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Table of Contents

1 Introduction

This document reviews the state-of-the-art in conceptual models that underpin serious games. It does so to provide a framework specific to ALICE for the combination of game and pedagogic elements to create an intuitive guided learning experience, applied within a civil defense game simulating a building evacuation, developed as a case study within WP4. In Section 2, this report discusses the manner in which serious gaming has rapidly gained prominence as an area of academic and commercial interest, as a result of two hypotheses increasingly proven by emerging evidence: that serious games possess an ability to stimulate intrinsic motivation, allowing games to reach demographics unresponsive to more conventional training methods, and that the addition of gaming elements to simulator-based training results in increased learning transfer over more traditional approaches which emphasize realism at the cost of learner engagement (Mautone et al., 2008). However, due to a lack of clear standards and guidelines for game developers, and a paucity of research in the area, it is frequently difficult to justify claims that a specific game meets the learner's requirements and/or expectations. In order to address the problems caused by unclear standards and to hence accurately and objectively consider the outcomes of the research programme within ALICE, this document considers not only the conceptual models that must underpin the design of serious games, but also their evaluation.

As a result of this consideration, the authors evolve the various methodologies presented in Sections 3 and 4, to address the requirements of serious game design and evaluation within the ALICE project. In Section 3, we also introduce the notion of intuitive guided learning, and its relationship to existing pedagogy. A framework is presented in Section 5, which combines a review of learners, context, representational medium, and pedagogy whilst advocating iterative, user centric design to provide a conceptual backdrop for prototype work within the project. The framework highlights the need not only for comprehensive user testing, but also careful consideration of the tension between engagement and instruction, and the identification of areas in which design flexibilities or constraints exist. Section 6 introduces a pedagogic model for intuitive guided learning building on established theories of learning and used to underpin development of the initial prototype.

Section 7 outlines considerations arising from experimental work with this prototype in two Italian schools, by consortium partner MOMA. These are fed into a methodology for intuitive guided learning in serious games, introduced in Section 8 through a combination of the literature reviewed in Sections 3 and 4, with the frameworks presented in Sections 5 and 6, in light of the experimental results in Section 7. Key considerations presented are how the individual aspects of an intuitive learning experience are fulfilled in a game-based learning environment, and how such an environment can be developed and blended with existing resources to create an effective solution. To assist with the implementation of these principles in practice, Section 9 outlines a range of implementation guidelines highlighting key considerations. Section 10 then discusses practical constraints that any designer seeking to implement such an intuitive-guided approach is likely to face, as well as how short term methods for overcoming these issues should also be reflected in longer-term research and policy objectives. Finally, Section 11 concludes the report by reviewing its findings and advocating future work to develop both pedagogic understanding and technical capacity for realizing intuitive guided learning approaches.

This task has been led by COVUNI. The content of this document represents the fulfillment of Deliverable 4.1.2 by the ALICE consortium.

2 Background

Before analyzing the design and evaluation methodologies described in the substantial literature, it is essential to address the wider question of why serious games are increasingly being considered as solutions to a wide range of challenges in modern education and training. Though the concept of a serious game is already well defined (Zyda, 2005), we first consider the various usage contexts and application areas in which game based learning has met with success, and relate this to development within ALICE through a series of case studies. This includes both the civil defence scenario developed as a prototype within WP4, and the concept of a virtual scientific experiment, of particular relevance when developing complex collaborative learning objects (CC-LOs).

2.1 Defining a serious game

Through the early days of simulation and gaming, the concept of using game design approaches for non-leisure applications steadily emerged. The broadest definition of a serious game, therefore, is perhaps best defined as a game played for a purpose other than entertainment. (Zyda, 2005) provides a broad-stroke definition of a serious game 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’. Yet as games evolve and the market expands, this definition is increasingly struggling to encompass the wide range of solutions being created. Platforms for serious games no longer are restricted to a desktop PC, with the rapid emergence of mobile gaming and cloud computing supporting a new range of mixed reality serious games (Doswell et al., 2006). The nature of the contest at the heart of a serious game is also diverging, to include player-to-player interaction as well as more sophisticated synthetic characters and artificial intelligences.

Figure 1 illustrates a sample of 30 serious games grouped according to two criteria:

- **Linearity** - can the player explore the game world freely, as opposed to a sequential structure driven heavily by scenarios, missions, objectives, and barriers? At the linear end of the spectrum are games that are click-through expositions of content, with little potential for failure or success on the part of the learner. A progression can be observed through branching scenarios, which allow multiple outcomes to a scenario, to emergent and ‘sandbox’ gameplay models, where the learner is provided with an environment and little else, and then proceeds to construct their own activities.
- **Fidelity** - to what extent does the game tries to recreate the real world (a simulation)? High visual fidelity can bring expectations of high functional fidelity, as immersed players begin to expect the virtual world to behave as the real one (Pausch et al., 1997). This can play into user expectations of non-linearity, as the real world is not linear: several clichés of virtual worlds such as the prevalence of locked doors, conveniently placed crates, and invisible walls can break the sense of immersion, and thus care in their placement is a pedagogic as well as aesthetic concern (Cliburn et al., 2007).

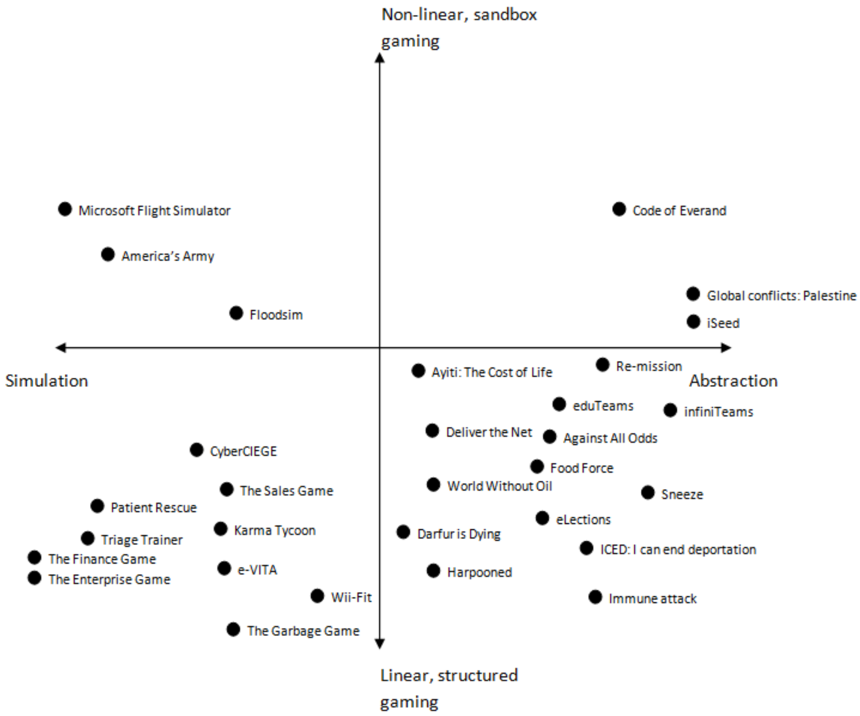

Figure 1: A sample of 30 serious games grouped by fidelity and linearity (See Annex I for reference links)

As can be immediately observed from Figure 1, the majority of serious games tend towards linear structures. A strong potential explanation for this is the cost implication of non linearity: the majority of games tending towards this approach typically have budgets in excess of €2m (including America's Army, Microsoft Flight Simulator, and Code of Everand). Non-linearity requires more content, and also implies that few users will experience all of the content that is created, placing a requirement on the educator to ensure pedagogic objectives can be universally met as learners diverge through the game. However, the benefits of non-linearity emerge through the ability to support alternative pedagogies: Code of Everand, a serious game developed by the UK Department for Transport to address road safety in the 10-15 age range supports social and collaborative learning through the adoption of a massively multiplayer online (MMO) approach, applying elements of social learning theory (Bandura, 1977). America's Army also uses community aspects and peer-groups of players towards its behavioural goals (Zyda, 2005). As technology advances, game engines are increasingly reducing the costs of both fidelity and linearity (Petridis et al., 2010), and hence consideration of such approaches is gaining increasing interest.

Yet despite the potential for more open game worlds to support innovative pedagogies, the majority of serious games are more tightly structured. Again, this is partly a reflection on available budget, but also a basis in instructional theories which caution against the potential for learners to deviate, unchecked, from the learning path (Egenfeldt-Nielsen, 2005). The lowest budgetary requirement for game development is the creation of abstract and structured games, which are deployed via the web through browser-based mediums such as Flash[1], or less commonly as standalone downloadable executables. The advent of mobile gaming has seen these platforms also gain interest for serious applications, with

[1] http://www.adobe.com/flash

mixed and augmented reality games applied for purposes such as cultural heritage (Anderson et al., 2010).

A final relevant note when considering the definition of a serious game is that the definition is often tied to intent rather than proof. Noting the relatively large sample of games listed in Figure 1, few have empirical research attached demonstrating their efficacy, with the notable exception of clinical trials of Re-Mission (Kato et al., 2008) and Triage Trainer (Knight et al., 2010). Several have qualitative studies attached which analysed usage statistics, for example FloodSim (Rebolledo-Mendez et al., 2009), though whilst these evidence good reach to their target demographic, their proof of efficacy is limited by available sample and the difficulty in measuring behavioural outcomes. Definition by intent rather than evidence is not unique to the sector, as terms such as 'educational materials' are often applied to items which in the absence of a broader learning process are unlikely to result in meaningful education – an issue whose resolution has led to the recent drive to encapsulate pedagogy within learning objects (LOs). Broader uptake of serious games and the larger development budgets required to create more non-linear and high-fidelity experiences which combine technical and pedagogic innovation implies a need for evidence on which business cases for serious game development can be formed, and therefore in the authors' view, adequate proof of efficacy is a necessary component of a successful serious game.

