: aspects related to the production process and outreach of the game
- Contextualisation: aspects defining the meaning and nature of game system dynamics
- Agency: aspects defining possibilities for the player to act upon and generate changes in the
game system
- Sociality: aspects fostering purposeful social interactions among players
- Adaptivity: aspects promoting player proactive and/ or responsive adaptation to changes in
the game environment

5.4 Games selection

The study analysed twenty games, selected based on their visibility on Google search engine. Only
games directly appearing or being mentioned by third parties in the first five pages of the search
results were chosen. This procedure was carried out in February 2011, which is important to consider
as visibility in search engines changes in time. The search strings used were “Games AND sustainability” and “Games AND sustainable development”. Consequently, the search only yielded
games in English.

We frequently found labelled as “games” series of activities and game-like applications that cannot be
considered as proper games (e.g. a website to calculate own carbon footprint). These were not
included in the analysis.

5.5 Data collection and analysis

Selected games were analysed either by playing them directly or by examining detailed information
found in online sources. Time spent analysing each game was varied, depending on their goals and
dynamics. Not all the games were completed, since some were open-ended games with no final winning condition, and others repeated game dynamics across different levels.

Data was gathered using a structured template describing the analytical criteria and procedure. The analysis was based on game elements allowing to study the contextualisation of the game and identify characteristics of systemic complexity in game dynamics. The template was structured in three parts:

1. **General information**, reporting:
   - Title
   - Creator of the game
   - Platform
   - Target age
   - Rating

2. **Contextualisation**, identifying and describing elements defining the impact of the setting, storyline and aims of the game on the definition of the meanings of game dynamics and their relationship with specific topics of sustainability. Elements analysed in this category mainly concerned:
   - Sustainability topics underlying the setting and storyline of the game.
   - Roles interpreted by the player and related motivations.
   - Relatedness of game aims with the domain of sustainability.

3. **Gameplay**, identifying and describing aspects of game dynamics related to complexity and the sustainability mindset. Elements analysed in this category concerned:
   - Game genre. Based on research on game genres (Fabricatore 2000b, Apperley 2006, Kim 2008) we classified games in categories differentiated by aspects of game dynamics potentially impacting the development of the sustainability mindset. We considered the following categories:
     i. Q&A (question and answer): games requiring players to answer questions relying on previously acquired knowledge in order to progress and/or earn credits/score. These games usually provide feedback promoting the understanding and memorisation of information.
     ii. Simulation: games focused on the simulation of the mechanics of some system (e.g. machinery, cities, ecosystems), requiring players to understand such mechanics in order to purposefully act upon the system.
     iii. Action-adventure: games involving players in interactive stories, requiring them to explore and interact with the environment in which they are immersed, solving problems and enigmas to contribute to the unfolding of the story. In this genre the degree in which action and narrative aspects are emphasised varies from game to game.
     iv. Strategy: games requiring planning skills in order to develop, administer and deploy limited resources in constrained conditions, in order to fulfil the purposes of the game.
     v. Puzzle: a form of game requiring players to configure a desired state (solution) employing different components (pieces). Puzzle games usually rely on objective rules determine whether a solution is correct or not, and/or compare solutions (e.g. a jigsaw, where pieces either fit with each other or not). However, it is possible that victory conditions are determined based on subjective rules (e.g. human judges comparing solutions to choose ‘the best one’).
  - Sociality
    i. In-game social interactions required/permitted by the game, and related communication infrastructures.
    ii. Affordances for game-related social interactions outside the game world.
  - Agency
    i. Possibilities of choosing roles and/or embracing alternative motivations corresponding to different play approaches.
    ii. Relatedness of gameplay activities with the domain of sustainability.
    iii. Scope of the game space (i.e. relation of material vs. virtual spaces in the game).
    iv. The nature of problem-solving activities involved in the game (i.e. exercises, well-defined or ill-defined problems).
v. Definition of objectives (i.e. degree: amount of information provided to the player to define the objectives; timeliness: moment when such information is provided).
vi. Non-linearity of progression, procedures and aims in gameplay activities (i.e. to what extent players can define their path of progression, decide how to achieve game goals and/or which aims to fulfil).

- Adaptivity
  i. Emergence of local and global phenomena from local events, either triggered by the player or by the system.
  ii. Unpredictability of game events.

Data was analysed calculating frequencies for individual game characteristic. The chi-square test was used to evaluate the association between characteristics found in games.

6. Results

Figure 4 shows the distribution of games by country and genre. Most games analysed were developed in the UK (6), Australia (5) and the USA (4). Eight (40%) games were supported by sustainability organisations (e.g. institutions promoting education for sustainability); seven (35%) by companies offering public services (e.g. energy and communication); and three (15%) were games originating from private or independent efforts (e.g. students, scientific associations).

The two most commonly found game genres are quiz-like (30%) and simulation (25%) games. Most quiz-like games require players to answer questions regarding environmental issues to advance in the game, promoting knowledge learning through textboxes with brief explanations about the question topic. Simulation games analysed usually demand players to create and administer a city or village, requiring sustainable economic, environmental and demographic management. Other games in this category involve specific topics like water and energy management, and business decision making. Fifteen percent (3) are Action-adventure games. Two of them involve players in detective and mystery stories such as discovering who, when and how an environmentally-related crime was perpetrated. The other game invited the player to explore the game world to re-establish an eco-balance. Two (10%) strategy games were found. Game dynamics in these games involve planning how to make a living from fishing maximising income while keeping an appropriate number of fish in a lake, and planning policies to reduce gas emissions in a virtual world. Two puzzle games (10%) were found. Despite both games belong to the same genre, they are very different from each other. One game...
requires players to sort elements according to their characteristics, within a certain time limit. The other game is a multiplayer non-digital game in which players have to draw objects satisfying certain recycling conditions, and winner is proclaimed by the whole group of players. We found one Massive Multiplayer Online game (MMO) in which players can freely explore and engage in different individual and collective activities (e.g. recycling). We also found one Alternate Reality Game (ARG) in which real and virtual spaces were combined to develop a fiction about an environmental crisis based upon players’ interventions.

Games have different target publics, although a significant proportion is oriented to children. 40% (8) are specifically created to be integrated in schools, usually complemented with supporting materials on how to use them in the classroom and/or combined with other educational activities. Two games (10%) are for pre-school and primary school-age children, requiring adult involvement or supervision. Two games were specifically oriented to adults (e.g. workplace-related games). 40% of the games have an unspecified target age.

The dimensions of sustainability are unevenly emphasised by games (Figure 5). The environmental dimension is present in all the games analysed. 35% of games include only topics regarding this dimension (e.g. energy efficiency, waste management, conservation of natural resources, gas emissions reduction). The same number of games deals with environmental and economic development (e.g. sustainable production and consumption). The remaining 30% of the games combine environmental, economic and social aspects (e.g. combining environmental and economic themes with demographics and development of human capacity and skills).

Figure 5: Sociality, agency and adaptivity traits in games

Game objectives are usually well-defined and are presented at the beginning of the game (55%). Few games (25%) have ill-defined goals, requiring the player to analyse and discover information during game play to better define the objectives. 20% of games present a combination of well and ill-defined goals, providing to players one or two explicit goals while requiring them to formulate new ones as they advance in the game.

The nature of problem-solving activities that players face during game play is variable. 35% of the problems have an exercise structure, requiring the application of previously acquired knowledge and skills (e.g. quiz and puzzle games). Notably, most games presenting this type of problems are targeted to children. 40% are well-defined problems with a finite number of possible solutions, requiring investigation as the solution is not immediately visible to the player (e.g. a mystery game). 25% of the games analysed present ill-defined problems. They have an undefined number of possible
solutions and thus no algorithm can be used to solve them. Solutions emerge throughout the resolution process, allowing the exploration of multiple strategies.

We analysed the possibilities to develop social skills and collectively engage players in the pursuit of common goals by investigating the affordances for social interaction in in-game and out-of-game spaces. We found that the vast majority of the games (75%) are single-player, thus not providing an in-game space for social exchange. We observed that 50% of the games offer players out-of-game spaces to share game-related experiences and information (e.g. the presence of a game community; dedicated websites and blogs). Three games (15%) provide players with in-game communication tools (e.g. chat, posting). Among the multi-player games, three exploit competition dynamics, one combines competitive and collaborative dynamics and one is a collaborative-only game. One game strongly relies on collective efforts and multiple perspectives to manage a global crisis.

Opportunities for choosing roles and/or embracing alternative motivations corresponding to different play approaches are present in 45% of the games analysed. These opportunities are not always explicitly offered to players, and they become evident as players advance in the game or play different matches. For example, in one of the games the player has to manage a company trying to keep a balance between the company's production and profit, environmental impact, labour union demands and social welfare. As the player advances, she realises that the game can be played using different approaches to achieve alternative successful balances of outcomes.

Non-linearity, found in 40% of the games, refers to both non-linearity of progression and procedures. The cases we found of progression non-linearity in general provide the possibility to choose when to complete sub-goals (e.g. building a hospital can be done before or after educating the general population to face a natural disaster). Procedural non-linearity is clearly appreciated in city management games in which players can choose the type of buildings to build (e.g. hospitals, schools, home apartments) to promote social sustainable development.

Opportunities for the player to face unpredictable situations are present in 35% of the games. Random events like earthquakes or economic crises while building a city are good examples of unpredictable situations that players face in the games that we analysed.

Systemic emergence is the complexity trait less frequently found in the games analysed. Player-triggered emergence is present in six games (30%), requiring players to deal with systemic dynamics triggered by their presence and/or decisions in the game. Examples of this type of emergence include the demographic change due to water management decisions taken by player. Game-triggered systemic emergence was found in four games (20%). This characteristic is almost always present in multiplayer games, in which the presence of other players determines changes in the game world without the direct participation of the player's own personal decisions or actions. A good example of this kind of emergence is found in the ARG game, in which the game evolves according to the input of many players trying to face an energy crisis.

In general, there is a tendency for complexity properties to appear in simulation, ARG and MMO games, although it is not possible to numerically verify this due to the insufficient number of games analysed belonging to each game genre.

Chi-square analyses show that games which deal with the three dimensions of sustainability tend to present more unpredictability ($X^2(2, N=20)=5.88$, $p=0.05$), process non-linearity ($X^2(2, N=20)=9.39$, $p=0.01$), and a preponderance of ill-defined problems ($X^2(4, N=20)=6.41$, $p=0.03$) and player-triggered emergence ($X^2(2, N=20)=6.85$, $p=0.03$). Although not statistically significant, the analysis shows that 80% of games treating the three pillars of sustainability are not specifically targeted to children. Most of the games designed for young populations present only environmental topics.

The preponderant type of problem-solving activities presented to the players appears to be associated to different game characteristics that would promote a sustainable mindset. Compared to games relying on exercises and well-defined problems, games presenting ill-defined activities offer to players: more possibilities of exploring different perspectives, roles and/or motivations ($X^2(2,N=20)=11.92$, $p=0.00$); more opportunities to face unpredictability ($X^2(2, N=20)=8.24$, $p=0.02$); a higher contextualisation of gameplay activities, favouring meaning making ($X^2(2, N=20)=16.67$, $p=0.00$); and higher process non-linearity ($X^2(2, N=20)=8.33$, $p=0.02$). Systemic emergence, both
player and game triggered, are found more frequently in games presenting ill-defined problems ($X^2(2, N=20)=12.86, p=0.00$ and $X^2(2, N=20)=7.03, p=0.03$ respectively).

7. Discussion

Our results suggest that broadly available sustainability games are generally focused on environmental topics and/or targeted to children. The idea of “using games to educate children about the environment” seems to be the ultimate synthesis of the frequent associations between “games and children”, “children and caring for environment” and “education and children”. Focusing mainly on children and environmental contents may lead to neglecting the potentialities that games can offer concerning target ages and integration of contents.

As to age, “learning for sustainability” is as important for children as it is for adults (UNESCO 2005), who currently constitute the majority of gamers (ESA 2010). Furthermore, games with an unspecified target age group usually rely on age-neutral dynamics and contents to attract a broad spectrum of players. We believe that it is important to create true multi-age games, integrating varieties of age-specific elements designed to appeal players of different ages, and fostering interaction and collaboration across different age groups.