2.2 Why use a serious game?

Having discussed the nature of serious games, this section goes on to consider why they have stimulated such interest from the education community. The most obvious advantage of electronic gaming is its **ability to foster intrinsic motivation,** in part due to the widespread popularity of the medium in a recreational context. A recent survey by the Interactive Software Federation of Europe (ISFE, 2010) showed 25.4% of adults[2] had played an electronic game in the previous 6 months, demonstrating the prevalence of gaming across Europe. This ability to engage and stimulate involvement in learning processes is a major influencing factor on the selection of game-based learning as an educational medium (Gobet et al., 2004), and has been used in a range of areas such as public health to reach demographics unresponsive to more formal means of education. An intrinsically-motivated learner has clear benefits for educators when compared to one driven by extrinsic motivation (Lin, 2007): they require less investment in guidance and support, tend to go beyond material immediately presented and learn with a greater degree of breadth, and engage more readily with the flow experiences (Cziksentmihalyi, 1997), due to the reduced impact of psychological constructs known to detract from flow, such as boredom, apathy, or anxiety. Conventional approaches to fostering intrinsic motivation amongst learners engaging with static training materials require learners perceive a clear benefit from engagement, which is increasingly difficult to establish, particularly amongst younger audiences, in an assessment-driven culture.

However, the benefits are game-based learning are not limited to the appeal of gaming to a wide audience. Electronic games present a number of pedagogic capacities unlike more conventional forms of instruction:

- **Immediacy of feedback**. Games typically convey feedback to learners rapidly, and as a component of the overall gameplay mechanic. The timing of feedback is an often debated element of instructional design, for example with the serious game *Triage Trainer* a comparison of feedback methods found increasing frequency resulted in more effective learning transfer (Jarvis and de Freitas, 2009), clearly identifying the importance of this variable, but few studies

[2] n=73,400; see ISFE 2010 for details on regional distribution

have been able to provide generalisable recommendations for the speed and immediacy of feedback. The authors have also previously explored the format of feedback, suggesting games have the potential to provide an 'evolutionary' feedback model (Dunwell et al., 2011), which allows the learner to explore the potential implications of their actions through exploratory learning (de Freitas and Neumann, 2009). In this case, one of the strengths of game-based learning, particularly for games whose basis is in simulation, is the capacity for the player to take the wrong action, even deliberately, and observe its consequence. Whereas more conventional forms of education often present ideal situations and methodologies, an evolutionary, 'sandbox' approach to gaming has the potential to allow the learner to explore multiple solutions to problems and conclude on their efficacy. Hence, higher order cognitive skills development (with higher-order as defined by (Bloom et al., 1957), can benefit from the capacity for learners to explore different approaches whilst receiving feedback which is both instantaneous, for example the reactions of virtual characters, and also delayed into pedagogically-driven summaries or reports.

- **Introduction of competitive elements**. Such elements are typically unexplored or avoided in more conventional pedagogy, for example Goodman (Goodman and Crouch, 1978) suggest competition in a conventional educational setting leads to anxiety and reduced learning enjoyment. However, it has equally long been recognized that competition is a powerful element of educational gaming (Fisher, 1976), and converging traditional pedagogy with entertainment gaming requires both sides of this discussion be evaluated. Lin (Lin et al., 2010) describe the impact of competition in terms of motivation, showing a strong positive effect on learner motivation through the use of a game-based approach. A pivotal consideration in stimulating this motivation, whilst avoiding the negative consequences well-defined by Goodman and Crouch (1978), appears to be a need for a degree of abstraction between game performance, and real-world ability. If learners fail to make this link, then their view of 'losing' the game becomes tempered by their perspective of its significance. Effectively, the less well-scaffolded the transfer from virtual experience to real world learning outcome is, the more effectively competition can avoid the negative impacts described by traditional pedagogic theory. This presents something of a conundrum for serious game designers: on the one hand, well-scaffolded transfer of virtual learning to the real world is essential for behaviourist pedagogy to function (Parker and Becker, 2003); on the other, the more effectively learners relate the game to real-world ability, the more likely they are to negatively perceive competition (Goodman and Crouch, 1978). However, the difficulty in creating this scaffolded transfer has often led to the conclusion behaviourist pedagogy is problematic as a basis for game-based learning, and that situative or cognitive models are broadly more effective (Egenfeldt-Nielsen, 2005). With such pedagogic approaches, several mechanisms can be implemented to create effective learning transfer without compromising game elements; competition can run parallel to the learning process to stimulate engagement without affecting pedagogic content.

- **Capacity for autonomous assessment.** Serious games have the capacity to track every user interaction, and therefore possess an intrinsic capacity for detailed assessment of the interactions of the learner with the game. However, effective assessment must blend this interaction into a broader evaluation of the impact of the game on learners, and furthermore, this assessment must then be fed-back in an appropriate fashion (Shute et al., 2010). Game engines are a rich source of data on user interactions (Calvillo Gamez et al., 2010), and if this can be harnessed to understand learners, the potential to provide detailed assessment autonomously exists. Previously, the authors of this report have considered the relationship between the type of feedback conveyed to the learner, and the technological sophistication required to achieve it (Dunwell et al., 2011). This led to the conclusion that to ensure a fully effective feedback model, some degree of blending into the curriculum was necessary. Through a game engine can provide interpretive and, through AI, even probing feedback, provision of understanding and supportive feedback remains largely restricted to educators and peers for all but the simplest tasks. However, as technology continues to evolve, and evaluations demonstrate the applicability and requirement for the various levels of feedback, it is possible to suggest compromises which allow for feedback to be completely automated whilst still ensuring, by rigorous evaluation, that learning transfer is facilitated.

- **Support for novel realisations of pedagogic approach.** Problems yet to be solved in learning theory, particularly those centered on effecting long-lasting behavioural change, require novel adaptations and implementations of existing pedagogy to approach a solution. Though game-based learning is by no means the only method for implementing such novelty, given the aforementioned capacity to stimulate intrinsic motivation, it is a compelling medium for pedagogic research. A key issue with more conventional forms of education is a difficulty in engaging and sustaining interest from learners, an issue particularly prevalent in younger age groups (Chiong and Shuler, 2010), as the media they experience and interact with during their school time becomes increasingly removed from their leisure time. Game-based learning, by comparison, seldom has issues in engaging learners - provided the nature of the game has not been compromised by instructional content - and therefore shifts the emphasis to ensuring effective learning transfer is still occurring across the change in representational medium. Serious games thus have the potential to effectively turn a key issue in education on its head, morphing a problem of effective engagement into a problem of effective instruction.

These key conceptual benefits of serious gaming have seen the sector expand rapidly over past decades as academia and industry have been eager to realise them in practice.

2.3 Critical success factors

Assuming the benefits of games listed in the previous section, a logical next-step is to consider how best to ensure they are achieved in the context of the development of an individual serious game.

- Realistic appreciation of timeframes. Serious game development is commonly undertaken to similar timescales as leisure games, or other e-learning interventions. Yet they are unique in their need to marry the two complex and often contradictory elements of education and entertainment. For reasons we detail in Section 3, multiple iterations of user testing and subsequent adaptation are essential, rather than desirable, components in the creation of a successful game.
- Accurate evaluation of impact. In particular, games deployed as standalone interventions have been evaluated primarily in terms of the number of players experiencing the intervention, rather than through a rigorous assessment of learning transfer. This is particularly true in the case of games which seek to foster behavioural change, since such change is notoriously hard to quantify, isolate, and evaluate. The factors behind this difficulty can range from differences in self-reported and actual behaviour, through to the long-term nature of behavioural change and subsequent need for longitudinal study to prove efficacy. In practice, some degree of compromise must be reached between assessing and understanding learner response to the game and the practical limitations of real-world research; however, this must not overlook the core issue that a large player base alone is not an accurate indicator of serious impact.
- Iterative design and user testing. Again detailed more in Section 3, it is essential that time be allowed for evaluatory work to feed into design.

Having identified some high-level benefits and best-practices in serious game design, the following two sections (2.4 and 2.5) go on to cover two specific application areas: civil defense, and virtual scientific experiments. These are selected as particularly relevant application areas towards the objectives of ALICE, with the civil defense area representing the focus of prototype work and development in WP4.

2.4 Serious games in the context of civil defence

In this section, we consider the development of a serious game for civil defence in the form of evacuation training for children aged 11-16. This group provides a particular challenge for training, since behaviour can be affected by a range of factors more potent in younger age ranges. These include:

- **A weak attitude-behaviour link**, whereby research methods such as survey tend to demonstrate a limited relationship between self-reported and actual behaviour (Elliott and Baughan, 2003). This is particularly prevalent in highly stressful conditions, and therefore reported intent to perform correct behaviour in an evacuation from children is correspondingly an unpredictable measure of actual behaviour. A meta-analysis of this link showed the correlation between intended and actual behaviour (r = 0.4) (Webb and Sheeran, 2006), leading the authors to conclude that *"medium to large changes in intention only lead to small to medium changes in behaviour"*.
- **Poor perceived behavioural control** – children can often feel adults are more in-control of their safety, and over rely on others to ensure they are safe (Ajzen and Fishbein, 1980). This is reflected in studies discussed later in this section such as that of (Kolshevnikov et al., 2009), which shows that without an adult or peers to respond to a fire warning alarm, a high percentage individually failed to respond.
- **Peer pressures and group norms** can be strong influencers on children's behaviour, to the extent that individual attitude and intended behaviour becomes irrelevant (Terry et al., 1999). This is a particular reason social learning theory, which seeks to achieve its aims on a societal as well as individual level (Bandura, 1977), is of particular interest for serious games seeking to influence behaviour in younger age groups.
- **Optimism bias or overestimation of skill** also are more prevalent in younger age groups (Weinstein, 1980). This can emerge as a tendency to discount events with a low probability of occurrence as impossible, impacting willingness and enthusiasm to train for their contingency. It can also present itself as an unwillingness to believe a situation is life-threatening until too late, again delaying potential evacuations.