As to contents, most of the analysed games address the three main pillars of sustainability unevenly, particularly overlooking the social dimension (e.g. poverty reduction and social equity). The challenges of sustainability originate from the interplay between social, environmental and economic elements. Hence, the lack of integration of the three core sustainability themes seems somewhat contradictory with the holistic nature and aims of learning for sustainability (Elkington 1999; Tilbury 2004; Sipos et al. 2008). Furthermore, the associations that we studied suggest that games based on settings integrating the three core themes of sustainability are also the most reliant on ill-defined problem-solving. The presence of ill-defined problem-solving activities, in turn, seems associated with further elements key to fostering sustainability learning (e.g. non-linearity, unpredictability and emergence). Hence, we believe that game settings based on the integration of the social, economic and environmental dimensions of sustainability could offer to game/instructional designers better possibilities for the creation and contextualisation of gameplay dynamics appropriate to promote and facilitate situated and deep sustainability learning. In addition, we believe that the interplay between the three dimensions would also enhance the entertainment value offered to players, as this interplay is already key to massively successful leisure games appreciated by millions of users worldwide (e.g. FarmVille, CityVille and SimCity).

We found that many games examined rely on educational approaches emphasising the dissemination of knowledge regarding environmental education. Furthermore, approximately one third of the games rely on Q&A dynamics, fostering decontextualised knowledge acquisition and the development of basic cognitive skills. This indicates a focus on embedding traditional learning contents and activities in ludic contexts, rather than leveraging learning processes properly contextualised in gameplay dynamics. This approach may lead to the creation of overly education-centred products which neglect aspects fundamental to making games fun and engaging. Sustainability games should be entertaining, so that players feel motivated to play them even outside formal educational settings. We believe that the potential of game-based learning would be fully exploited by designing intrinsically motivating games, engendering dynamics that naturally require situated, sustainability-relevant learning.

Approximately three quarters of the sustainability games analysed require players to face problems and pursue goals which are well defined. This is somewhat discrepant with educational research indicating that the ability to deal with ill-defined problems and emerging objectives is key to the development of mindsets capable to deal with complex systems and sustainability (Tilbury 2004; Tilbury & Wortman 2004; Davis and Sumara 2006; Bloom 2010).

Approximately three quarters of the games analysed are single-player, thus precluding any form of in-game player-to-player interaction. This suggests that designers frequently conceive games as individual experiences, regardless of their educational aims. Social interactions are fundamental to engage in complex dynamics involving other human beings. Learning in complex systems can be considered a trans-level process, unfolding through the interplay between individual and collective understandings emerging from and feeding back into each other, in a continuous process of adaptive
evolution (Davis and Sumara 2006). Hence, we believe that the integration of social interactions in gameplay dynamics benefits the overall learning value of sustainability games. It is worth noting that approximately half of the games analysed were complemented by facilities promoting out-of-game interactions within game communities. Out-of-game communities represent a good possibility of promoting game-related social interactions (Steinkhueler 2008). However, based on the nature and success of game communities in the case of social and MMO leisure games (e.g. Farmville and World of Warcraft) we believe that the potential of game communities can be better leveraged if communal interactions are actually driven by social interactions within the game.

Our findings indicate that key game dynamics aspects fostering adaptivity (e.g. emergence and unpredictability) are rarely harnessed (the most present of these aspects – unpredictability – is integrated in only 35% of the games). This might be detrimental to the development of the sustainability mindset, considering that to facilitate complex learning learners should be involved as much as possible in complex dynamics (Davis and Sumara 2006).

In conclusion, our exploratory study suggests that games can indeed provide key conditions and opportunities to foster sustainability learning. When designed with complexity in mind, games are most suitable to promote the development of complex systems thinking and facilitate a systemic understanding of sustainability. However, complex system dynamics and integrated contextualisations are not as common as we would have expected, given the educational aims of the games analysed. Further studies are needed to determine whether what we observed are general problems or simply issues incidental to the games we studied. However, at the moment there seems to be large space for improvements oriented at creating more ‘complexified’ game systems through a better leveraging and integration of non-linearity, emergence, uncertainty, ill-defined problems and social interactions, and requiring players to address issues from multiple perspectives.

Finally, we believe that efforts should also be made to enhance the accessibility of sustainability games, addressing issues such as language, specific user needs (e.g. disabilities), geopolitical barriers and access to technology. This is essential to maximise the outreach of the benefits of gaming for sustainability.

References


Leadership in MMOGs: A Field of Research on Virtual Teams

Sofia Mysirlaki and Fotini Paraskeva
University of Piraeus, Department of Digital Systems, Piraeus, Greece
smyrsila@unipi.gr

Abstract: As our need for collaboration constantly grows, new tools have emerged to connect us in social networks, supporting the development of online communities, such as online games and virtual worlds. MMOGs (Massively Multiplayer Online Games) and MMORPGs (Massively Multiplayer Online Role-Playing Games) are complex systems, in which players are self-organized and collaborate in guilds; constantly improve to remain competitive, visioning the enemy’s and guild’s reaction. Nevertheless, these are considered to be important leadership skills for the real world, revealing multiple similarities that link the gaming world and the real world. However, despite the significant amount of educational research and the growing interest of the scientific community in MMOGs, there is a lack of empirical research considering the cognitive and social aspects of these games. This paper outlines the theoretical rationale behind a doctoral research project which is currently in progress and examines the leadership skills that can be developed in a self-organized community of MMOGs. The main questions that this project attempts to address are: What characteristics related to the social nature of MMOGs activate leadership skills? What MMOGs can teach us about the design of successful online social spaces and activities for teaching leadership skills in virtual teams? In order to address these issues, this paper presents a theoretical framework for analyzing the social interactions in multiplayer games, within the context of community of practice, connectivism, self-organization and activity theory. This framework aims at examining the creation of communities and the development of leadership skills in MMOGs, in order to explore the role of leadership in these virtual teams. The study of the social structures of a group and the leadership skills that can be developed in a MMOG should result to specific design principles that could be used as design methods for developing effective collaborative environments for virtual teams.

Keywords/Key Phrases: MMOGs, MMORPGs, leadership, virtual teams, activity theory, connectivism, self-organization, communities of practice

1 Introduction

Advances in internet technologies have brought changes in our everyday life and workplace and as our need for collaboration via internet constantly grows, new tools emerge to connect us in social networks and support the development of online distributed communities (Haste 2001; Schrage, 1990). This has led to the creation of social media, such as collaborative projects (e.g. Wikipedia), blogs and microblogs (such as Twitter), content communities (such as Youtube), social networking sites (such as Facebook), virtual social worlds (such as Second Life) and virtual game worlds (such as World of Warcraft- WoW) (Kaplan & Haenlein, 2010).

During their interaction with these technologies, users spend thousands of hours “analyzing new situations, interacting with characters they do not really know, and solving problems quickly and independently” (Beck & Wade, 2004), developing problem solving and collaboration skills (Reich, 1992). It is claimed that online communications facilitate groups of people coming together over the network to discuss any issue imaginable, to ask questions and share provocative insights to which others can respond (Lessig, 2001). These online social environments can evolve into “online learning communities” when they foster participants to actively engage in sharing ideas with others, fostering knowledge sharing (Gibson, Aldrich & Prensky, 2006). In these online communities “knowledge is generated through social interaction, through which we gradually accumulate advanced levels of knowing, according to theories derived from Dewey and Vygotsky” (Anderson & Kanuka, 1998).

Moreover, Information and Communication Technologies (ICT) have allowed the evolution of traditionally organized firms to networked firms where work is performed by virtual teams (Jarvenpaa & Leidner, 1999). Over the years, team-based work units have become increasingly more prevalent and there has been an emphasis on distributed virtual teams (Bell & Kozlowski, 2002).

Virtual teams are “groups of geographically and/or organizationally dispersed co-workers that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task” (Townsend et al., 1998, p. 17), and as Bell and Kozlowski (2002) state they “will play an important role in shaping future organizations, we know relatively little about them”.
Despite the benefits from virtually distributed work (such as high flexibility), there seem to be some difficulties associated with coordinating and controlling virtual work (Bell & Kozlowski, 2002), arising the important issues of team orientation and team coherence. Moreover, leadership is thought to be an essential element for success in virtual teams (Bell & Kozlowski, 2002; Yoo & Alavi, 2004). A leader’s role in a team is to develop the members of his/her team into a coherent, seamless, and well-integrated work unit, focusing “on the enactment of team orientation and coaching to establish team coherence” (Kozlowski et al., 1996).

Leadership theories have developed over the years, and various models have been applied to many domains, such as corporate organization, politics and economies. From the Leadership Grid (Blake & McCanse, 1991), to path-goal theory (House, 1971), Transformational leader (Bass, 1985) and Gerstner and Day’s LMX (Leader-Member Exchange) theory (Gerstner & Day, 1997), researchers are trying to find out “what makes an effective leader”.

In the case of face – to- face team working, leadership skills are usually needed to lead a team by influencing a group toward a shared goal, framing reality for others, giving purpose to collective effort, starting evolutionary change processes (Yukl, 2006). However, in an ever increasing networked world where “business becomes increasingly distributed and virtual in nature, what kinds of leaders might emerge and what attributes will they have?” (Reeves et al., 2005).

Many unknown aspects of leadership in virtual teams seem to be yet unknown (Bell & Kozlowski, 2002) and more empirical studies of leadership within virtual teams are needed (Yoo & Alavi, 2004). The limited research on leadership in virtual teams suggests that a successful team needs guidance, some structure, and effective communication, but leadership is typically examined indirectly if at all (Martins, Gilson, & Maynard, 2004). As Lisk, Kaplancai and Riggio (2011, p.2) state “by examining leadership in context, researchers can understand leadership in a specific situation, and they can use this knowledge to inform predictions in a similar situation that has not yet fallen under the lens of science”.

Moreover, despite the significant amount of educational research and the growing interest of the scientific community in MMOGs, there is a lack of empirical research considering cognitive and social aspects of these games (Steinkuehler, 2004). This paper outlines the theoretical rationale behind a doctoral research project currently in progress, which examines the leadership skills that can be developed in a self-organized community in MMOGs. In order to address these issues, this paper presents a theoretical within the context of community of practice, connectivism, self-organization and activity theory. The study of the social structures of a group and the leadership skills that can be developed in a MMOG should result to specific design principles that could be used as design methods for developing effective collaborative environments for virtual teams.

2 Leadership in Virtual Teams: The case of MMOGs

When people form collaborative groups they have a shared goal that cannot be reached by any group member alone, they cooperate by communicating with the other group members (Stohl & Walker, 2002). This cooperation can overstep organizational borders, is not tied to a place or time, and the group can also operate as a team, without a formal leader (in such a case leadership is shared).

In a MMOG, the players create large groups called guilds, which are naturally formed groups, fulfilling the definition of collaborative groups (Siitonen, 2009). These virtual teams are formed spontaneously, and the learning processes occur naturally and continuously (Steinkuehler, 2004). In MMOGs, players are self-organized into communities around a game activity, yet “this self-organisation results in the development of a range of capabilities towards which the players are not directly striving, but are fundamental to mastery within the environment” (Galarneau, 2005).

The social structure of MMOGs (and MMORPGs) is thought to explain their popularity, offering opportunities for shared experience, collaboration, reward and reputation in the group members. In these complex systems the groups and communities have to fulfil increasingly complex tasks, often requiring precise coordinated effort and high levels of communication and collaboration, increased with the complexity of the tasks at hand (Siitonen, 2009). Thus, as Siitonen (2009) states “it is not surprising that leadership, both formal and emergent, is an integral element of the social organization
of many player organizations”. The social organization and the dynamics of group structure and role – playing in MMOGs have been studied in previous studies (Koster, 2005; Reeves et al., 2005), stressing the importance of the community in these games and focusing on issues of leadership and leadership communication, which can have drastic effects on the operation and social cohesion of online groups.

Moreover, as Klabbers (2006, p.18) state, “free-form games are self-organising, or self-reproductive (autopoietic systems). However, these definitions of have received only minor attention in the literature”. Online games, such as MMOGs, represent an important element of a networked society and of digital culture, and the experience in games challenge many of our traditional views of game, play and society (Corneliussen & Rettberg, 2008, p. 7). Understanding these complex forms of participation in communities and environments such as MMOGs, where learning is the forerunner of the game is critical (Steinkuehler, 2004).

Lately, the scientific community focus its attention to the development of leadership skills, which can be enhanced or developed in virtual worlds and multiplayer games, and their transferability to real life and work situations. A number of researches, as the representative example of IBM, studied the identification of employees with leadership skills in virtual worlds and explored the characteristics of leadership in a popular MMOGs called Word of Warcraft (IBM, 2006; DeMarco, Lesser, O ’Driscol1, 2007; IBM, 2007; Kahai, Carroll, & Jestice, 2007). According to these studies, leadership behaviors appear to be relevant in both gaming and corporate environments (IBM, 2006; 2007), and that MMORPG leadership approaches can be used to improve leadership effectiveness within the enterprise (Reeves et al., 2007). By leveraging the lessons from online gaming environments, companies can gain a better understanding of the ways in which the next generation of leaders will need to operate in the future (IBM, 2006; 2007; Reeves et al., 2007).