Kolshevnikov provides an analysis of key issues through a survey of 446 schoolchildren who had experienced an evacuation, identifying several important points (Kolshevnikov et al., 2009). Firstly, only 38% of children identified and recognized the sound of the fire warning system. The remaining 62% took their cue from others. This reinforces other research suggesting without the presence of an adult, children are highly likely to fail to react to a warning siren or other signal. This demonstrates a combination of all the above four factors: children knew how to evacuate, but low perceived behavioural control caused them to wait for adult or peer reassurance, whose absence, coupled with optimism bias leading them to assume it was a drill, resulted in inaction. Secondly, 82% of children made their decision of evacuation route independently, with 67% showing divergence between decision and action. Again the gap between intended and actual behaviour emerges: few children would self-report willingly behaving in a dangerous fashion, but when presented with a highly stressful and alien environment, conscious decision was not reflected in action.

A simulation-based serious game could offer a basis for overcoming some of these issues. Stress is related to unfamiliarity and uncertainty (Mishel, 1984), and given the fact that virtual worlds have the capacity to recreate a familiar environment in an unfamiliar form, for example during a fire, and their use has the potential to strengthen the link between intended and actual behaviour by increasing familiarity and hence reducing stress. Furthermore, a simulation can reduce optimism bias by demonstrating to the learner the consequence of their actions and severity of an event, bringing it to the "top of mind".

Hence it is little surprise that several simulation-based serious games for evacuation training exist; in an academic context, HCI Lab Udine (Chittaro and Ranon, 2009) developed a serious game which used an immersive 3D reconstruction of a building to train its occupants in evacuation. The model of learning here is partly exploratory, and shows the consequence of incorrect action – for example, if the player attempts to use the lift during a fire, they become trapped and collapse from smoke inhalation. Similarly, the commercial Emergency Evacuation Simulator (EES, 2010) builds upon an exploratory model whereby users can attempt multiple courses of action and repeat scenarios. In both cases, the difficulty in evaluating efficacy comprehensively is caused by the infrequent nature of real-world evacuations. In general, behavioural interventions which seek to reduce low frequency, high cost incident rates are difficult to quantitatively assess, due to the required sample sizes. With respect to this simulation-based approach, evaluations have typically sought to equate behaviour in the virtual world, to that in the real world, in an attempt to ascertain the validity of the overall approach (Kobes et al., 2009). In this case, it was shown ($0.01<p<0.05$) that participants selected the same emergency exit in a simulation as they did in the real world environment it recreated. This demonstrates participants responding in the virtual world as they may do in the real, an effect which evidence has shown benefits from high levels of fidelity (Slater et al., 2009). Therefore, it is little surprise these approaches have focused on exploiting detailed 3D structures and immersive environments, as shown in Figure 2, though this is not where the similarities end.

Both methods employ an overlaid “heads up display” (HUD) on-screen to convey non-visual information such as the level of smoke inhalation, making the type of necessary detraction from realism for gameplay purposes shown effective in other domains (Mautone et al., 2008). Yet this is a cognitive distracter from the environment as a whole, with much evidence suggesting users seldom focus simultaneously on both HUD and scene, and rather alternate their focus of attention between the two (Wickens and Long, 1982). Entertainment gaming has responded to this, particularly in first person games, by attempting to minimize and remove overlays to the greatest extent possible. This avoids a situation where visual fidelity becomes effectively unnoticed as users focus on the HUD rather than the scene, particularly if the task can be accomplished through observation of the HUD alone (Wickens and Long, 1982). Its removal is compensated through post-processing effects, for example injury is simulated by shifts in colour balance, loosely simulating the physiological effect of adrenaline release on vision (Keeler and Doehne, 1966). Following the findings that suggest realism in the virtual world results in more realistic user response (Slater et al., 2009), similar methods may be considered for the ALICE prototype.

Figure 2: Serious games for evacuation training: Emergency Evacuation Simulator (top left), HCI Lab Udine’s evacuation simulator (bottom left), and the ALICE prototype (top and bottom right)

Simulation approaches have also been used extensively for evacuation planning (Shen, 2005). In this case the key to effective simulation is not only in utilising accurate models of the structure, but also effective simulations of human behaviour in navigating the building towards the exits. A noteworthy characteristic of both EES and HCI Lab Udine's simulators is the absence of any other characters from the building. Many evacuations result in casualties not from fire itself, but from the resulting panic and stampede (Kolshevnikov et al., 2009), and hence person-to-person interactions are highly desirable elements of a realistic simulation. In fact, a key characteristic of evacuation situations that have resulted in a high proportion of deaths is population density within the locale (Raubal and Egenhofer, 1998). Their omission to-date is a result of the complexity of introducing virtual characters who behave in a believable and robust fashion, though the application of crowd simulations to first-person game engines and evolution of approaches such as that of Shen (2005) offer a potential platform to explore the benefit this element can bring.

2.5 A particular Serious Game: The Virtual Scientific Experiment

The scientific community, in the latest years, seems to be unanimous in expressing the need for major innovations in learning techniques. While plenty of texts confirm an overcoming of conventional methods and the importance of motivation, network and entertainment in the learning context, industry provides with increasingly quality and scientific interest responses.

Research into educational games has captured many people's attention, particularly in this new millennium. This is due to the huge popularity of video and computer games, especially among the younger generations (ISFE, 2010). The appetite for videogames among adolescents and young adults is an universal social phenomenon, and the number of large companies wishing to train their employees using videogames is growing daily. This growing demand for Serious Games has created a need in companies specialized in creating didactic software to acquire experience and a methodology in developing serious games. Using a series of "Serious Games", tailored to meet the specific needs of the learners, intuitive learning systems train people to achieve their optimum potential, as individuals and in groups. Serious games encompass the same goals as edutainment, but extend far beyond teaching facts and rote memorization, and instead include all aspects of education – teaching, training, and informing – and at all ages (Michael and Chen, 2005)

The learning outcomes from computer games are often divided into skill based (technical, motor), knowledge based (declarative, procedural, strategic), and affective (confidence, attitudes, dispositions) (Garris et al., 2002b). Garris et al. also suggest that the learning outcomes occur outside of the game during reflection and Debriefing, shown in Figure 3:

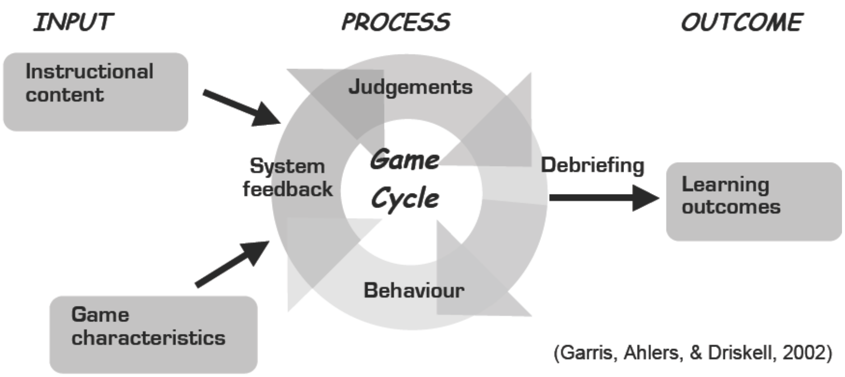

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Figure 3: Game based learning cycle

Starting from this analysis, we focus our attention on combining elements of the disciplinary context with the development of high-level cognitive processes. This is to manage Learning Experiences supported by highly interactive simulations.

From these considerations, we define a conceptual framework model that includes over a simulation component also a moment of cognitive abstraction. Since Serious Game, usually, refers to game used for the simulations, a Virtual Scientific Experiment can be seen as a specific SG including also other aspects.

Figure 3 illustrates some examples of “virtual scientific experiments”, showing the diverse range of forms these may take.

Figure 4: Examples of serious games teaching science through experimentation. Clockwise from top left: Virtual Lab [3], a virtual lab in Second Life developed by the University of Ohio[4], the BBC’s ‘interactive body’ 2D game[5], and Re-Mission from HopeLab (Kato et al., 2008)

Considering these examples, several traits become apparent: for games focussed on knowledge transfer, such as the ‘interactive body’ game, realism takes precedence. For games focussed on higher levels of Bloom’s taxonomy and extending to behavioural change, a more abstract approach is taken. Such is the case with Re-Mission, a game targeted at treatment adherence amongst young cancer

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[3] http://www.virlab.virginia.edu/VL/contents.htm

[4] http://secondlife.com/

[5] http://www.bbc.co.uk/science/humanbody/body/index_interactivebody.shtml

sufferers. Here, knowledge is used as a facilitator for behavioural change, under the hypothesis that empowering children with an understanding of their physiology and pathology, they become increasingly willing to adhere to medication with severe short-term side effects but long-term benefits. Virtual laboratories have spanned a range of platforms, from standalone systems such as the Virtual Lab shown in Figure 3, through to scripted additions to the Second Life environment, allowing open access to members of this virtual community. In the latter case, substantial potential for collaboration exists, though it highlights one of the key considerations for collaborative learning of virtual scientific experiments: the environment needs to be configured to allow collaboration between learners and manipulation of environment content, whilst simultaneously ensuring all learners are able to experience the content fully. Clearly some degree of “instancing” of this content is required, a topic which is explored through the use of “virtual collaborative sessions” in ALICE.