MMOGs are thought to enable players to self-organize, develop skills and change roles, providing opportunities for taking risks, seeking for improvement and accepting failure through collaboration and communication channels. In such collaborative environments, a leader must be able to inspire players, urging them to collaborate in order to achieve shared goals.

In MMOGs, guild leaders seem to recruit, organize, motivate and direct large groups of players toward a common goal in a distributed, global, hyper-competitive and virtual environment (IBM, 2007). A guild leader must make decisions quickly, often based on incomplete information. These kind of qualities of gifted gaming leaders seem to be similar to those needed in a corporate setting (IBM, 2006; 2007).

In search of leadership skills in MMOGs, IBM conducted a study in a popular MMOG called World of Warcraft (WoW), taking into account the leadership behaviors described in Sloan Model (Ancona et al., 2007), which has been used for analyzing distributed leadership (Reeves et al., 2007).

According to this model (Reeves et al., 2007), “leadership skills are:

- **Visioning** – Setting a vision for what that organization can be in the future
- **Evaluating** – Gathering information to determine strategic risks for the organization
- **Collaborating** – Leveraging the value of connections and relationships to overcome organizational barriers and accomplish key activities
- **Executing** – Getting the most out of followers and achieving desired results”.

Using the Sloan Leadership Model (Malone, 2004; Ancona et al., 2007), usually applied for analyzing distributed leadership, Reeves et al. (2007) revealed that leaders in MMOGs have important leadership skills such as sensemaking, visioning, relating, and inventing. In general, good leaders have at least a minimal competence on all four capabilities, but no leaders are perfect on all dimensions.

This study revealed that leadership behaviors appear to be relevant in both gaming and corporate environments. Important skills such as self-organizing and regulating behaviors seem to be more appropriate in an increasingly flexible and virtual environment. However, collaborative behaviors where found to be vital to leadership success within MMORPGs and will be increasingly so within corporate environments, where more than ever, employees are becoming increasingly distributed and virtual, with different culture and social needs, are expected to collaborate and share their knowledge.
The best gaming leaders build credibility by first creating strong personal relationships with their followers, revealing the most important skills in these games; the ability to communicate, organize and activate guild members (IBM, 2006; 2007). According to the implication of these findings, virtual leaders should focus on developing trust among the members of their team, visioning the future and communicating with a diverse team of people, making quick decisions based on scarce information and giving immediate feedback and rewards (IBM, 2006; 2007).

Moreover, other studies highlight as important leadership skills the ability for conflict resolution, discipline, motivation, coordination, nurturing and emotional support, delegation, training, retention, recruitment, scheduling, and politicking (Gastronova, 2005; IBM, 2006; IBM, 2007; Reeves et al., 2007). According to the findings of these studies, there are lessons to be learned in corporate environments form the paradigm of leadership in MMOG.

This social and constantly changing collaborative world of MMOGs seem to be a good example of connectivism in full practice and an interesting field of research concerning the distribution of knowledge across the network of players.

3 The need for research

Most players of MMOGs, usually state that the most attracting feature of this game is “the social factor” (Ducheneaut, Yee, Nickell & Moore, 2006) emphasizing the importance of joint activities and time spent in groups (Goh, 2010). As Galarneau (2005) states “MMOGs, in particular, present a tremendous opportunity to explore a nascent area of media convergence, while understanding how the naturally occurring phenomena of self-motivated social learning, sociocultural participation, and collaborative problem-solving can be leveraged into other contexts”. According to Gee (2008, p.34), “such games hold out the potential for the discovery of new forms of social organization, new ways of solving social problems, and new ways of researching and testing collaborative learning, knowledge building, and performance. MMOGs, in particular, “present a tremendous opportunity to explore a nascent area of media convergence, while understanding how the naturally occurring phenomena of self-motivated social learning, sociocultural participation, and collaborative problem-solving can be leveraged into other contexts” (Galarneau, 2005).

While many researchers have focused on usability issues concerning gaming environments and their ability to immerse or attract players, there is still surprisingly little data available to understand how MMOGs function as social worlds (Ducheneaut, Yee, Nickell & Moore, 2006). Despite the scientific community’s focus on understanding the social interaction that occurs within the limits of virtual worlds, the majority of research focuses on using scientific methods of empirical investigation of the interaction of people with their virtual worlds, offering little empirical data to assess the social experiences of players and the social nature of virtual worlds (Steinkuehler, 2004; Bonk & Dennen, 2005; Ducheneaut, Yee, Nickell & Moore, 2006). Moreover, there is such a lack of empirical research considering cognitive and social aspects of these games (Steinkuehler, 2004; 2007).

On this basis, there is a need for researching the social structures formed in these multiplayer games through their interactions with their players. Important issues concerning MMOGs are associated with the sense of community developed in these games, the group structure, the endogenous and exogenous factors that stimulate their users, the collaboration between users, and cognitive skills such as decision making, problem solving, and develop leadership characteristics (Bonk & Dennen, 2005; Ducheneaut, Yee, Nickell, Moore, 2006; Sidorko, 2009; Papargyris & Poulymenakou, 2009; Wyld, 2010; Konetes, 2010).

Such studies can shed light on the factors that enhance the effectiveness of virtual environments and promote the creation of user communities. The study of social structures and relationships between individual and social factors should reveal ways to develop cognitive, emotional skills and social skills, such as leadership skills in the context of virtual communities. These can be important life skills for surviving, living with others, and succeeding in a complex society. Life skills as “those skills that help an individual to be successful in living a productive and satisfying life” (Hendricks, 1996, p.4). In real life, leadership can be an important life skill, such as communication and interpersonal skills.

Leadership in MMOGs seems to influence commercial leadership in the future in different ways (Reeves, 2007). However, despite the growing scientific interest in this issue, understanding leadership in virtual gaming settings is still in the beginning stages and many questions remain about
what characteristics and leadership styles are more effective within MMOGs (Goh, 2010). The potential of these popular environments should be studied in order to exploit and enhance the capabilities of educational and training virtual environments. It is important to understand how to achieve the development of skills in unconventional environments, in contrast to the conventional classroom environment to promote educational theory and practice beyond the preset limits and stereotypes (Lave & Wenger, 1991, in Steinkuehler, 2004). Scientific results in view of these skills in MMOGs and MMORPGs can be used to improve leadership effectiveness in real life, enterprise and training settings, and revealing ways to educate the next generation of life leaders.

4 A theoretical framework for analyzing the social interactions in Multiplayer Games

This paper presents a theoretical framework for analyzing the social interactions in multiplayer games, within the context of community of practice, connectivism, self-organization and activity theory.

4.1 Community of Practices in MMOGs

In situated learning theory, Lave and Wenger (1991) argue that learning, thinking and knowing emerge from a world that is socially constructed. Lave and Wenger were the first to introduce the concept of a Community-of-Practice (CoP), based on socio-cultural learning theory of Bandura (1962). The basic concept of the theory is the term "legitimate regional participation", through which people learn in loosely-organised groups through a "gradual acquisition of knowledge and skills as novices learn from experts in the context of everyday activities".

In such communities, learning is not usually deliberate and happens naturally as learners become members of a community of practice, adopting the culture of the community and taking on the role of an experienced member. The key concept of learning in communities of practice is the intrinsic interest for participation in the community, which requires newcomers to move towards full participation in the community (Galarneau, 2005). Thus, the newcomers are inevitably involved in the community and the acquisition of knowledge and skills is a result of their full participation in the sociocultural practices of the community (Lave & Wenger, 1991).

Since its appearance, communities of practices have been applied in virtual communities since they demonstrate a vital boost in participation through the physical meeting of members (Kimble, Hildreth & Wright, 2001) noted that these communities. MMOGs are considered to be complex learning systems with a full range of social and material practices (Steinkuehler, 2004). In MMOGs, players are part of communities within which they work together to kill enemies, exchange goods and develop their status and solidarity (Lau, 2005). Just as in a real world community, when newcomers enter the game, they are gradually introduced to a complex social framework through the tutelage of other community member (Delwiche, 2006). They learn to “make sense of new areas, especially by engaging with others, discussing, reflecting, and sharing” (Egenfeldt-Nielsen, 2006, p.201).

These communities are formed spontaneously, and the learning processes occur naturally and continuously in the game (Steinkuehler, 2004). Like a virtual community of practices, MMOGs are characterized by “loose cooperation”, since players collaborate in order to enhance their performance. Moreover, in MMOGs players seek the help of others to survive in the game, gaining "mutual commitment" to a "joint venture".

4.2 Activity Theory

Activity Theory extended the relationship between the individual and the community to the much more complex idea of "the dialectical relations between human agents (subjects) and that which they act upon (objects) as they are mediated by tools, language, and socio-cultural contexts." (Squire, 2002; Engeström, 1993). According to Activity theory, "the minimal meaningful context is the dialectical relations between human agents (subjects) and that which they act upon (objects) as they are mediated by tools, language, and socio-cultural contexts" (Squire, 2002). It describes the world (physical and virtual) as a constitution of Subjects –the people or groups-, Objects, Tools -which mediate a subject’s interactions with an object-, the community of a system, Rules and Division of Labor (Figure 1). Communities mediate activity through division of labor and shared norms and expectations (Squire, 2002).
This framework is used to explore the relationships between variables, events, and complex patterns (Egenfeldt-Nielsen, 2006). In a multiplayer game, the activity theory system would represent the interactions among the Subjects, the Objects, the Tools, the Rules, the Community and the Division of Labor as they appear in a game.

Furthermore, MMOGs can be played at anytime, anywhere and by anyone, upgrading the complexity of human interactions and forming large communities in an expanded and more complex socio-cultural context. Thus, Activity theory could be an interesting theoretical framework for analyzing these communities of practices, where numerous players interact with others (subject), using the tools of the game (object), under specified rules and create communities, in order to win (outcome) through certain game activities (division of labor).

4.3 Connectivism

Connectivism is a theoretical framework for analyzing learning in communities, where a learner is exchanging information with the member he/she is connected to. In connectivism, a community is thought as “the clustering of similar areas of interest that allows for interaction, sharing, dialoguing, and thinking together” (Siemens, 2004).

The starting point of connectivism is the individual, and while a person has its personal knowledge, this is shared through nodes - a learning community is described as a node - into a larger and ever extending network of peers, colleagues and why not players. Nodes can vary in size and strength, depending on the concentration of information and the number of individuals “who are navigating through a particular node” (Downes, 2006). In this sense “learning is no longer an internal, individualistic activity” (Siemens, 2005). As Siemens (2006) has suggested, “the learning is the network.”

In MMOGs, players self-organize into communities of practice around a game activity, yet “this self-organisation results in the development of a range of capabilities towards which the players are not directly striving, but are fundamental to mastery within the environment” (Galarneau, 2005).

This social and constantly changing collaborative world of MMOGs seem to be a good example of connectivism in full practice and an interesting field of research concerning the distribution of knowledge across the network of players. As Galarneau (2005) states “only by examining social learning in an environment where it occurs naturally through spontaneous self-organisation of participants into learning ecosystems will we gain insight into its true possibilities within an educational framework”.

4.4 Self-Organization

The theory of self-organization stems from the fields of biology, where the living organism spends much of its life as thousands of distinct units, each of which moves separately from the others, but then, under the right conditions, those thousands cells will be merged into a single larger organization (Wheatley, 1999).

The term Self-organizing Systems refers to the systems that are able to change their internal structure
and their function in response to external circumstances. Self-organizing systems have been discovered in nature, in the non-living (e.g. stars) and living world (e.g. organisms). However, Self-organization theory has been applied to other systems such as economics (Krugman, 1996) and computer-supported collaborative work, examining the ways in which “groupware” systems support self-organization (Eriksson & Wulf, 1999).

This analysis of living systems and cognition was the base for the development of Autopoietic theory, which provides a theoretical framework for analysing the social systems in which we, as living organisms, participate. Taking the example of autopoiesis as a cell, Maturana and Varela viewed autopoietic systems as unities, “as network of productions of components, which through their interactions generate and realize the network that produces them and constitute, in the space in which they exist, the boundaries of the network as components that participate in the realization of the network” (Maturana, 1981, p. 21).

In an attempt to analyse social systems as autopoietic systems, Luhmann (1886) studied the autopoiesis of social systems, defining “communications as the basic elements of social systems”. He viewed communications as the essential elements for any social system, “recursively produced and reproduced by a network of communications and which cannot exist outside of such network” (Luhmann, 1986, p.174). Later, Teubner (1988) attempted to describe law and the legal system as an autopoietic system, while Robb (1989) described the field of accounting and Zeleny and Hufford (1992) cite the family as autopoietic social systems. These studied aimed to extend the applications of Autopoietic theory, which seem to provide an interesting theoretical basis for addressing our everyday social interactions, constituting a very complex social system in which we all live and strive to survive.

In multiplayer games the concept of self-organization occurs as players form social networks. At the start of the game any player is not part of a group by a central mechanism. In addition, there are no rules about how they should fit the players into groups. However, the clustering in a multiplayer game is totally spontaneous and self-organized, through a process of negotiation between players, based on based on emergent norms and relationships (Galarneau, 2005). Gibson, Aldrich and Prensky (2006) state that it is remarkable how well the diverse groups of people of different age groups, gender and culture, manage to play together and self-manage conflicts when they arise.

In multiplayer games, players are self-organized into social groups (clans, guilds). When groups are initially formed, “they are often chaotic and disorganized; but over a period of time, a spontaneous order emerges as players learn to sync their behaviours to the behaviours of other players” (Gibson, Aldrich & Prensky, 2006, p.76). The numerous groups of players, including individuals from around the world, “emerge in an entirely decentralised and self-organised way, engaging in group pursuits and assisting each other to learn how the game world functions, or even co-producing the game world in a negotiated dance with developers. This group emergence follows the classic rules of emergence in biological systems” (Galarneau, 2005).

5 Methodology

This paper outlines the theoretical rationale behind a doctoral research project currently in progress, which examines the leadership skills that can be developed in a self-organized community in MMOGs.

The main questions that this project attempts to address are:
- What characteristics, related to the social nature of MMOGs, activate leadership skills?
- Do these leadership skills activate teamwork and sense of community?
- What MMOGs can teach us about the design of successful online social spaces and activities for teaching leadership skills?

Moreover, it is noted that “researchers interested in pursuing leadership in games would be well served to start by seeing if the foundation is strong, as there are evidences that leading a virtual team has many differences that using leadership techniques when leading a traditional team” (Lisk, Kaplancall & Riggio, 2011, p.12).

Thus, the first stage of this research approach is an in depth exploration of the basic leadership theory models, in order to assess their suitability for analyzing the virtual teams of MMOG players. This project aims at highlighting the characteristics of these social massively gaming communities that
foster leadership skills and activate team work, offering design principles and educational activities for teaching leadership skills to virtual teams.

Online gaming environments offer an opportunity to gather data remotely and anonymously (Wood, Griffiths, & Eatough, 2004), either by the environments itself, or using self-reports from the players. And while ethnographic research has the benefit of understanding true depth and context, this can never be fully captured by survey or experimental methods (Ducheneaut, Yee, Nickell, Moore, 2006). In this project a multi-method approach will be used to take advantage of ethnographic work (depth) and combining it with the advantages of most survey-based work (breadth and representativeness) (Ducheneaut, Yee, Nickell, Moore, 2006) in order to bring together the strengths of both forms of research to validate results.

In social sciences, mixed methods research is considered a legitimate, stand-alone research design (Creswell, 2003). A mixed methods study is a “collection or analysis of both quantitative and qualitative data in a single study in which the data are collected concurrently or sequentially, are given a priority, and involve the integration of the data at one or more stages in the process of research” (Creswell, Plano Clark, Gutmann, & Hanson, 2003, p. 212). By including both quantitative and qualitative data in a study, the results may be enriched in ways that one form of data does not allow (Hanson et al., 2005). This mixed methods design will be used to combine different but complementary data to “uncover some unique variance which otherwise may have been neglected by a single method” (Jick, 1979, p. 603).

The unit of analysis for this PhD project will be the individual leader of a guild in a MMOG. The individual analysis was chosen since this project aims at focusing on the leaders’ skills (Subject) and their affect to the guild’s teamwork and sense of community (Community), according to Activity Theory, which will be the main framework of this study.

6 Preliminary Findings

In order to investigate the relationship of MMOGs’ players, a preliminary study was conducted in a population of 64 guild members, playing a MMOG called World of Warcraft (WoW). The research focused on this MMOG, due to its popularity across the globe with more than 12 million subscribers worldwide (Blizzard Entertainment, 2010). The sample of the research were 64 WoW players, who were chosen from a wider sample of 100 MMOG players, due to their participation in WoW’s groups (guilds) (response rate =64%).

The preliminary work of this thesis focused more on the investigation of the relationship between physiological factors in MMOGs, such as sense of belonging in a group and intrinsic motivation. The research hypotheses where:

Ho1: Is there a relationship between the sense of community and performance in the game?

Ho2: Is there a relationship between the sense of community and intrinsic motivation in playing the game?

The theoretical framework of intrinsic motivation in games by Malone and Lepper (1987) was used to create a 7-item closed-response questionnaire, with which subjects were asked to rate each item (challenge, fantasy, control, curiosity, cooperation, competition and recognition) on a 5-point Likert scale. In order to examine the sense of community in WoW, the questionnaire of McMillan and Chavis (1986) was used, which is broadly validated and widely utilized questionnaire concerning sense of community in the psychological literature. Subjects were asked to rate their feelings concerning their sense of belonging in the gaming community (in a game’s guild) for each of the questionnaire’s items (feelings of membership, feelings of influence, integration and fulfillment of needs, and shared emotional connection), on a 5-point Likert scale. Finally, a questionnaire was used for the collection of self-reported data concerning players’ performance, including the frequency of game play (hours per week), their current level in the game and the level completion time (amount of time required for a level to be completed) on a 5-point Likert scale.

The reliability of the instrument used in this research (Cronbach's Alpha) was α=0.736. Pearson correlation analysis indicated a strong positive relationship between sense of community and intrinsic motivation (r=0.479**) and between sense of community and game performance (0.298*) (Mysirlaki & Paraskeva, 2010).
We conclude that there seems to be a relationship between the sense of belonging in a games’ community (strong feelings of membership, influence, integration, fulfilment of needs and shared emotional connection) and the players’ intrinsic motivation (high levels of challenge, fantasy, control, curiosity, cooperation, competition and recognition in the game). Moreover, there seems to be a strong positive relationship between the feeling of belonging in a community (strong feelings of membership, influence, integration, fulfilment of needs and shared emotional connection), and high performance (higher frequency of game play, higher level in the game and higher level completion time) in MMOGs.

Thus, the ability to create groups and develop a strong sense of community in a game can be motivating for the players and can be positively related to high game performance. This means that the performance of a player can be enhanced when the sense of community in a game is strong. The findings of the research imply that the development of communities in a game is possible to increase intrinsic motivation to players and enhance their performance in the game.

In these preliminary findings, the activity theory system was highlighted by some important psychosocial issues (Figure 2). This system is considered as a complex social network, where subjects interact with numerous factors of the games to lead themselves to the desired outcome.

Figure 2. The Findings of the Preliminary Study under the light of the Activity Theory

For the purposes of this PhD thesis, the activity system theory will be used to analyze MMOGs (such as the game WoW) not as just games, but as complex systems that have characteristics that can be useful for other domains, such as enterprise and training settings, by exploring players’ leadership skills and their effect on their team.

In a multiplayer game, an activity theory system would represent the interactions among the Subjects, the Objects, the Tools, the Rules, the Community and the Division of Labor as they appear in a game, forming large communities in an expanded and more complex socio-cultural context. Thus, Activity theory could be an interesting theoretical framework for analyzing these communities of practices, where numerous players interact with others (subject), using the tools of the game (object), under specified rules and create communities, in order to win (outcome) through certain game activities (division of labor).

This framework aims at examining the creation of communities and the development of leadership skills in MMOGs, in order to explore and validate factors that could strengthen or undermine the relationships between players in Multiplayer Games. The study of the social structures of a group and the leadership skills that can be developed in a MMOG should result to specific design principles that could be used as design methods for developing effective collaborative environments for virtual teams.

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Students’ Constructionist Game Modelling Activities as Part of Inquiry Learning Processes
Zacharoula Smyrnaiou, Moustaki Foteini, Chronis Kynigos
Educational Technology Lab, School of Philosophy, Faculty of Philosophy, Pedagogy and Psychology, Department of Pedagogy, National and Kapodistrian University of Athens, Greece
zsmyrnaiou@ppp.uoa.gr
fotmous@ppp.uoa.gr
kynigos@ppp.uoa.gr

Abstract: Learning science requires the understanding of concepts and formal relationships, processes that -in themselves- have been proved to be difficult for students as they seem to encounter substantial problems with most of the inquiry-learning processes in which they engage. Models in inquiry-based learning have been considered as powerful ‘tools’ that may help students in enhancing their reasoning activity and improving their understanding of scientific concepts. Modelling, however, in the form of exploring, designing and building computer models of complex scientific phenomena has also been embedded in the constructionist learning approach. Working collaboratively with constructionist game microworlds that by design invite students to explore the fallible model underpinning the game and change it so as to create a new game, may provide students opportunities to bring into the foreground their conceptual understandings related to motion in a Newtonian space and put them into test making them at the same time objects of discussion and reflection among the members of the group. Apart from the meaning generation, we also study in this paper, the students’ group learning processes i.e. the construction of emergent activity maps to either plan their actions as they engage in game modelling activities or to report on the outcomes generated when these actions are implemented. The connections between the students’ activities as they work with a constructionist medium and the inquiry-based learning activities from which the students are considered to pass when engaging in scientific inquiry also constitute one of the main issues this paper attempts to study.

Keywords/Key Phrases: modelling, games, half-baked microworlds, constructionist and inquiry-based learning.

1 Theoretical framework

Research in Science Education has been shifting focus with respect to positivist/relativist epistemology, learning concepts and learning processes, individualistic learning and learning in collectives. Inquiry learning for instance has been focusing on process, highlighting students’ difficulties with each one of the phases of the inquiry-learning cycle, i.e. orientation of the domain(s), hypothesis formation, hypothesis testing through experimentation and drawing conclusions through an evaluation of the attained knowledge and the whole learning process (De Jong and Van Joolingen, 1998). Learning science requires understanding of concepts and formal relationships, processes that have in themselves been proved to be difficult for students. In particular the literature indicates that students have difficulties in translating theoretical variables from their hypothesis into manipulable and observable variables of the experiments they carry out (Lawson, 2002), they often attempt to control simultaneously too many variables (Keselman, 2003), they fail to make predictions and misinterpret the collected data (Lewis et al., 1993).

In science education, modelling is perceived as a key context for the supporting of inquiry based learning in students. Research efforts in science education reveal the impact the combination of inquiry and modelling may have on students’ conceptual understanding of science, especially when suitable technology-based educational tools are used, is well documented (Smyrnaiou and Weil-Barais, 2005; Zacharia and Anderson, 2003; Zacharia, 2006). Recently, research has indicated that modelling processes could be a powerful ‘tool’ that may help students in enhancing their reasoning activity and improving their understanding of scientific concepts (De Jong and van Joolingen, 2008). In model-based inquiry learning, the students may work with computer models that they explore by changing the values of the input variables and then observing the outcome of their actions at the values of the output variables. Restructuring, consequently, these models using the data gathered throughout the previous inquiry process with the objective to create a new model that behaves like a...
real system is also part of model-based inquiry learning. The computer models used in model-based inquiry learning constitute the underlying mechanism that controls the simulation that the students observe on screen. The difference between using these simulations and using games (that also contain an underlying model) in model-based inquiry learning is that simulations allow students to develop knowledge about a specific domain by using scientific tools and methods while games seem to bring forward mostly intuitive knowledge since the most important goal to attain when playing the game usually doesn’t include systematically exploring and defining the underlying scientific model (De Jong and van Joolingen, 2007).

Apart from model-based inquiry learning, however, exploring, designing and building computer models of complex scientific phenomena has also been embedded in the constructionist learning approach (Wilensky, 1999; Wilensky and Reisman, 2006). Constructionism builds on the idea that that students learn more effectively when building sharable artefacts that are personally meaningful to them (Harel and Papert, 1991; Kafai and Resnick, 1996). Under this perspective, computer-based modelling, especially in the form of programming (Penner, 2001), may allow students to engage in processes that will bring into the foreground their own conceptualizations and ideas regarding the behavioural dynamics of the scientific phenomena they study and test these ideas by implementing them in the model they create. These models when created collaboratively or when published by the students become objects of discussion and reflection among the peers and provide students opportunities to go deeper in gaining an analytic understanding of the phenomena under discussion (see for example, Simpson, Hoyles and Noss, 2005).

Model designing and building, as described above, when it occurs in the context of working with game microworlds, may offer students opportunities to learn about academic subjects as they play a game themselves or create games for others to play (Harel and Papert, 1991; Kafai and Resnick, 1996). Microworlds embed a coherent set of scientific concepts and relations, combined all in an underlying model that is run when starting the simulation. When the microworld is built under the white box perspective (for a discussion on the black and white box approach, see Kynigos, 2004), this model is made visible to the students who may explore how it works and -having “deep structural access” (diSessa, 2000)- change it to incorporate their own ideas and conceptualizations regarding the scientific concepts the microworld embeds.