3 Design methodologies for serious games

In this section, the report examines the range of design methodologies for serious games, with a view towards identifying trends and commonalities in their definition and application. We first note the role of methodology in design; certainly established methods for entertainment game design exist, yet their application directly to serious game design fails to address the difficult balance of engagement and pedagogy a serious game needs to provide. Therefore, in Section 3.2, we present methodologies specific to serious games, as well as general conceptual tools of relevance to serious game designers. In creating a methodology to support intuitive guided learning, we capitalize on key emergent traits of serious game design methodologies, including support for iteration, broad contextual consideration, and effective pedagogic selection, to provide guidelines on how this novel approach can be effectively realized within ALICE.

3.1 The role of methodology in serious game design

In discussing design methodology for serious games, it is worth noting first and foremost the *purpose* of the methodology. Serious games are unique to entertainment games in that a talented designer alone is often not enough to ensure a functional product: a fun game without effective pedagogy is as comprehensive a failure as a game which is not fun (and hence is not played sufficiently to have serious impact). Whilst a talented game designer can often ask themselves 'is this fun?', they often struggle to place themselves in the context of the learner and simultaneously ask 'is this educational?' (Zyda, 2005). The methodology, then, must safeguard against both these failure conditions: on the one hand, it must ensure the game retains the engaging characteristics that make game-based learning an optimal selection for the learning context; on the other, it must ensure that effective pedagogy is implemented in a synergistic fashion with gameplay elements. Even at this high-level, we can see the immediate impact of the learning context on methodologic selection, since if a game is blended into a learning environment where extrinsic motivation exists, reliance is no longer placed on the game alone being sufficiently engaging to attract and retain learners.

The case for more formal design methodologies for serious games has often been made (Gunter et al., 2006). A central challenge in creating a prescriptive approach is being able to sufficiently evidence context-independency of development models, since a proven approach for one serious game may not be applicable to another, given the broad range of topic areas and learner demographics games such as those listed in Annex I can address. Existing e-learning development methodologies have met limited success when transposed to serious gaming, as they emphasise instructional content with little affordance for the unique way in which games attract and retain learners (Belanicn and Orvis, 2006). Games developed in such a fashion tend to be conventional e-Learning interventions repackaged in a loosely game-based format, for example a multiple choice assessment converted to a 'quiz', and though this does not guarantee they will fail to impart learning transfer, it brings their definition as serious games into question, and hence their ability to provide the benefits listed in Section 2 becomes the subject of debate.

The development context of serious games is also driven by the expectations of those funding the project. This can range from the public to private sector, and from industry to academia. A completed end-product is a central goal, and this can conflict with the need to provide objective user study and iterative development, particularly when return on investment in a serious game over other methods of training can be difficult to establish. Such difficulty often emerges from the fact games are applied to areas for which more conventional methods of training have failed to satisfactorily address, and chief amongst these is behavioural change (Kato et al., 2008). Though one reason existing methods have failed to induce such change reliably is undoubtedly the complexity of the pedagogy and psychology underpinning such change, another issue is the difficulty in accurately assessing impact when faced with learners whose self-reported attitude may exhibit a weak link to actual behaviour (Ajzen and Fishbein, 1980).

There is little question that in the face of a paucity of empirical research comparatively and objectively evaluating serious games, user testing and analysis must be closely integrated into the design methodology. The lack of existing research on which to base, for example, a pedagogic selection, is compounded by the vast number of serious game evaluations wherein a dual role is played by evaluator-stakeholders, and hence evaluations are at best focused on positive outcomes and at worst exhibit some degree of experimental bias. In fact, the overall methodology should ask first and foremost "is a serious game an appropriate solution in this context?". It is critical this question is asked in research terms; misunderstanding learners is a common pitfall of serious game design and can almost universally be traced back to inadequate interaction with users at the early stages of analysis and conceptualization (Yusoff et al., 2010). Adequately answering this question before commencing development can not only prevent wasted resources and sunk future costs, but also provide invaluable insight into the learner demographic and their interactions with the game at the earliest possible stage. Referring back to the criticism of evaluator-stakeholders, the predominant causal factor behind the dearth of objective and empirical evaluations of serious games is the prevalence of post-hoc evaluations. Clearly, research is of little use as a design aid at this stage, and therefore risks ending as little more than a marketing aid for the developed game, with clear implications for its objectivity.

It is straightforward to identify this issue, yet resolving it is, predictably, a complex task. Post-hoc evaluations reflect the need to develop a product before having anything to evaluate. A tendency to place high value on visual fidelity and sophistication (if a serious game 'looks' good, then attracting players is a far simpler task), over a less appealing iteratively developed solution, is understandable as learners can engage more with high-fidelity games (Slater et al., 2009). Given the high costs associated with visual fidelity and rapid prototyping, repeated focus groups or user studies are often approved in principle and neglected in practice. Similarly, the roots of serious games within the leisure game industry tend to result in similar development methodologies being applied, for example Boehm's spiral model (Boehm, 1986), or Royce's waterfall (Royce, 1970) as shown in Figure 5, without a complementary methodology for user testing and assessment being applied. An effective overall methodology must meet the difficult demands of synergizing research and technical development, and doing so in a cost-effective and practical fashion. Preaching 'more research needed' is simple to do, but much as technical development must justify its return on investment, so must the research component of the development process justify its selection over investment in fidelity or depth of content. Few serious game developers would be interested in investment in a research programme more invested in general conclusions than practical and beneficial returns during development, and it is for this reason the sector continues to benefit from research funding targeted at the creation of serious games intending to explore and evaluate pedagogic mechanisms rather than create productized solutions.

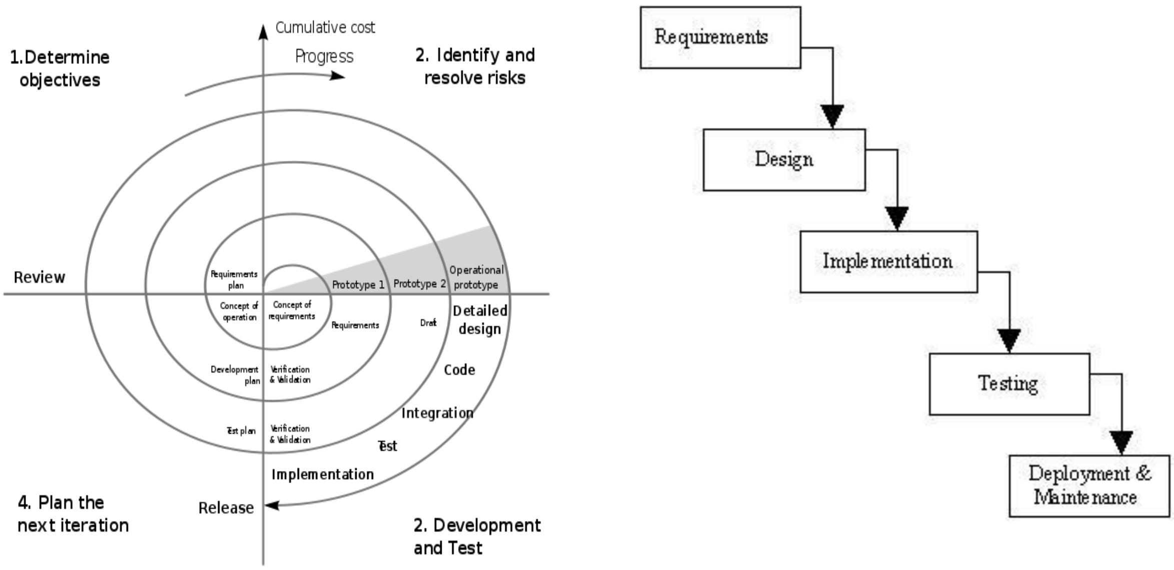

Figure 5: Models of software development: Boehm's spiral (left) and Royce's waterfall (right)

3.2 A review of existing methodologies

In this section, we review existing methodologies which seek to achieve this compromise between a need for extensive user testing and investment in visual and technical aspects of the game. Primarily this is through case-study, as methodological selection is often closely linked to the type of serious game developed and its target audience. We note that, as a result of the inescapable link between evaluation and development, reference to evaluatory aspects is unavoidable. However, we focus in this section on the high-level structure of serious game design, leaving our fine-grained consideration of the evaluation process itself (which, as previously noted, should not be purely post-hoc).

A complex integration of methodologies and approaches from the disparate areas of game design and instruction is a central challenge to the creation of effective serious games (Mehm, 2010). Existing frameworks for serious game development, such as the four-dimensional approach of de Freitas and Oliver (2005), or the EMERGO methodology (Nadolski et al., 2008), promote a participatory design approach seeking to involve users at the earliest possible stages of development.