Half-baked microworlds (Kynigos, 2007) hold this potential since they are incomplete by design, a feature that invites and challenges students to explore the model that is responsible for the “buggy behaviour” and change it so as to make it work according to their own understandings. They are meant to operate as starting points, as idea generators and as resources for de-composing and building pieces of software. In case these pieces of software are games, the players of the initial game, soon become the designers of a new game, engaging in the way in mathematical and scientific meaning making (Kynigos et. al, 2010).

Although modelling has its own distinct place in the inquiry-based and the constructionist learning approach, the role of modelling in bringing together those two approaches remains an issue that needs to be further explored. In a recent study, De Jong and van Joolingen (2008) connect the “learning from models” process to inquiry-based learning and the “learning by modelling” process to constructionist learning. Presenting Co-Labs, an digital environment in which students may engage in both “learning from models” and “learning by modelling” activities, they attempt to identify and study the scientific inquiry processes from which the students pass as they work with the models which the find ready-made or create themselves. In their findings, they assert that the inquiry processes that appear when “learning from models” and “learning by modelling”, resemble to the ones appearing at the inquiry-learning cycle proposed by de Jong (orientation, hypothesis generation, experimentation, and conclusion).

In this paper we look at the inquiry process focusing on constructionist modelling in student collectives. We studied students collectively trying to make sense of a model which was presented to them as questionable and malleable with respect to the rules underlying object behaviours and relationships and the influence of field parameters. The students addressed this activity as a group and discussed ways in which they would coordinate their investigations in order to change the models’ functionalities as results of their experimentations. Apart from looking into the ways in which they generated meanings with respect to concepts in kinetics, such as velocity, force on an object, gravity, trajectories, collision rules we also wanted to study aspects of the students’ group learning process,
i.e. the construction of emergent activity plans, their mutual engagement with the task and their socio-meta-cognitive processes. Stahl (2005) has recently suggested that mutual engagement with a shared artefact is a learning context which may support group cognition.

Particularly, we focus on the students’ game modelling processes as they work with a half-baked microworld designed for constructionist learning. Our interest lies in specifically identifying the connections between these processes that take place when the students interact with a digital artefact that invites them to engage in both “learning from models” and “learning by modelling” processes and the inquiry-learning activity stages from which students are considered to pass in the context of scientific inquiry. Moreover, we attempt to specify if and how students’ game modelling activities when working with a half-baked microworld may provide them opportunities to gradually evolve their conceptual understandings regarding motion in 2d Newtonian space.

2 The Juggler Half-baked Microworld

“Juggler” is a half-baked microworld (Kynigos, 2007) that is designed to offer students opportunities to explore and build models of 2d motions and collisions inside a Newtonian 2d space as they play a juggling game with two moving balls and two rackets (Figure 1).

In order to play the game, the students need to first define the initial conditions for running the model that underpins the game. To do so, three Vectors Manipulation Components are available: one for the red ball’s initial velocity, one for the green ball’s initial velocity and one for the field force. The students set the values for each of these physical quantities by dynamically manipulating an arrow (a vector) whose direction, angle and length are changeable. The vector’s tail is attached at the 0,0 point on a Cartesian 2d pad that serves as a background, while its arrowhead’s (X,Y) coordinates (Cartesian coordinate system) are displayed on screen along with the length and angle measurements (Polar coordinate system).

When the players start the game, the values for each one of the vectors’ angle and length take their place in a set of motion equations integrated inside a Logo program and the model starts to run. From this point on and until the model is stopped, the velocity vectors become reading instruments as they show at each instance the direction and magnitude of the velocity for each of the two balls and the values for its Vx and Vy components.

Once the Juggler game starts, the simulation of the model shows two moving balls which the player must keep up in the air using the two rackets. If the field force vector is set to the magnitude and direction of the gravitational pull, the two balls move in projectile motion trajectories until they are hit
by one of the rackets. The collision with the rackets makes the balls move in a projectile motion once again, only this time in the complete opposite direction in the horizontal and vertical axis.

The goal of the game is to juggle the balls up in the air as long as possible by moving the two rackets so as to hit the balls and not let them fall in the ground. To do so, it is crucial for the students to initially manipulate the three vectors in a way that would make it easy for them to hit the moving balls when the simulation starts. However, when designing a game so as to give it to their peers, the most important thing to do could be choosing initial conditions that would make the game extremely difficult for the others to play. In any case, no matter whom the game the students are creating is intended for, discussing in collectives about the initial values to select could bring into the foreground scientific explorations related to motions and collisions in a 2d Newtonian space.

3 The FreeStyler

FreeStyler (Hoppe and Gaßner, 2002) is a CSCL environment designed to support synchronous discussions between collaborative learners. The students (working individually or in groups), may communicate their ideas with their peers by adding textual contributions inside a shared workspace. Since these contributions also have a graphical form (the text is typed inside a shape) and links can be added to connect them to each other, FreeStyler can be used for the collaborative creation of maps -such as argumentation or concept maps- as well as for the collaborative creation of Plans depicting a course of action to be taken. According to the intended use and the scenario activities, the students can be asked to use one of the several predefined sets of contributions available through FreeStyler's Palette. These contributions can be fully-structured and standardized (in terms of the shapes/cards and text/content used) or editable and semi-structured allowing the content inside the shapes to serve as sentence openers for the students' ideas.

To customize FreeStyler to our own scenario needs, we created a set of contributions that we randomly placed on the environment's main UI instead of inserting them in the system's Palette. These contributions emerged from a synthesis of the main Activity Stages as these are proposed by a number of theoretical frameworks that describe students' activities when engaging in inquiry learning processes (Wegerif and Yang, 2011). These key Activity Stages are: Make Hypotheses, Experiment, Observe, Analyze data, Gather information, Exchange ideas, Keep notes, Build a model, Evaluate, Reflect, Rethink my hypothesis, Discuss, Explain, Draw conclusions, Find a mathematical expression, Reach an agreement and Present (Figure 2).

![Figure 2: The FreeStyler environment with a set of contributions that correspond to the inquiry-learning framework](image-url)

To make sure that all these contributions were conceived by students as being of the same type (Activity Stages), they were all represented by the same kind of shape (a rectangle). Although the type of shape was standardized and fixed, the content inside them was editable, since text could be
added by the students after the words and phrases already inserted. The functionality that allows linking the shapes to each other was also activated giving students the opportunity to structure their contributions inside the shared workspace and connect them to each other to describe a kind sequencing among the Activity Stages they selected.

The idea behind creating a kind of “vocabulary” that corresponds to specific Activity Stages and putting them in shapes that can be structured and linked to each other inside a shared workspace, is to provide students an environment in which they can collaboratively create “Plans” to describe their course of action when addressing problems in the context of inquiry-based learning. Planning the actions towards as specific goal, monitoring the progress done towards these goals by looking at the Plan and evaluating it at specific time points are considered to be important parts of the students’ regulative activities as the engage in inquiry learning processes (Njoo and de Jong, 1993). To scaffold these activities we didactically engineered an environment in which collaboratively creating a Plan would be for the students just a matter of choosing a contribution that corresponds to the scientific inquiry phase in which they engage and linking it to others to define a sequence of actions to be taken towards the goals they have set.

To support, however, the students in planning or reporting their course of action as they work with a constructionist medium, such as the Juggler half-baked microworld, this “vocabulary” needs to transform so as to correspond not to inquiry-learning processes, but to constructionist learning processes. Thus, a constructionist “vocabulary” (Giannoutsou et al., 2011) was designed to provide students with new tools to explain their actions as they were experimenting with microworlds. To support students in describing these actions, the available constructionist “vocabulary” includes contributions such as: Run an experiment, Change something, Observe what is happening, Draw conclusions, Make a hypothesis on what’s going to happen, Interpret the feedback, Detect what is causing it, Explain, Find relationships, Predict, Create a model that explains the behaviour. These contributions were also randomly placed on the environment’s main UI and were also designed to serve as sentence openers for the students’ ideas.

The question that emerges here is if specific constructionist learning activities that belong to the second “vocabulary” may also be considered processes of Inquiry learning Activity Stages that belong to the first “vocabulary”. Special attention is given to the “Experimenting” Activity Stage as this is one the inquiry learning phases in which the students are considered to conduct controlled scientific experiments by manipulating variables and observing the outcomes their actions. These actions (i.e. “Change something” and “Observe what is happening”) are also part of the constructionist activities in which the students engage when working with the microworld.

4 Research design and method

In this study, we used a design-based research method (Cobb et al, 2003), which entailed the ‘engineering’ of tools and tasks, as well as the systematic study of the forms of learning that took place within the specific learning context.

4.1 Context and Participants

The study took place at the Educational Technology Lab with six 9th grade students (14 to 15 years old). All six participants were students at the 2nd Experimental Lower Secondary Education School which has a long tradition in organizing extra curriculum activities for groups of students having a particular interest in specific school subjects such as mathematics and science. The students taking part in the study had formed with the initiative of their Physics teacher a “Studying Science Club” and came to the Lab voluntarily as part of their after school activities. For the needs of the study, two groups of three were formed by the students themselves without any intervention from the researchers and the members of each group worked together with the digital artefacts prepared from them for three school hours. The experimentation process was carried out by two ETL researchers while the class teacher was also present but didn’t actively participate in all the experimentation phases.

The adopted methodological approach was based on the participant observation of human activities taking place in real time. Each researcher chose to focus on one of the groups throughout the experimentation process. The researchers’ interventions were mostly restricted in posing intriguing
questions and encouraging students to express clearly and explain to each other their ideas and strategies as they worked with the digital artefacts.

4.2 Data collected

For the data collection, screen-capture software was used to record the students’ interactions both with their peers and with digital artefacts provided. The corps of the data also included the maps the students created using FreeStyler, the games the students created using the Juggler half-baked microworld as well as the researchers’ detailed field notes. The analysis of the data collected entailed looking at the students’ activities as they interacted with the digital artefacts, giving special attention to the ways these were used by the students: 1) in order to plan or report their actions and 2) in order to make sense of the scientific concepts and relationships embedded in a game’s underlying model. The interplay between the digital artefacts was also taken into consideration to study how the reporting of actions progressed as students’ meaning making with regard to motion in 2d space evolved.

4.3 Activities

For the first phase of the experimentations, the students were initially shown a You-Tube video in which a performer tried to juggle two balls and were asked to collaboratively design in groups a juggling game in which the balls would move in a similar way to the one they were watching on the video. To describe how they would work in order to design a model that would generate the phenomena they were watching, the students were asked to use FreeStyler to construct a “Plan” of actions to be taken.

In the FreeStyler environment we had already prepared a set of predefined contributions that we had randomly placed on the environment’s main UI. These predefined contributions represented the cognitive phases of scientific experimentation according to the inquiry learning theoretical framework. The students were asked to select the contributions they considered best fitted and structure them in a way that would depict their course of action in the process of designing a Juggling game. As these contributions were created to also serve as sentence-openers, the students were encouraged to add supplementary content if they felt this was needed.

For the second phase of the experimentations, the students were introduced to the Juggler half-baked microworld (Kynigos, 2007) and were given enough time to try to play the game. As the Juggler half-baked microworld is incomplete by design, the simulation invites the students to explore the model underpinning the game and change it, incorporating their own conceptualizations on how it should work. In this phase, the groups of students were asked to use the Juggler half-baked microworld in order to collaboratively design a game that they would consequently give to the other group of students to play with.

To describe their course of actions in the process of changing the game and designing a new one, the students were asked to go back to FreeStyler and create a new Plan using the constructionist vocabulary. The students were free not only to just use only the available ready-made contributions as they were, but also edit them so as to further explain their ideas on how they should proceed in working with the microworld. This new map created in FreeStyler was meant to be both for reporting their work with the microworld as well as for organizing what to do next.

5 Results

In the first phase of the experimentations, the students, after watching the juggling video, were asked to construct a Plan in FreeStyler (Figure 2) to explain their course of action in the process of designing a game in which two balls would be moving in similar ways as in the video they were watching.

The students of Group A after having observed the motion of the balls in the video shown to them and having “Discussed” it with their peers, determine the “Make a Hypothesis” Stage as the first Activity to be done in order to construct a model that would generate a simulation similar to the one depicted in the video. According to the Plan they made, this hypothesis should be examined using “Information” gathered about juggling, which should be consequently “Analysed” in order to come up with new ideas to be discussed and “Exchanged” with their peers. “Rethinking” the original hypothesis should be the result of this part of the process helping then students “Reflect” on the situation at hand and prepare an “Experiment” with the available resources. To test the hypothesis the students expect that
they will need to “Create a Model” which they would then have to “Present” to their peers and “Explain” how it works (“Present” and “Explain” are combined in one contribution). The final Activity Stage will be to “Evaluate the outcome” (Figure 3).