The four-dimensional approach (de Freitas and Oliver, 2005), suggests the four dimensions of *learner*, *context*, *pedagogy*, and *representational medium*, must be considered with respect to their dynamicism and relationship to learning requirements at multiple stages of serious game design. Typically multiple dimensions are held static from an early stage; for example, the learner demographic might be defined by the business case, the usage context restricted to a PC with an Internet connection, and the representational medium defined as an immersive 3D environment or 2D game built using web technology. The framework argues that the better these dimensions can be understood though research, then the better the remaining dimensions can be adapted to meet the learning requirements. Again with reference to the previous example, a good understanding of learners, their context, and technological limitations is essential when making a pedagogic selection. The four-dimensional method advocates participatory design, whereby learners are involved within the development process as active creators as well as subjects of research, but most crucially the framework requires that its respective dimensions be understood through objective research or in absolute terms, rather than design approximation. Though this understanding of the fixed dimensions benefits the adaptation of the remaining, more flexible dimensions, the framework avoids recommendations for how these dimensions should be adapted, instead focusing on the establishment of information to inform decision making. Such decisions are commonly made in the pedagogic dimension, since it is the most flexible in practice, with the remaining three dimensions often inextricably linked to the business case and budget.

Another complete methodology is presented by Nadolski, Hummel et al. (2008) as the EMERGO method. The EMERGO approach is narrow in scope, focused at supporting serious games for the higher education sector, but broad in its remit, covering not just the methodology for game design, but also deployment and blending into the wider curriculum. The methodology capitalizes on core principles of software design, namely the cyclical nature of the design – development – delivery – evaluation lifespan of a software product. However, it adapts this cycle to apply directly to learning cases, rather than the developed software, focusing the developer on end product rather than underlying technology. A core principle here can be seen to be the emphasis away from a software product and towards an educational product with a software *component*, reinforcing the supposition that game based learning is often most effective when selectively blended into other educational approaches (de Freitas and Griffiths, 2007).

A specific case exists for cases where the selection of game-based learning is driven by the intrinsic motivation gaming is capable of fostering (Garris et al., 2002a). Typical examples of such games include those deployed in the public health sector to reach demographics who will engage with a web-based serious game far more readily than other training media, particularly if the educational objective is obscured. In this context engagement and 'fun' aspects of the game must assume the forefront, as failure to engage with the audience will result in a game which is ineffective regardless of the efficacy of the pedagogic model.

The argument that learning can occur indirectly or even tangentially to gameplay is supported by a range of arguments, including that of Shaffer (Shaffer, 2006), who argues the development of skills and knowledge can be motivated by, rather than a consequence of, interaction with a serious game. In a review of the development of the Immune Attack game, Kelly et al. consider a number of best-practice guidelines for serious game design (Kelly et al., 2007). They note that the game itself need not be the mechanism by which learning is achieved, rather it can act as a stimulus for learning beyond the game. In such a case, design can focus on creating a game in which players become intrinsically motivated to solve problems whose solutions require learning beyond the confines of the game. This has been explored through efforts to apply massively multiplayer online games to a learning context (de Freitas and Griffiths, 2007), on the basis that core skills required to be a good player, such as numerical analysis, economics, teamwork, and communication, are equally valid skills outside of the game world. Similarly, the authors have explored such a pedagogy in the development of a game for childhood obesity (Powell et al., 2010), wherein a knowledge of healthy eating is required to succeed in the game, which was deployed as a series of cognitive puzzles, but the knowledge itself is not contained in depth. The theory still requires detailed evaluation, though a small qualitative study indicated children who engaged with the game were eager to develop their knowledge to support their gameplay. Hence, further evidence exists that a sound methodological approach should not consider only the game, but the wider learning process.

Examining this wider picture, one important consideration is the role of other actors in the learning process, including tutors. Studies have shown the pivotal role of tutors in effectively scaffolding learning outcomes from virtual spaces to real contexts (Warburton, 2008), and continuing the principle that the methodology must reach beyond the game itself, such issues are a relevant consideration.

Multi-user games also present a specific methodological case. An exploration of the use of multi-user games led several researchers to suggest a model of "motivated reinforcement learning" was effective in this context (Merrick and Maher, 2009). This approach focuses not only on the use of other players and their interactions, but also the use of AI to create plausible non-player characters (NPCs), synthetic machine-driven avatars whose role is to interact with users and appear believable. This is an essential requirement if such avatars are intended to interact with learners within a serious game to provide humanistic feedback, such as the levels of interpretive, probing, and supportive feedback in Roger's established model (Rogers, 1951). Within the motivated reinforcement model, AI is implemented in what could be considered a pedagogic fashion, able to learn and adapt though definition of a series of core motivational goals, and positive and negative reinforcement applied to create evolutionary intelligence. Under such an approach, the potential for these virtual agents to learn is limited primarily by the extent to which they are able to interact with other humans, and in the case of an expansive multiplayer online environment such as Second Life[6], the potential exists for these interactions to number in the thousands, if not millions, over the long-term.

Many serious games evolved from simulations - for example, America's Army emerged from early defence simulators (Zyda, 2005). Therefore another logical avenue for methodological approach is to extend the simulator methodology to encompass gaming elements (Raybourn, 2007). However, an intriguing contradiction exists between serious gaming and simulation; simulator methodology conventionally strives to maximise fidelity, on the proven basis that more realistic environments result in more realistic learner response (Slater et al., 2009), however, the introduction of game based elements has been shown to increase learning transfer (Mautone et al., 2008), leading to the conclusion that creating a less realistic environment which builds upon gameplay elements, themselves intrinsically unrealistic, can improve, rather than detract from, effective simulation-based learning transfer. For example, a real-life activity is seldom scored or simplified into a win/lose scenario, yet as Mautone (2008) demonstrates through control study, this method applied to flight simulation resulted in more rapid learning transfer and better retention. Hence, conventional simulator methodology is at-odds with evidence from serious game design, and caution must be taken when attempting to adopt simulator design methodologies to serious gaming. Simulation-based gaming has been shown to be effective when dealing with younger audience (aged 0-5), where the principal objective is knowledge transfer, but struggles to address older groups of children when behavioural outcomes take precedence over knowledge acquisition (Renaud and Stolovitch, 1988).

The use of 'exploratory learning' (de Freitas and Neumann, 2009) for supporting immersive learning in virtual environments plays to the strengths of 'sandbox' entertainment games, in allowing the learner the ability to free-roam within a virtual world and explore various solutions to problems, such freedom places a high technical demand on the virtual world to accommodate the many potential actions of learners, and a high demand on educational designers to ensure learning objectives are met through non-linear experiences. However, a need to structure, reflect and learn from these social interactions is critical to support assessment and validation of learning. This is particularly true for younger age groups, who often have high expectations of technology, and who benefit particularly from 'stealth' learning principles, whereby learning occurs indirectly as an outcome of an enjoyable and engaging activity (Luckin et al., 2010). Therefore, a clear requirement exists for the development of such exploratory learning principles to better understand how to reinforce adherence to learning outcomes, and provide a clear route for educators seeking to create an early-state serious game design from a set of learning requirements.

The roles and responsibilities of individuals within the serious game development process have also drawn attention from researchers. An ethnographic study of a serious game development team (Tran and Biddle, 2008) analysed social and technical factors influencing collaboration in serious game

[6] http://secondlife.com/

development. The authors noted the importance of an iterative design approach, and participation from both instructors and game designers within the development process. Particular challenges were noted when team members were not geographically co-located and socially engaged, a consequence of the need for an open atmosphere for discussion around the tension between entertainment and instruction. Further studies have noted the pitfalls of distributed development of serious games. In particular, the barriers of managing a team with equal responsibilities and participation in a distributed fashion is not simply a communication issue (Oliveira and Duin, 2008), rather, the difficulties in distributed and simultaneous development of code and need for frequent and rapid feedback to minimize abortive work, as well as a reticence from individuals to rework developed content, can present a significant challenge.

Technological solutions addressing the need for engagement from both instructors and game designers often centre on the provision of content development tools to educators, since a central issue capable of unbalancing game and pedagogic design is the more ‘hands-on’ role game developers have in the creation process (Tang and Hanneghan, 2010). A particular difficulty can emerge when game designers tackle day-to-day feature implementation, and refer back to instructional designers on a consultancy basis, since this places the game designers (who may have no pedagogic expertise) in the role of an evaluator of which features are worthy of pedagogic consideration. Content development tools, therefore, can bridge an essential gap in allowing educators to become directly involved in a game’s creation. The selection of an appropriate game engine is also a common challenge, and in the past the authors have proposed approaches which consider the feature sets of various engines with respect to pedagogic need (Petridis et al., 2010). Here the issue is repurposing game engines devised for a broad range of applications to a serious context. Though any engine can be employed for a serious game, particular characteristics inherent to the area such as the common need for rapid prototyping are a worthwhile consideration.

Usability and uptake is also an important consideration. The well-established technology acceptance model (Davis, 1989), shown in Figure 6, has demonstrated that if users self-report high levels of perceived usefulness and ease of use, high intention to use and subsequent usage follow. As a technology-driven training intervention, the model has also been shown to apply to serious games (Yusoff et al., 2010), and due to its relative ease of implementation the model can prove a useful early-stage design aid. Specifically, since perceived usefulness can be assessed from a conceptual standpoint through early stage qualitative or quantitative work, part of the equation for high usage behaviour can be resolved before embarking on development work to create a functional and easy-to-use solution. However, high usage does not guarantee high learning transfer, and caution should be exercised in ensuring usability and ease-of-use do not obstruct learning requirements.