Figure 3: The Plan Group A prepared to explain their course of actions in designing a Juggling game (students’ additions to the predefined contributions are in italics)

The students of Group B, on the other hand, start with the “Gathering information” Activity Stage as they consider that they first need to know more about what a Juggler does. This would give them ideas about the functionalities to be implemented in the game which they should “Exchange” with each other so as to be able to “Discuss” all the data collected (“Keeping notes” seems to be is necessary so as to make sure nothing is missed). (Figure 4).

Figure 4: The Plan Group B prepared to explain their course of actions in designing a Juggling game (students’ additions to the predefined contributions are in italics)

“Discussions” should eventually lead to some kind of an “Agreement” about what the game should look like. “Reflecting” on the design before implementing it seems to be an Activity Stage that would
give students extra information on the functionalities and the form of the game. “Experimenting” seems to precede “Building a model” for the game which they would need to “Observe” in order to “Draw conclusions” and consequently “Evaluate” it. “Presenting” the results would be escorted by “Explaining” to others how the game works.

In this phase of the study, the students of both Groups seem to use the majority of the predefined inquiry-based learning contributions available to them in order to construct their Plan on how to design a juggling game. To make their ideas more explicit, for some of these contributions, they choose to insert additional information, expressing mostly issues concerning the existence of specificities in the process of addressing the problem at hand (e.g. the need to work with the “available resources” and to evaluate and explain “work done so far”). What is interesting here is that, although the task the students had at hand was to design a game in which two balls would be thrown up in the air and juggled so as not to fall in the ground, no reference is made in these two Plans to scientific concepts that relate to motion or collisions in a Newtonian space.

For the second phase of the study, we gave students the Juggler half-baked microworld (Kynigos, 2007) and asked them to collaboratively design a game for the students of the other group to play. After giving them enough time to play with the initial game, the students were encouraged to go the FreeStyler and create a new map using the constructionist ontology so as to describe their course of actions in the process of changing the game and designing a new one.

The students of Group A start their work with the half-baked microworld by placing the two balls at the same vertical distance from the two rackets. To make sense of how the initial model of the game works, the students start experimenting with the directions of the two vectors that control the initial velocities assigned to the two balls and consequently run the model to observe the simulation generated. Their experimentation process seems to be rather systematic, as, each time, they choose to manipulate only one velocity vector (either the first or the second ball’s) and maintain the force vector to its default direction (it was by default set to a vertical direction with a 270 degrees direction to represent the gravitational pull). This strategy seemed to be successful, as the students managed to find the suitable directions for the two velocity vectors to make the game quite easy to play.

After having played the juggling game a few times, the students move to the second task which was to design a new game for the students of the other Group to play. Their first action is to change the Force vector’s direction, making it vertical with a 90 degrees direction, and run the model to see how the balls move. Going to the FreeStyler environment, the students add three contributions to document this design choice. These three contributions are: “Run Experiment”, “Change something” (adding “the direction of the force”) and “Observe what is happening” (adding “the ball moves upwards in high speed”, which was the outcome they observed when changing the direction of the force).

The students move back to the microworld and change once again the direction of the force vector, giving it a 180 degrees direction (Figure 5).
Figure 5: The students explore what happens when giving the Force vector a 180 degrees direction

Just before “Running this Experiment”, they go to FreeStyler and add the same three contributions. This time the comments in the “Change something” contribution are more detailed, as they also insert information about the exact direction given to the Force vector (“make it go to the left”). The students also add the “Observe what is happening” contribution which they complete after going back to the microworld to run the model.

After running the model, the students return to FreeStyler to record the outcome they observed from the simulation generated (“the ball moves in high speed to the left”).

Once again, however, the game that the students of Group A try to create has a disadvantage that can’t be ignored: the balls move in really high speed which makes it practically impossible for the others to play. Having to make another design choice, the students try out making the Force’s vector vertical with a 270 degrees direction once again. As this seemed to work just fine and the juggling of the balls became again a manageable task, they place in the FreeStyler the exact same set of cards (“Run an Experiment”, “Change something” and “Observe what I happening”) explaining that when the direction of the Force is vertical and downwards, the simulation generated makes the balls move in the opposite direction to the one set to the vector of the force. To make sure this idea works, the students go back to the microworld and try this design choice for the vector of the Force by placing the balls in different initial positions to make sure the students of the other Group will be able to play the game.

Figure 6: The three sequences of contributions from the map the students of Group B created to explain their actions with the microworld and the outcomes observed when attempting to create a Juggling game (students’ additions to the predefined contributions are in italics)

The students of Group B also take their time in playing the initial game, making no changes to the default direction of the vectors controlling the field’s force and the velocities assigned to the balls. After a while, and in order to address the problem of designing a game for the other Group to play, the students move to the FreeStyler environment so as to create a Plan on how they will work. Without first systematically experimenting with the microworld’s vectors, the students immediately add four...
types of contributions on FreeStyler’s interface: the “Make hypothesis”, the “Run the Experiment”, the “Observe” and the “Explain” contribution. Going back to the microworld, the students manipulate the Force vector and run the model to observe the outcome of their actions. In order to report this process, the students also add in FreeStyler’s interface the “Change” contribution and explain that the change they made was to “the force applied to the ball by the hand”. The also assert that what they “Observed” was that “the ball went away” and “Explained” this behaviour as a result of “changing the magnitude of the force” (Figure 7).

Figure 7: The students manipulate the Force vector and run the model. The ball is lost from the available simulation space.

The students re-open the microworld to recover the initial size and direction of the force vector and this time instead of increasing the magnitude of the force, they choose to substantially decrease it. They try a series of smaller values for the Force’s magnitude both in the 90 and 270 degrees direction and manage each time to play the Juggling game without much effort. To make, however, the game a bit more difficult for their peers to play, they also try the 180 degrees for the Force vector’s direction. Unfortunately, their choice makes the ball move to the left in high speed and to eventually disappear (Figure 8).

Figure 8: The students manipulate again the Force vector and run the model. The ball is lost from the available simulation space.
The students report their actions with the microworld by adding in the FreeStyler interface once again the “Make Hypothesis”, the “Run the Experiment”, the “Observe” and the “Change” contribution. This time, however, the additional information they provide for each contribution seems to be more detailed, especially when it comes to the hypothesis formed, the changes made/actions tested in the microworld and the observed outcome. Although, the students of Group B during the previous round of their experimentations with the microworld, had made a hypothesis that was quite generic (“I make a hypothesis on what is going to happen”), this time it seems that their hypothesis become more specific since they refer both to the action to be tested and to the outcome to be observed (“I make a hypothesis that when I will move the vector to the left (on the X axis), sooner or later, the ball will move to the left”). Similarly, the reference to the action tested when “Running the Experiment” is more precise since in the “Change” contribution, the students particularly focus on the “direction” of the Force (“I change the direction- turn it to the left”) and not just to the “force applied to the ball by the hand”. To explain the outcome observed after implementing this action, the students in the “Observe” contribution choose to insert one more physical quantity: the “time”, which is considered to be one of the fundamental concepts in kinematics (i.e. “eventually – after some time”) (Figure 9).

Figure 9: The map the students of Group B created to explain their actions with the microworld and the outcomes observed when attempting to create a Juggling game (students' additions to the predefined contributions are in italics)

The final form of the map created inside FreeStyler comes when the students connect their contributions to each other. However, they choose to preserve two separate sections inside their map, each one corresponding to a different round of their experimentations with the half-baked microworld. The two different sections of the map contain just about the same predefined contributions (“Make hypothesis”, “Run the Experiment”, “Observe” and “Change”), which are structured in just about the same way, creating a kind of a repeated pattern of actions to be taken when working with the microworld. The difference between the upper and the lower section of the map seems is situated at the supplementary information added by the students inside their contributions to explain the particularities of their actions and the details of the outcomes observed. At the lower part of the map, the students seem to take a more elaborated stance in their explanations, which seems to be fed by their gradual understanding of the Force as a vector physical quantity. In the first round of their experimentations, the students focus on the magnitude of the Force and explain the simulation generated without taking into consideration that they also had changed the direction of the Force (Figure 7). In the second round of their experimentation, however, the students try out different magnitude values of the Force for different directions. Considering making the direction of the Force 180 degrees a good design choice for their game, the students report on their FreeStyler map the outcome they observed for this action.
6 Discussion

In this paper, we attempt to study the students’ game modelling processes as they work with a half-baked microworld designed for constructionist learning and identify their connections to inquiry learning activity stages. To do so, we initially asked the students to watch a video in which a performer was juggling two balls and then create a Plan to describe their course of action in designing a similar game. To create their Plan, we provided students with a set of predefined contributions that represented the Activity Stages used to describe students’ actions when engaging in inquiry and model-based inquiry learning. The students created a Plan in the FreeStyler environment using the majority of the available contributions and added supplementary comments to further explain their ideas. In the second phase of the experimentations we gave students the Juggler half-baked microworld (Kynigos, 2007). Being incomplete by design, game half-baked microworlds invite students to deconstruct the model underlying the game and reconstruct it to create a new game according to their own conceptualizations. To report on their actions when creating a new game to give to their peers to play, we also gave students a pre-defined set of contributions that were considered to relate more to constructionist learning processes than to inquiry learning processes. The students could choose any of those constructionist learning contributions and add any information they considered necessary to describe their actions with the microworld and the outcome these actions generated.

Taking a look at the maps the students created to report their actions with the game microworld, it seems that the contributions that they chose to use were mainly the: “Make hypothesis”, “Run the Experiment”, “Observe” and “Change” contributions. The students of Group A performed several experimentations with the half-baked microworld in their attempt to find a direction for the Force vector that would make the game to be given to their peers quite difficult to play. Their investigations were reported each time in FreeStyler using first the “Run the Experiment”, then the “Change” and finally the “Observe” contribution. The “Run the experiment” contribution in this sequence, however, serves more or less as an opener, as it is placed first in the row so as to signify the general activity within which the “Changing something” and “Observing the outcome” actions are included (i.e. Run an Experiment: that means first “Change” something and then “Observe” the outcome). Similarly, the students of Group B also used the “Run an Experiment” contribution in both sections of their map, before the “Change”, “Observe” and “Explain” contributions.

Matching the “Run an experiment” contributions the students use in their maps when interacting with the game half-baked microworld with the “Experimenting” contributions they use in their initial Plans to define a course of action in designing a game (Figure 3 & 4), we attempt to identify the kind of specific constructionist learning activities “Experimenting” as a inquiry-learning Activity Stage entails. We view “Experimenting” in the students’ initial Plans as a generic inquiry activity that includes specific actions which were revealed only when the students engaged in actual game modelling activities. Looking at the maps the students created to report their modelling activities when experimenting with the microworld, it seems that these specific actions are: “Change” something, “Observe” and “Explain” the outcome generated. We consider these specific processes actual parts of the general “Experimenting” Activity Stage that appears in the inquiry-based learning cycle. Moreover, as the students’ experimentations with the microworld evolved and each time the outcome of their previous tryouts fed the next ones, it also seems that the “Change” something, “Observe” the outcome and “Explain” sequence repeats again and again making the “Experimenting” Activity Stage an iterative one as conclusions turn into new hypotheses inducing new explorations.

Our interest also lies in identifying how students’ game modelling activities with the half-baked microworld provided them opportunities to evolve their conceptual understanding regarding motion in a Newtonian space. Taking a look at the Plans that the students initially created to describe their course of action in designing a Juggling game (Figure 3 & 4), it seems that their understanding of the what they needed to do from a physics point of view restricts in “Building” a “model”, which they would then “Observe” and “Evaluate”. However, the use of the word “model” in their maps is not escorted by any references to concepts or relationships between concepts related to motion in a Newtonian space. These come into play at the second phase of the study where students explore the half-baked microworld and attempt to create a new game for their peers to play with. At this phase the students, engage in a number of investigations mostly about the role of the Force in the model created. The students of Group A working rather systematically change the direction of the Force vector and record
the outcome of their actions for 90, 180 and 270 degrees of direction before selecting the 90 degrees as an appropriate game choice.

The students of Group B add more supplementary comments in their contributions and the evolution of their understandings is better illustrated in their map. These students initially view Force as a scalar quantity and, although they change both the magnitude and the direction of the Force vector, they explain the outcome of their actions taking into consideration only the magnitude of the Force. Trying different values for the magnitude for different directions of the Force vector the students come to add a set of contributions in their map in which they specifically refer to the direction of the Force vector as an important element in explaining the outcome generated. The supplementary information added by the students inside their contributions to explain their actions seem to become more precise and detailed as -through their exploration with the microworld- they gradually come to perceive Force as a vector physical quantity. Moreover, it seems that their understanding of the concepts and rules embedded in the underlying model starts to include not only the visible and directly manipulable variables (Force and initial velocities), but also concepts such as "time" which are not operationalized in variables but constitute an integral part of the simulated phenomena.

In this paper we focused at students’ constructionist modelling activities as they collaboratively work with the Juggler half-baked microworld. The model underpinning the Juggling game was presented to them as questionable and malleable with respect to the rules underlying the behaviours of the objects and the effect the available manipulable variables had on it. The students addressed this activity as in groups and immersed in a series of investigations in order to change the models’ functionalities and create a game for their peers to play. The group learning processes in which the students engaged related to meaning generation regarding concepts such as velocity, force on an object and gravity and to the collaborative construction of activity maps in which the students depicted the course of action to be taken when designing a juggling game and reported of the actual actions put into test when creating a game using the half-baked microworld. The development of group cognition aspects as a result of the students’ mutual engagement with the two different kinds of shared artefacts (i.e. the models and the activity maps) and the ways it could result in progressing students’ conceptual understanding with regard to science concepts remains an issue that needs to further researched.

Acknowledgements


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The place of game-based learning in an age of austerity

Nicola Whitton
Manchester Metropolitan University, UK
n.whitton@mmu.ac.uk

Abstract: Digital games have the potential to create active and engaging environments for learning, supporting problem-solving, communication and group activities, as well as providing a forum for practice and learning through failure. The use of game techniques such as gradually increasing levels of difficulty and contextual feedback support learning, and they can motivate users, using challenges and rewards, competition and mystery. Above all, computer games provide safe spaces in which learners can play, explore, experiment, and have fun. However, finding appropriate games for specific educational contexts is often problematic. Commercial entertainment games are designed for enjoyment, and may not map closely to desired learning outcomes, and the majority of educators do not have the time or specialist expertise to create their own games. Computer games are expensive to purchase or produce, and learners, particularly busy adult learners, need to be convinced of their effectiveness. So while there are many theoretical benefits to the use of computer games for learning, it given the increasing economic constraints in education, their use may simply not be practical.

This paper presents three alternative ways in which the theory and practice of computer games can be applied to education, without the expense. First, the option of developing simple and cost-effective games with low technical specifications, such as alternate reality games, or using virtual worlds or one of the growing number of accessible game-builder toolkits to create educational games, will be explored. Second, learning from games rather than with them is discussed, examining game techniques that naturally enhance learning, and embedding those elements in traditional teaching practices. Third, the paper presents the option of giving learners agency as game creators rather than simply players, so that it becomes the process, not the product, which facilitates learning. The advantages and drawbacks of each approach are discussed, looking at both practical and pedagogic issues. In this way, the paper aims to offer alternative ways of thinking about the potential of digital games for learning, and present possible solutions to the increasing financial constraints that face the field.

Keywords: budget constraints, alternative approaches, game development, theory

1 Introduction

There is a great deal of evidence that digital games have the potential to support learning in a variety of contexts, from primary and secondary schools (e.g. Bottino & Ott, 2006; Suh et al, 2010; Watson, Mong & Harris, 2011), to universities (e.g. Connolly, Stansfield & Hainey, 2007; Ebner & Holzinger, 2007; Whitton & Hollins, 2008), adult education (e.g. Kambouri et al, 2006) and workplace contexts such as military training (Fong, 2004) and medical practice (Mann et al, 2002). Digital games have the can create active and experiential constructivist learning environments, which support problem-solving and collaboration, and create a forum for practice and learning through failure. Scaffolding through increasingly-difficult levels allows learners to gradually take more control over their learning and immediate, contextual feedback supports the transition from novice to expert. Games can engage different users in different ways, using a range of mechanics such as compelling challenges and rewards that demand puzzle-solving or creation of artefacts, competition, stories, working with others, and supporting the human urge to complete sets (Whitton, 2009). Above all, games can provide safe playful spaces in which learners can make mistakes in a safe environment, free from external consequences; in which failure is a recognised and accepted part of the process. Players can reflect on those mistakes, experiment, explore, build things, and create their own communities and mythologies.

Despite the many pedagogic and motivational benefits of using computer games in learning and teaching, their use is problematic in many ways. A major barrier is cost, both in terms of the monetary expense of purchasing games and associated hardware, and also in terms of time for educators to develop the skills to evaluate or create games and the activities to support them. There are also issues of the acceptability of games in formal educational contexts, and practitioners need to be convinced of the potential of the medium as well as its limitations and be confident in the use of games (Becker, 2007). In many educational settings, particularly in Higher Education, where topics become increasingly niche, commercial games – for entertainment or education – are limited because of the small potential market. Designing and developing original computer games is beyond the expertise of most teachers and lecturers, and even when a good game design idea is used as a starting point, educators often lack the technical expertise is often lacking to be able to translate the design into a working game. While excellent examples of bespoke educational game developments...
do exist, they are typically in technical areas such as engineering or computing, and are the projects of individual enthusiastic teaching staff (e.g. Yaneske, 2010).

This paper presents three possible solutions to this problem of finding or creating appropriate games for learning in an environment where increasing monetary pressures exist and budgets are becoming more and more limited. It aims to provide ideas and suggestions for educators and researchers, of alternative approaches to the use of expensive commercial games or high-end game creation. The paper will first consider the background to this issue in more detail, such as the options that are available for finding or developing appropriate games in the current financial climate, and the practical limitations of using high-end commercial games. Second, the paper will consider three alternative approaches to using games to support teaching and learning, by:

- presenting a range of tools and techniques for creating low-cost games;
- considering ways in which teachers can learn from games and apply these techniques to traditional teaching; and
- exploring the notion of empowering students as the game creators themselves.

The paper discusses the relative advantages and potential drawbacks of each of these approaches, and concludes by discussing the future of games and learning in this age of austerity.

2 Background

Worldwide, educators are experiencing the impact of the global financial crisis, with budgets greatly reduced and increased pressure to create cost-efficiencies. There is no question that learning with computer games can be expensive, particularly when it involves the development of high-end graphics or interfaces. This highlights the question of whether computer games are really an appropriate tool to be endorsing in a harsh economic climate. Obtaining or developing appropriate games for formal educational contexts is often problematic; two basic options exist for teachers who want to use digital game-based learning as a teaching tool. First, they can use (or possibly modify) an existing commercial game; second, they could develop an original game from scratch. There are benefits and drawbacks to both of these options, and both are typically expensive.

Commercial entertainment games provide top-end aesthetic quality and game fidelity, giving the look and feel of a professional game, which some argue is important for acceptance by learners. They are usually robust games, thoroughly tested, and explicitly designed to be fun and engage the player, with the benefit of professional design teams and large budgets for development. However, commercial games can be expensive, in terms of purchasing the initial software and any associated hardware. Institutional networks may also not have the capacity for installing or running applications of this nature. A second problem with commercial entertainment games is that they are unlikely to map directly to intended learning outcomes, and players may spend more time learning the game play, mastering a complex interface, or focusing on game goals than learning anything appropriate. In practice, commercial games are typically used in education for imagining possibilities, stimulating creativity or fuelling discussion, rather than teaching content directly (e.g. Squire & Barab, 2004) or for teaching low-level skills (e.g. Miller & Robertson, 2010). Many commercial games now offer the option to extend or modify the basic scenarios, which offers greater potential for mapping to curricula, and this approach has been effectively used to support learning, but again typically as a tool support general creativity and discussion rather than being used directly to teach specific learning outcomes (e.g. Robertson & Howells, 2006). This approach may be limited in terms of the range of games that offer the potential of add modifications (typically role-play and shooters) and the games may still be expensive to purchase.

There is also the potential to use commercial games that have been designed specifically for learning (e.g. Goldsmith & Hall, 2010), which offer many of the benefits of games created for entertainment, in terms of design quality, but are also designed to meet specific learning outcomes so that the game goals align with the learning goals. However, these games can still be expensive to purchase, may be difficult to customise if they do not meet the exact requirements of the learners or curriculum. They also tend to be limited to areas where there are large amounts of potential sales (e.g. generic business skills), so higher levels or more specialist learning areas are less likely to be served. Commercial games may also be difficult to customise to the practicalities of the teaching environment, and issues may arise such as the time taken to play a game segment, and the availability of suitable places to start and stop playing.
The second option, an alternative to using existing commercial games, is to design and develop original bespoke games from scratch. This allows a much closer alignment between learning goals and game design, where the learning outcomes are aligned closely with gaming outcomes for a specific curriculum and student group. The disadvantages of this approach are that a significant amount of skills and expertise is required, in terms of both game design and technical knowledge, as well as aspects like graphics design, narrative design and interaction design. Creation of bespoke games is usually the preserve of educators in scientific or technical disciplines, who have the skills to create appropriate games (e.g. Connolly et al. 2006). Even with the appropriate skills, development is time-consuming and production values are unlikely to be as high quality as top end commercial games; although it has been argued that the graphic fidelity is secondary to game play in engendering engagement (Whitton & Whitton, 2011).

While digital games for learning have sound pedagogic advantages, they also have significant drawbacks in terms of the ability of a typical teacher to obtain and use an appropriate game for a given context. As budgets decrease and less money is available generally in education – and particularly to support innovation in learning and teaching – games may become too expensive to be a viable proposition, in terms of money, time and expertise. However, there are alternative approaches to simply using commercial computer games, or building high-end games to support learning. In the sections that follow, three different approaches to game-based learning without the expense will be presented. First, the option of developing low-cost, lo-fidelity games, such as alternate reality games, or using virtual worlds or one of a growing number of accessible game-builder toolkits to create game-based learning experiences will be considered. Second, learning from games rather than with them, by examining what games are good at and how they achieve it, and looking for ways to embed those elements in traditional teaching practice, will be discussed. Finally, the idea that learning can be facilitated by giving learners agency as creators of games rather than as consumers, so that they become the developers and it becomes the process, not the product, will be presented.

3 Game development on a budget

Creating high-end games, with high technical specifications and graphics quality, to support learning is beyond the means of the majority of educators, particularly in terms of the technical skills and development time required. However, teachers and lecturers often have excellent ideas for computer-based games to enhance their teaching, and there are various other options for implementing these. One option, which is not discussed in any detail in this paper, is the use of non-digital or traditional games, such as card games and board games (e.g. Baker et al, 2003; Moseley, 2011). This option is appropriate for a whole range of classroom teaching situations and does not require technical skills beyond the production of the physical artefacts associated with the game. There is already a long history of research into the use of traditional games in education, so it will not be discussed further here since the focus of this paper is specifically on computer games.

The use of alternate reality games (ARGs) is a growing area in formal education (e.g. Moseley et al, 2009; Whitton, 2009; Connolly et al, 2011), and one that offers great potential for educators to create engaging game-based learning experiences on a budget. The emergence of ARGs is comparatively recent, and they differ from traditional computer games in that they blend real life and narrative into an ‘alternate reality’ using a variety of online and real world artefacts such as web tools, social networking sites, as well as physical objects and places. ARGs combine real-life treasure hunting, interactive storytelling, video games and online community (Borland, 2005); they merge the real world and the digital world to create an alternative version of reality, which unfolds in an overarching narrative as the game is played out over several weeks or even months. This interplay between the real world elements and fantasy narrative is one of the defining elements of ARGs, in that they ‘take the substance of everyday life and weave it into narratives that layer additional meaning, depth, and interaction upon the real world’ (Martin & Chatfield, 2006, p.6). Players work collaboratively in online spaces, and sometimes in the real world, to solve challenges, which can be puzzle-based or involve the creation of real or digital artefacts. This game format potentially provides engaging collaborative learning spaces where students can be supported to work together to achieve desired learning outcomes that map on to the game challenges.

ARGs offer numerous pedagogic benefits, such as the ability to facilitate problem-solving at different difficulty levels, and steady and ongoing progression with tangible rewards. They use of narrative to stimulate curiosity and drive the game action, and players have the agency to influence the game trajectory. Regular delivery of challenges helps to maintain engagement over time and offers space
for reflection, and there is also the potential for a large, active learning community (Moseley, 2008). The fact that alternate reality games are based on simple, existing technologies and do not require high-end production values or technical expertise to build also makes them a particularly affordable option. Previous examples of the use of ARGs in education have met with mixed success because, to some extent, of the cryptic and unfamiliar nature of the genre and its niche appeal. However, there is still a great deal of potential for this genre of games to support learning if student engagement can be supported by linking the game to assessment or a mandatory course activity.