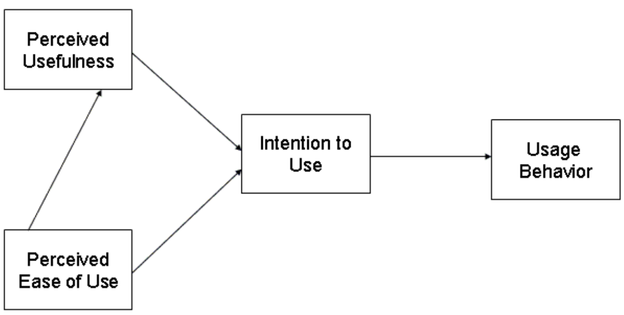

Figure 6: The technology acceptance model (Davis, 1989)

Reviews of serious game design specifically for use in a distance learning context (Annetta et al., 2006), have suggested that they have considerable potential in the area, particularly as younger generations emerge who have, as Annetta, Murray et al. describe, “spent thousands of hours engaged in small-group digital competitions". At the risk of repeating an argument frequently repeated elsewhere (Oblinger, 2003), for emerging generations across Europe gaming is the norm rather than the exception, and hence the importance of integrating and ensuring an understanding of the learner demographic into the overall design methodology is essential. Educators must retain awareness that technology which appears novel to them may not be novel to their students, and indeed the expectations of younger age ranges for serious games which mirror the state-of-the-art in leisure games has previously been observed (de Freitas, 2006). This is particularly true for games which are deployed in a free-to-play context over the web, since these games either partially or wholly compete with leisure games for screen-time.

In summary, we can identify the key goals of a methodology for serious game design as being:

- **Consideration the entire learning context.** It is inadequate to consider a serious game in isolation, since this is broadly unrepresentative of the usage context. Even the simplest web-deployed game places the learner only a single web search from additional resources on the subject matter. If a game can stimulate the learner to utilize this subject matter it can have substantial long-term impact, but this is difficult to measure through interaction with the game alone.
- **Pragmatic support for iterative design.** In the absence of the ability to guarantee the efficacy of the serious game, it is only logical to conclude some form of end-user testing and subsequent modification will be required. However, an effective methodology must avoid over-prescribing this iteration. Changing a game, particularly with respect to artistic assets such as character models and animations is a costly process, and this can be seen as a cause of the gap between academic models which stress iteration, and commercial development which seldom has the opportunity to undertake more than three or four transitions round Boehm's spiral. Hence, a fundamental criteria of effective methodology is that whilst is must note the importance of iteration and consider its facilitation, it must also minimise the extent to which it is necessary.
- **Pragmatic support for user involvement.** Again, a highly participatory approach has been discussed as an effective model (de Freitas and Oliver, 2005), under which learners are involved in the creation of the game. This must similarly be grounded in pragmatism; a game with an infinite development budget and timeframe would of course benefit from this involvement as part of a highly iterative development cycle, yet in practice unlimited budgets and timescales do not exist.
- **Provision of equal weighting for game designers and educators.** Referring back to the example by Tang and Hanneghan (2010), if either of these groups are intended to develop the game in isolation, or the development model favors one of these groups, then the need for iteration and user participation to create an effective solution is likely to increase. This can manifest itself as a bias towards instruction, in the case of games developed by tutors and academics, or a bias towards gameplay if a game designer takes the lead. Yet it can also be difficult to predict; certainly few if any individuals can walk the careful line required to apply expertise in both areas (Prensky, 2003), and hence
- **Support for generalisability of findings and transposition.** A framework inextricably tied to a single game is of little academic (though perhaps considerable commercial) interest. Generalisability must be achieved by the adoption of standardised methodologies for evaluation which allow results to be compared between domains. Ultimately this must reach to the definition of learning requirements at the analysis stage, since if these requirements do not equate to measurable objectives, a conclusive demonstration of efficacy will be difficult to achieve.

Our review of existing methodologies demonstrates the fragmented nature of development approaches across the sector. Methodologies are either constrained in their scope (Nadolski et al., 2008), or lack adequate evaluation to ascertain their efficacy in general terms, a particular issue since a rigorous evaluation of a development methodology would need to consider its application to different contexts, and the high development cost of a serious game makes rapid prototyping a cost-intensive process. However, despite the lack of a consensus on proven and demonstrated models for serious game design, certainly a range of notes on best-practice and case studies can be found throughout the literature. Therefore, in the next section we go on to apply this understanding of best-practices to define a methodology to facilitate "Intuitive Guided Learning" in a game-based context.

3.3 Developing a methodology to facilitate Intuitive Guided Learning

We consider in this section the concept of "*intuitive guided learning*". Under this paradigm, the learner is not forced down a particular course of action, but the surrounding pedagogic design guides them towards learning objectives in an unobtrusive fashion. As such, it can be seen to bear clear parallels to 'stealth' learning, whereby learners are not explicitly aware they are learning (or, rather, the learning has zero intrusion on the gameplay experience). Though the fundamental components of a development methodology for this pedagogic approach do not intrinsically differ from those outlined earlier in this section, worthy of some particular consideration are the implications that an intuitive guided approach places on the design and evaluation process. In order to consider this in detail, we firstly note some important characteristics of such pedagogy: the experience is non-linear: 'guided' (as an antonym of 'forced') implies that the learner can deviate from the intended path through the learning experience. Therefore, the game must allow different outcomes and routes to success or failure. Any game is linear to an extent – even the most expansive virtual worlds ultimately end in impassable cliffs or oceans – though the shift towards non-linearity in the entertainment gaming industry through approaches such as 'sandbox' gaming supports well as shift towards non-linearity in instruction and pedagogic approach. Non-linearity has particular implications for assessment: as no two learners can be relied upon to take the same path through the intervention, the assessment methodology must accommodate this non-linearity by assessing learners in terms of the path they take, rather than through simple, absolute variables.

Considering the notion of intuitive learning, clear reference can be seen to the psychological typology of Jung (Jung, 1921), who describes intuitive learners as tending to focus on the range of possible outcomes, rather than immediacy and immediate detail. Similarly, more recent learning theories such as those of Kolb (Kolb, 1984) who capitalises on the extension of Jung's theories over the 20th century to provide further classification and taxonomy of learning styles. Intuition implies this sense of exploration of multiple outcomes, and through a virtual world this exploration can be visualised and acted out, giving virtual substance to theoretical constructs. Following this principle, a great deal of synergy can be seen between intuitive and exploratory (de Freitas and Neumann, 2009) approaches, as well as experiential approaches to learning (of which the exploratory model is a derivative). Hence established experiential theory on best learning practice (Kolb, 1984) is applicable to an intuitive learning context. This implies a focus throughout the experiential cycle on the core aspects of the process, which, must also span a gap between real and virtual and the inherent abstraction this implies. Thus, if we are to truly capitalize on an intuitive guided approach in a serious game, we must meet three essential criteria:

- **The game must not be entirely linear.** A linear game cannot be explored, and only has one potential outcome. Therefore, the game forces, rather than guides, the learner down its path. Referring back to the previously cited works of Jung and Kolb, this is at odds with how intuitive learners learn, and therefore cannot be an optimal environment for intuitive guided learning. This matches a shift in entertainment and serious game design, which is increasingly considering how environments can be designed to facilitate a more open experience for the player and learner: take for example Bethesda's Oblivion[7], or the massively-multiplayer online World of Warcraft[8]. The latter is reflective of the fact that in general multiplayer games must facilitate some degree of non-linearity, because by nature player-to-player interactions are hard

[7] http://www.elderscrolls.com/

[8] http://us.battle.net/wow/en/

to anticipate, and if only able to follow one path, are not effective social interactions.

- **The game must provide a guidance mechanism for the learner.** This can take multiple forms, but ultimately must stimulate some form of motivation to adhere to the objectives of the learning activity. This must avoid the behaviourist trap of attempting to align learning outcomes with in-game objectives (Egenfeldt-Nielsen, 2005), since much evidence suggests gamers approach games with a view towards creating the most efficient route to high performance (Binsubaih et al., 2008). Through the example of early versions of the MathBlaster[9] serious game, Binsubaih et al. suggest that when presented with a score mechanism that balanced answering mathematical problems against quick shooting, children quickly learnt that they could focus solely on rapid shooting and hence avoid the more challenging mathematical aspects of the game. This reinforces the supposition that humans tend to approach games with efficiency foremost in their mind, either mentally in the case of MathBlaster, or physically in the case of the Nintedo Wii[10] and similar active gaming devices, where games intended to promote exercise have shown steady reduction in impact as learners develop optimum strategies for beating the game with a minimum of physical exertion (Graf et al., 2009). The aforementioned issue with behaviourism arises when the design implies that beating the game is synonymous with an effective educational outcome. We have already defined in Section 2 approaches whereby learning can occur more indirectly through gameplay, and such approaches are particularly relevant when seeking to avoid this problem in an intuitive guided approach.
- **The preferences of the learner must be understood.** A logical follow-on from the typology in learning theory and psychology (Jung, 1921) is that, for some groups of learners, an intuitive style may be unfamiliar or unwanted. In the former case, the emphasis must be on gradually blending in the approach through supporting instruction in more familiar forms. An example, though possibly trivial, are the introduction courses commonly given to learners by tutors though conventional materials prior to placing them in an environment such as Second Life (cited previously). In the latter case, that of a learner who resists the style, then again the educator must consider potential alternatives. Any pedagogic approach is limited in its efficacy by the learner demographic, and intuitive guided learning is no exception. Therefore, it is essential this demographic be understood in terms of its acceptance and understanding of intuitive approaches, and any need to advance this understanding provided as part of the overall learning intervention.