A second option for educators who want to develop low-cost games is the use of multi-user virtual environments (MUVEs) as game environments, such as Second Life or OpenSim. There is debate within the field about whether virtual worlds can be described as games in and of themselves. The author takes the view that while they share some characteristics of games (e.g. use of an avatar, exploration in a virtual space), they are not games in themselves because they are open-ended and do not offer goals or challenges or a structure to interaction. However, virtual worlds do provide the potential for creating simple games, such as competitions or treasure hunts, within the environment; they are a space with many potential uses, games being just one. The advantage of using virtual worlds for game development is that many are free to use (although there may be costs associated with building or owning land), development is relatively quick and easy, and incorporation of communication, such as text or voice chat, is seamless. However, there may be technical issues, particularly when dealing with a range of networks, operating systems and hardware, and some students (particularly those not familiar with three-dimensional game play) may find navigation in environments such as these problematic.

A third option for creating low-cost games is the use of free, or inexpensive, digital game development toolkits, such as Adventure Game Studio (www.adventuregamestudio.co.uk) for developing point-and-click adventure games, Game Maker (www.yoyogames.com/gamemaker) that allows the creation of a whole range of game types, Inform (www.inform-fiction.org) for creating interactive fiction, and Sandbox Gamemaker (sandboxgamemaker.com) for the development of three-dimensional games. These game-builder kits are easy to obtain from the web and cheap to use. While most development environments require the user to have a basic degree of technical ability, they often have large and active online user communities to provide support where required. The use of development kits allows the swift creation of original games that, while they may not match commercial games in terms of graphic quality or fidelity, can still have effective game mechanics and be engaging for learners. While using these game development engines is still associated with a learning curve, they do make the creation of computer games a more feasible option for many educators. However, the potential of games for learning – particularly in an age of austerity – goes beyond simply using computer games as a teaching tool. Games, by their very nature, embed many techniques that facilitate learning and engagement, and the next section focuses on the lessons that can be learned from games and how they can be incorporated into traditional classroom teaching.

4 Learning lessons from games

Game-based learning is not simply about using games to teach. A second way of looking at the potential of games and learning is to see them, not as tools for teaching, but as artefacts to be studied and from which to learn. All games, digital and traditional, naturally embody a range of techniques that help to create effective learning experiences, and ways of stimulating and enhancing player engagement to create environments that are motivational, safe and free from consequences in the real world. Digital games also employ techniques that support interaction, usability and the ability of players to learn the game controls quickly and easily. The study of games in order to determine the range of techniques they use, and how to apply them learning and teaching, offers another potential way of using games for learning without massive expense.

The use of games can be an excellent way to support constructivist pedagogies through active learning and participative teaching approaches. Many games – such as adventure games, role-playing games and simulations – use techniques such as learning through problem-solving or enquiry. They provide a contextualised experience that allows learning through practice, failure, reflection, and repetition; mistake-making and experimenting with different approaches is taken for granted in many genres of computer game. Games can also promote collaboration as players need to work together on shared goals either face-to-face or virtually, in real time or asynchronously. Massively multiplayer role playing games, for example, provide opportunities for real-time team working, mentoring and development of social skills (Duchenet & Moore, 2005). Games also employ mechanisms such as
scaffolding, where lots of help and support is provided for the player at the start, which is gradually removed as the game becomes harder and the player moves from being a novice to an expert. The use of regular, timely intrinsic feedback allows players to see the immediate consequences of their actions and keeps them constantly informed as to their progression through the game.

As well as embodying elements that support active learning, games also employ a variety of techniques for enhancing engagement and keeping players immersed, which could also be employed within learning and teaching situations. These techniques include the use of a structured environment, with clear and meaningful goals, and challenges that are suitably difficult yet achievable. A framework of rules or constraints, with appropriate rewards, such as moving up a level, achieving a place on a high score table or gaining a new artefact or ability also supports ongoing motivation to play. Devices such as competition with other players, stimulation of curiosity through exploration and the discovery of mysteries or secrets, also contribute to engagement. Many games also tap in to the human urge to complete things and collect sets, such as finding all the possible artefacts or finishing a jigsaw, which is another way in which to hook the players and keep them involved in the game.

A crucial aspect of games, particularly in relation to their potential for learning, is that they provide safe and playful environments in which failure is an accepted part of the game dynamic, and learning through mistake-making is the norm. Players do not necessarily expect to complete a game on the first attempt – in fact, that might even be boring – but to re-assess strategies and try again. Games also provide a place for players to have fun, relax and release tension and typically provide environments that are safe from external consequences (although there are some notable exceptions here, such as professional sports), in which players can do things in fantastic or non-realistic environments. This raises the question of the extent to which games for learning can use in-game assessment (where performance in the game directly influences a formal mark) without losing the important safety aspect of the game. In games, players have control over their own actions, the ability to make flexible decisions, freedom to explore the game environment and discover a wide range of potential options, paths and directions within the game. Many games allow players to make a further leap out of the real world with narratives, characters and plots, and often the ability for players to engage further through the creation of their own narratives or digital artefacts.

While there are some aspects of all games that could potentially be studied and applied to traditional teaching, there are also some that are specific to digital games. Computer games can teach a lot about successful interaction design, which could be applied to the design and development of online learning and teaching experiences. This includes the effective use of visual and auditory media, such as pictures, graphics, animation, video, and sounds, and appropriate ways in which to use multiple media in a single environment. Games can also exemplify excellent interaction design such as the ways in which players access game functions, game usability and user-centred design. There is also much to be gained from the study of learnability of game interfaces, as game players will typically not engage with manuals or tutorials but want to start playing the game straight away; discovering the options available in a game environment is often half of the fun of playing the game. Further study of what makes gaming interfaces usable and entertaining and how this could be applied to online learning interfaces, as well as how to apply more general game principles into traditional teaching and learning would allow educators to learning from what is good about digital games without the expense of high-end development.

5 Learning by building games

In the field of game-based learning, there has been growing interest in recent years in the use of games to support students to learn by developing or creating games for themselves, rather than simply being players of games (e.g. Korte et al, 2007; Al-Bow et al, 2009; Lim, 2008; Robertson & Howells, 2008). This is an approach that many learners, particularly school-age males, are likely to be enthusiastic in developing and has the advantage that it gives learners greater agency and control over the process of game creation, supporting them to learn a whole host of associated design, planning, communication and teamwork skills.

Game creation can be long and complex, requiring a variety of technical and design skills. Prensky (2008) argues that there is a fundamental difference between ‘mini-games’, which are simple, focused and take less than an hour to play, and ‘complex games’, which are the typical large-scale commercial game, rich and multi-faceted, with many hours of game play. He says that mini-games are more appropriate for education games, particularly those developed by learners because the “design of
mini-games is relatively simple, and is often easily borrowed from other mini-games. Game construction takes a couple of months at most, and testing is relatively easy." (p1006). While this approach provides a realistic option for development by learners, and may be valuable for supporting learning-by-development, these games tend to be based around knowledge-acquisition and other low-level learning outcomes, and do not make full use of the potential of games as constructivist learning environments. Game design for learning has been used effectively, however, Lim (2008) argues that using game-based learning or students as game designers within traditional institutional frameworks will be ineffective because “computer games challenge the prevailing culture of schools where externally determined knowledge is packed clearly for teachers to dispense to their students. If bringing games into schools merely reproduce these power relations or knowledge transmission, it is unlikely going to be any significant increase in learning engagement among students." (p1002). He suggests that fundamental changes such as redesign of the curriculum to focus on key questions, re-structure of timetables, and a focus on assessment for learning (rather than assessment for evaluation) are necessary before game development can truly support learning.

The easy availability of game development tools and modification engines (such as the selection described in section 3) make the development of games by learners a feasible option, but still some level of technical and design expertise is required by students, as well as confidence by teachers to support teaching in this manner. A further drawback of this approach is that it will be time consuming, require a great deal of commitment on the part of both teacher and learners, and will only be suitable in a limited number of contexts where it is possible to meet the desired learning outcomes through the process of game development. While using the model of learners as game creators can be a very effective pedagogic tool, it is applicable to a limited number of curricula, and the institutional infrastructure needs to be in place to make this approach effective.

6 Conclusions

This paper has presented three alternative ways of approaching game-based learning, beyond the more usual models of using commercial or enthusiast-developed games in formal teaching situations. Finding, or creating, appropriate games for specific learning situations is one of the main difficulties of game-based learning, particularly when learner numbers are relatively low and value-for-money is an objective. Games can be shown to be a very effective way for students to learn, but not necessarily an efficient one in terms of the expense of creation and deployment. The three solutions offered in this paper are not presented as the only alternative options, but are intended to encourage game developers, educators and researchers to think beyond the more typical ways of using games for learning.

Of course, each of the possible solutions discussed here is not without its disadvantages. While the possibility of developing low cost games is tempting in terms of the lesser expense in buying development software, they may still be expensive in terms of the time taken to develop. The process of creating a good game, even if the actual development cost is ignored, is long and involves creativity, specialist skills, and comprehensive testing. The process of designing any game that is fun to play and appropriate for learning is never easy – whether it is a high-end digital game or one played with pencil and paper. Getting that balance right takes practice, play-testing and a willingness to ‘go back to the drawing board’. Other specialist skills may also be needed in the design and development process, such as graphic design, narrative design, or interaction design skills, even when low cost or accessible development software is used. There is always the possibility that low cost games, or amateur designs could put learners off, although this is debatable and arguable that learners do not compare the aesthetic quality of learning games with high end entertainment games, they compare them with traditional learning activities (Whitton & Whitton, 2011). A final drawback is particularly associated with the ARG format (but holds true for any emerging game genre), which may be unfamiliar to many learners, and therefore may have a steep learning curve just to get students to appreciate and accept the philosophy and mechanics of the game – before they even engage with the intended learning outcomes.

The idea of learning from games, identifying what they do well and how this could be used in education is also problematic in some ways. There is a danger that the use of game techniques, particularly simple techniques such as scoring, prizes or the use of high score tables (sometimes called gamification) may be seen by learners as trivialising learning, or put an emphasis on meeting game objectives without learning. This approach focuses on game techniques that support extrinsic motivation, while those that support intrinsic motivation to play can have a more profound effect. The
lessons learned from games need to be deeper and richer, looking at the underlying motivational and pedagogic lessons, and further research is essential to ensure the appropriateness of these techniques in an educational setting. This is the case in terms of the perceptions of the learners, as well as teachers, and in relation to the pedagogic value created. It is also crucial to remember that while some elements of games may be motivational for some, this might not be the case for others; in particular, things such as the use of competition and fantasy may have limited appeal. There are also issues with the approach of learners as game creators. This method may only be appropriate in certain circumstances, for certain curricula elements and with certain groups of learners. While some learners may find game creation intrinsically motivational, it is crucial not to forget that others will simply not be interested. This pedagogic approach will also require additional skills from the learner – such as teamwork, negotiation, planning and time management – and from the teachers – such as trust and willingness to move from being the holder of knowledge to the role of co-learner.

While there is evidence that computer game based learning can be an effective tool for creating active learning and teaching experiences, and engaging students in safe and playful spaces, the costs associated with obtaining, or developing high-end games may make their mainstream use prohibitively expensive, particularly in an increasingly-difficult economic climate. This paper has aimed to suggest other ways in which games can be used to support and enhance learning, beyond simply using them as vehicles for learning. There are certainly other approaches to the issue of how to lower the expense of game based learning in a difficult economic climate, but this paper hopes to open up the discussion in this area and encourages people to bring new ideas and thoughts into the forum. In this way, through conversation and the sharing of ideas, it is hoped to make learning with digital games a more accessible option for a wider range of educators.

Practitioners, researchers and policy-makers in the field of digital game-based learning need to rethink the true value of games, and focus on instances where they add significant value to a learning experience. The cost-effectiveness of games needs to be taken into account, and evaluations of game-based methods need to take this into account as well as simply considering the pedagogic effectiveness of the approach. Digital game-based learning should be used when appropriate, and seen as another tool in the educators’ toolkit, rather than a solution that can necessarily be implemented into the educational mainstream. The three solutions outlined in this paper offer alternative ways of thinking about the potential of digital games for learning, beyond the model of big budget commercial games. The low-cost ways in which teachers and lecturers can build their own games, to support their own practice and students, could be used to build up an evidence base of examples of innovative practice. It could also be used to provide examples of when games are less successful, so that the community can learn from mistakes without the political imperative of justifying large amounts of money invested by always telling a success story. However, the use of digital games in education also has to move beyond simply using games to teach content, but using the elements that make computer games, and their design, effective for learning and engaging educators to reconceptualise and re-think the practice of learning and teaching as a whole. A move from didactic content-focussed pedagogies to collaborative co-construction of knowledge is essential to support learners to gain the critical thinking and information literacy skills they will need for the future, and games (as well as other innovative pedagogies) can be a key tool to underpin this transition. In conclusion, this paper aims to offer alternative ways of thinking about the potential of digital games for learning, and present possible solutions to the increasing financial constraints that face the field of education.

References