Referring again to the notion of ‘guided’ learning, some form of guidance must be present to lead a learner down a specific path. Other research has considered how information placement can best be performed to cue users down certain routes (Dixit and Youngblood, 2008), and other methods have looked at how aspects such as lighting of a virtual space can be used to change a users affect (Knez and Niedenthal, 2008). This broader range of work allows us to consider the impact of guidance not only on learners’ immediate actions, but also their long-term response to the system. An immediate question is what form the guidance mechanism should take. Several examples of guidance exist which are of relevance to intuitive learning. Belotti et al. describe a methodology for supporting developers of task-based learning approaches in virtual worlds (Bellotti et al., 2010). In their case, the task itself provides the guidance in terms of high-level objectives. By keeping these objectives sufficiently broad, non-linearity and exploration is allowed to occur, yet is guided by the purpose of the learner in solving the high-level task. It should be noted the task itself need not necessarily be a direct learning outcome; rather, the learning occurs indirectly through learners’ exploration of the task. Taking for example the work of the authors’ within the Roma Nova project (Panzoli et al., 2010), an overall objective of retrieving an object within the Roman Forum can involve development of communication skills bartering with merchants, numerical skills buying and selling, and cultural and historical understanding through the experience.

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[9] http://www.knowledgeadventure.com/mathblaster/

[10] http://www.nintendo.com/wii

Narrative is another potential mechanism to guide, rather than force, learners down an ideal path. Its use in an exploratory learning context has been well-documented (Mott et al., 2006), with studies showing it has the potential to guide learners whilst supporting a flow experience. Riedl et al. (Riedl et al., 2008) describe the IN-TALE system for creating interactive narratives for a broad range of purposes, including entertainment, education, and training. An autonomous management agent handles the formation of narratives, and a developed practice environment explores the use of the system to promote cognitive skills development. Narrative based frameworks are common for serious games (e.g. (Mehm et al., 2009, Warburton, 2008)), particularly since they support a branching dialogue approach to balancing linear elements with exploratory approaches. Role-play is a core component of many game narratives; placing the player in a role such that a 'Proteus effect' (Yee and Bailenson, 2007) occurs, and the player effectively transposes their sense of presence to their avatar, ceasing to disassociate themselves from their in-game character, has a powerful impact on presence as well as pedagogic implications.

A study of guided learning in the workplace (Billett, 2000) suggests a number of effective mechanisms for guided approaches, including questioning dialogues, use of analogy, and critical incident reviews. Guided learning is strongly linked to the notion of scaffolding transfer of abstract learning outcomes to practical contexts, and hence can be closely linked to these areas. Success has been shown for performing this guidance autonomously through software at the lower levels of Bloom's model (Jackson et al., 1998, Bloom et al., 1957), yet higher, metacognitive levels of learning have yet to benefit from demonstrable, software-based solutions for their transfer from abstract to real contexts. It is for this reason blended learning is commonly cited as an effective usage context for a serious game (de Freitas and Griffiths, 2007), since the educator can assume the role of scaffolding this transfer in lieu of a technological solution. Since analogy and abstraction can offer a firm practical basis for creating game designs which effectively avoid instruction obstructing engagement.

The strong influence of peer groups on children's behaviour (Schunk, 1987), suggests that collaborative and social learning mechanisms are also viable mechanisms for guiding learning. As these are covered in detail in D.3.2.1 within the ALICE project, only a brief discussion is given here, through their importance should not be overlooked. Indeed, the relationship between intuitive guided learning and social elements is particularly strong, since guidance from peers has the potential to affect motivation and learning transfer in a potent form, as focus shifts from a more conventional pedagogy centered upon a facilitator. The social emulation at the core of Bandura's social learning theory can also be exploited in virtual worlds through the use of synthetic characters able to demonstrate best practices. As an example, the authors' own work in Roma Nova (Panzoli et al., 2010) has considered a 'Level of Interaction' (LOI) approach to providing collaborative and social learning, where collaboration and socialisation takes place not between the learner and their peers or tutors, but with synthetic virtual characters. Though such approaches are still in their infancy, and much more evaluatory work is required to confirm their true potential to facilitate learning effectively, they offer substantial long-term potential for methods of learning in which the tutor assumes a role of content selector and scaffolder, rather than conveyor.

In the specific case of ALICE, the impact of integration into an e-learning system also requires consideration. Such integration has been described as a convergence of the learning object (LO) model with serious gaming (Torrente et al., 2009). A key part of this integration is the facilitation of the overall pedagogic approach by not only the serious game, but also the e-learning platform on which it is deployed. In D.3.2.1 we discuss the notion of the "complex collaborative learning object" (CC-LO), which is able to sit between the two platforms and evolve through virtualised collaborative sessions. On a technological level, this requires the game and e-learning system are able to intercommunicate information on the learner profile and states of CC-LOs. Hence the overall system supports guided learning through the non-linearity the evolution in state of these CC-LOs affords; furthermore, it supports peer interaction through collaboration, further guiding the learner through peer as well as facilitator-led interactions.

4 Evaluation methodologies for serious games

In this section, we provide a review of evaluation methodologies for serious games. We note, first and foremost, that since the sector is rapidly broadening in terms of both application areas and underlying technology, there are few established and generic approaches specifically designed for evaluating serious games. A striking characteristic of serious game evaluations is the dependency between the sector for which a game is developed, and the subsequent nature of the evaluation design. This presents something of a dilemma when attempting to provide a comprehensive review of evaluation methods: approaches such as randomised control trials (Kato et al., 2008, Knight et al., 2010), focus groups (Powell et al., 2010), interviews, narrative inquiries, and quantitative analyses of game engine data (Calvillo Gamez et al., 2010) have all been conducted. As an emerging form of training medium, a strong argument exists that serious games should be evaluated exactly as any other educational medium, and affording them specific consideration with respect to their evaluation detracts from the comparability of any results. Therefore the methodological toolkit of a serious game evaluator needs to be a broad one: often the sector dictates the most appropriate methodology, rather than the use of a serious game itself.

Even then, this toolkit often lacks the ability to comprehensively demonstrate the efficacy of a given solution. The main cause for this is the fact serious games are often deployed to solve issues conventional education has not been shown to satisfactorily address. The key word here is “shown” – often, the challenge lies in proving the efficacy of difficult-to-measure variables such as motivation. In the evaluation of the serious game Code of Everand[11], the authors have reflected on the particular difficulty of proving the impact of behavioural interventions which target issues with low incidence rate, yet high incident cost. The entertainment aspect of serious games has also merited research: for example the GameFlow approach describes a method for evaluating entertainment as separate from serious outcomes (Sweetser and Wyeth, 2005). We note in this section the benefits of such separation, leading to our conceptual framework in Section 5.

4.1 A review of evaluation techniques

As mentioned in the introduction to this section, a key challenge in presenting any review of evaluation techniques is scoping sufficiently well to ensure the review is relevant to the aims of the ALICE project. Any evaluation must consider its relationship to the learning requirements of the serious game which it seeks to understand, and therefore we present in this section a review with particular emphasis on approaches which have sought to ascertain how well these requirements are achieved. To combat the inherent costs of in-person experimental approaches such as focus groups, several examples of methods have emerged that take a purely online approach to evaluation (Pandeliev and Baecker, 2010). Serious games present a unique advantage in that the game engine itself may be analysed to understand player behaviour, though relating this to real-world behaviour and ultimate educational impact typically requires some degree of real-world interaction with learners (Calvillo Gamez et al., 2010). Given the difficulty in assessing factors such as motivation and behaviour directly, emphasis has frequently been given to establishing proxy measures of efficacy, such as how realistic a simulation is through analysis of technological aspects of the human-computer interaction (Pausch et al., 1997). However, in a review of evaluation practices for virtual agents in serious games, Norling notes that believability is often not a paramount concern, and that excessive focus on this criterion can be to the detriment of games’ ultimate goals (Norling, 2009). Therefore it is inadequate to simply transpose

[11] http://codeofeverand.co.uk/

simulator evaluation methods to serious games; rather, the broader educational context must be given prominence.

Flow (Cziksentmihalyi, 1997), is often referred to in this broader context of educational gaming, since engaged gamers tend to exhibit many of the characteristics of a flow experience, such as high levels of focus on task and decreased peripheral awareness (Cowley et al., 2008). The understanding of flow in games examined by Cowley et al. presents some interesting questions – is immersion in a virtual world the same as immersion in educational content, and, if so, can so-called immersive technologies be applied to create immersive learning experiences? From the perspective of a computer scientist, immersion is a relatively easy quantifiable measure of practical context, for example what proportion of the field of view filled by the display, whether stereoscopy is employed, or the frequency range of audio output equipment and the capacity to spatialise sound (Slater et al., 2009). Yet from the perspective of an educator, immersion can occur equally well when reading a good book, a far less multisensory experience (Mott et al., 2006). Hence, there is a clear discrepancy between what educators measure and define as immersion, and have linked to the learning process, and the attempts of technologists to quantify and measure immersion (Pausch et al., 1997). Computer scientists tend towards a definition of immersion as objective and presence as subjective (Slater, 2003), and have hence questioned how presence in non-immersive, non-realistic environments is possible (Nunez, 2004). If we are to assume immersion can be evaluated as a proxy for flow, and hence quality of educational transfer, then this important duplicity in the definition of immersion must be carefully considered; adding immersive technology to learning material does not automatically guarantee immersive learning.

We have noted throughout this document that serious games must be able to demonstrate effective learning transfer (to be ‘serious’), whilst also remaining engaging and entertaining (to be ‘games’). The need for engaging gameplay as well as effective instruction must also be evaluated, and several studies have focussed on assessing the gameplay experience in isolation (Nacke et al., 2009). It is increasingly evident through the literature that these are two different phenomena, and serious games may exist which show success in one dimension but not the other. These are evidenced at the extreme ends of the scale as either games which are fun but struggle to demonstrate educational value, or as educational material which is neither fun nor engaging. Can we, then, isolate and evaluate these criteria independently? Though the two are intrinsically intertwined throughout the design process, a common criticism of evaluations is they evaluate engagement but not education, and too easily cite high usage statistics as a measure of success (Prensky, 2003). Thus this segregation is perhaps a norm rather than an exception; and provided both aspects can be adequately evaluated, there are immediate benefits to the design process from separating the evaluation process into a dichotomous relationship between engagement and education. Iterative design benefits from being able to iterate selectively, and successful elements can be held constant whilst weaker aspects of the serious game are enhanced. Furthermore if we expand this beyond the game’s development cycle and into its lifetime, as common in software development methodology (Boehm, 1986), then engaged players become an important resource in our evaluation of learning outcomes. For this reason, we can also conclude that, in the majority of contexts, engagement must be established before considering educational aspects. If a design cannot pedagogically guarantee success, as is typically the case given the unpredictable nature of learners, then we must compensate by evaluating and refining the learning process in response the learner feedback. However, if a game cannot engage learners, then sourcing an adequate sample of experienced players with whom to assess learning outcomes becomes an impossible task (Sweetser and Wyeth, 2005). We therefore go on to describe evaluation techniques with respect to these two key areas of **engagement** and **learning transfer**.

Evaluating Engagement

Engagement has been measured in the medical area for applications such as stroke rehabilitation (Burke et al., 2010). As this rehabilitation must be early, intensive and repetitive, problems can rapidly arise with patient motivation and engagement. In assessing the applicability of a serious game to overcome this need for intrinsic motivation, Burke et al. identify game design principles for upper limb stroke rehabilitation and present several developed games using video-capture technology. In this case, the evaluation approach adopted a randomized control trial which monitored usage between healthy subjects and stroke victims, showing positive early results. Thus a control trial approach is not limited in its applicability to the assessment educational transfer; rather, the metric (in this case an objective logging of playtime) proves an effective indicator of engagement. This is reflective of the relative simplicity with which engagement can be measured as opposed to learning. Valid indicators of this engagement have in the past included the sum total of players and analysis of their demographic, coupled with qualitative work (Rebolledo-Mendez et al., 2009), or other easily ascertainable metrics such as the tracking of total playtimes and return visits to a game (Calvillo Gamez et al., 2010). Reversing the technology acceptance model (Davis, 1989), we can suggest that high usage indicates a combination of high perceived ease of use and usefulness, which may also be supposed as latent constructs of engagement.

Heuristic approaches to evaluation also offer some potential. Pinelle et al. describe a set of heuristics created to help identify usability problems in both early-stage and developed game prototypes (Pinelle et al., 2008). Taking a unique approach, they developed the heuristics by a structured analysis of 108 reviews of games from a popular gaming website, 18 from each of 6 major genres. Analysis of the reviews identified twelve common classes of usability problems seen in games, leading to the development of a set of ten usability heuristics based on these problem categories. A preliminary, small scale evaluation of the heuristics suggests that they help identify game-specific usability problems that can easily be overlooked otherwise. However, the work is not specific to serious gaming, and the more limited market size, coupled with the difficulty in sourcing reviews which would include the pedagogic aspects of the game, may preclude such approaches from being used in the serious game arena in the immediate future.

Evaluating Learning Transfer

Many frameworks have been developed such as TILT, CIAO!, and Flashlight (Oliver, 2000), all of which have been designed to evaluate the integration of technology into teaching. Of note is the way such frameworks have been formed with blended learning implied – they evaluated the integration into *teaching* rather than *learning*. Such a perspective can be difficult to apply for serious games, particularly those distributed online or in an e-learning context where the presence of the tutor cannot be relied upon. Few frameworks specifically delineate methods for game-based learning, understandable, since any such evaluation benefits from its ability to be compared methodologically and in terms of results to other learning solutions. Qualitative work has been used extensively to assess serious games, though it is easy to argue its selection is often grounded more in pragmatism than suitability. Certainly qualitative work can be essential in providing insight into learner response and understanding, and when conducted rigorously can form a core basis on which to build structural models for quantitative assessment. However, qualitative findings alone, particularly with a limited sample size, are often one of the central criticisms of inadequate serious game evaluations

Certainly in the public health sector a tendency to adopt evaluation techniques for serious games such as randomized control trials has been evident, though the issue of evaluator-stakeholders described in Section 3 persists. Re-mission[12] was developed by US not-for-profit institution HopeLab, and targeted at

[12] http://www.re-mission.net/

improving the adherence of children to chemotherapy regimes. This is a substantial problem amongst younger age ranges, as children struggle to perceive long-term benefits in light of the shorter-term discomfort and symptoms induced by the medication. Re-mission sought to tackle this by embedding knowledge about cancer and the function of chemotherapy treatment into an abstract, game-based form. Within the game, players control a 'nanobot', fighting cancer at a cellular level. Missions included themes which addressed not only the cancer itself, but also the behaviour of the patient, such as the negative impact of high stress levels and anxiety, as the player is empowered as a virtual character and their role is shifted to that of an expert and source of treatment and solution, rather than patient. In a randomised control trial (Kato et al., 2008), the game was found to have a positive outcome on treatment adherence through both self-reported survey results and clinical examination.

4.2 The relationship between design and evaluation

It should be noted that the evaluation of serious games is strongly and implicitly linked to the corresponding development methodology. As previously noted in this report, post-hoc evaluation is of little practical use if it cannot be fed back in to the development process, particularly if this evaluation is limited to the specific game developed. Though extremely desirable, generalisable findings are difficult to attain, particularly as the depth and content of many serious games is highly specific, and the pedagogic approach an interpretation, rather than direct implementation, of a stated theoretical basis. Pedagogy cannot deliver content, rather, it prescribes its methods of formation and use, and for this reason evaluations which fixate on the value of content are not easy to translate to general findings. However, there is considerable evidence through both a shift in design processes, and the results of several studies (Egenfeldt-Nielsen, 2005), that behaviourist pedagogy has gradually given way to cognitive and situative methods, as well as methods of social learning based on established theory (Bandura, 1977).

The notion of a game engine itself as a research instrument is gradually gaining prominence (Calvillo Gamez et al., 2010). In addition to tracking user interactions through specifically implemented logging tools, many game engines have content databases at their core which can be mined for player behaviour as a secondary source of data. In particular, multiplayer online games provide an interesting source of information on player interactions, since the database can include a large social network of interaction data, as well as information on time spent in-game across the playerbase. Large-scale analyses of these data sources can be particularly useful when seeking to advance pedagogic design, since understanding how long players spend involved with a game allows the evaluation of learning transfer to more accurately reflect a typical user interaction. In turn, this can allow pedagogy to be refined to deliver learning outcomes more or less rapidly as player behaviour dictates.

A key factor which merits particular attention during the evaluation process is the extent to which players are capable of demonstrating transfer of knowledge from of a digital game environment to real world problem. Several studies have suggested this is an ongoing problem in learning within virtual worlds (Squire, 2002); the solution must be found either within the game design itself, or through a broader examination of how games may fit into a wider educational context. Egenfeldt-Nielsen (2008) provides an overview of several studies that highlight areas that may affect the extent to which knowledge developed in digital games is transferred to out of game settings, providing an example of students who were focused on solving problems on paper while playing a game-based mathematics tool. Quantative examination suggested those involved in tackling the paper-based problems were able to transfer knowledge more readily, resulting in the suggestion this resulted from their more active role in knowledge construction and formal involvement in the educational process. In reviewing the research on the extent to which playing digital games can improve problem solving, this overview concludes that though playing digital games may improve problem solving abilities and that these abilities can be transferred between different games, yet little evidence exists to suggest playing digital games improves problem solving abilities in the real world (Egenfeldt-Nielsen et al., 2008).

5 A conceptual framework for serious game development in ALICE

This section presents a conceptual framework grounded in the methodological and evaluatory considerations presented in Sections 3 and 4. We consider the core needs of the project to be an iterative approach to the implementation and testing of the intuitive guided learning model, and therefore present firstly in Section 5.1 a technical framework which seeks to create a dichotomy between pedagogic and engagement elements of the serious game, and provide a model for considering how these two elements can be separated to maximize the ability to undertake iterative and user-centric design within the constraints of the ALICE project. The remaining sections address the critical components of this overall conceptual framework: the pedagogic mechanisms underpinning intuitive guided learning, and need to support

5.1 Establishing an overall framework

We have discussed in the previous section the holistic approach a serious game development framework needs to adopt if it is to guarantee an effective learning solution. It is inadequate to consider solely the game itself; rather, the wider context into which the game is being introduced must be understood, the learner demographic understood, and the limits of the underlying technology and budget made clear (de Freitas and Oliver, 2005). Only then can an appropriate pedagogic selection be attempted, and even in this case, iterative and user-centric design is essential to ensure an end-product which achieves the careful balance of engagement and instruction central to an effective serious game. Unique to ALICE is the need to apply an integrative approach with the Intelligent Web Teacher (IWT) system, a complete e-knowledge and knowledge management platform. Returning to the need for methodology to consider fully the context in which a serious game is deployed, and in particular how it is blended with existing resources, it is clear this overall integration must feed in to the overall design methodology. In particular, how assessment is undertaken and returned as feedback to learners is a central concern. The notion of content representation as complex collaborative learning objects (CC-LO)s must also be afforded consideration, and how collaborative elements are deployed either in-game, or as part of a broader community established through IWT. In terms of objective, we focus on the civil defense scenario, having described this in more detail in Section 2.4. Notable characteristics of this type of scenario are a need to change behaviour as well as imparting knowledge: often poor evacuation practices are a result of failure to react rather than lack of knowledge of best-practice. Our overall method, grounded in the iterative approaches of other development methodologies outlined in Section 3 (de Freitas and Oliver, 2005, Nadolski et al., 2008), as well as the iterative process common to game development (Boehm, 1986), is shown in Figure 7.

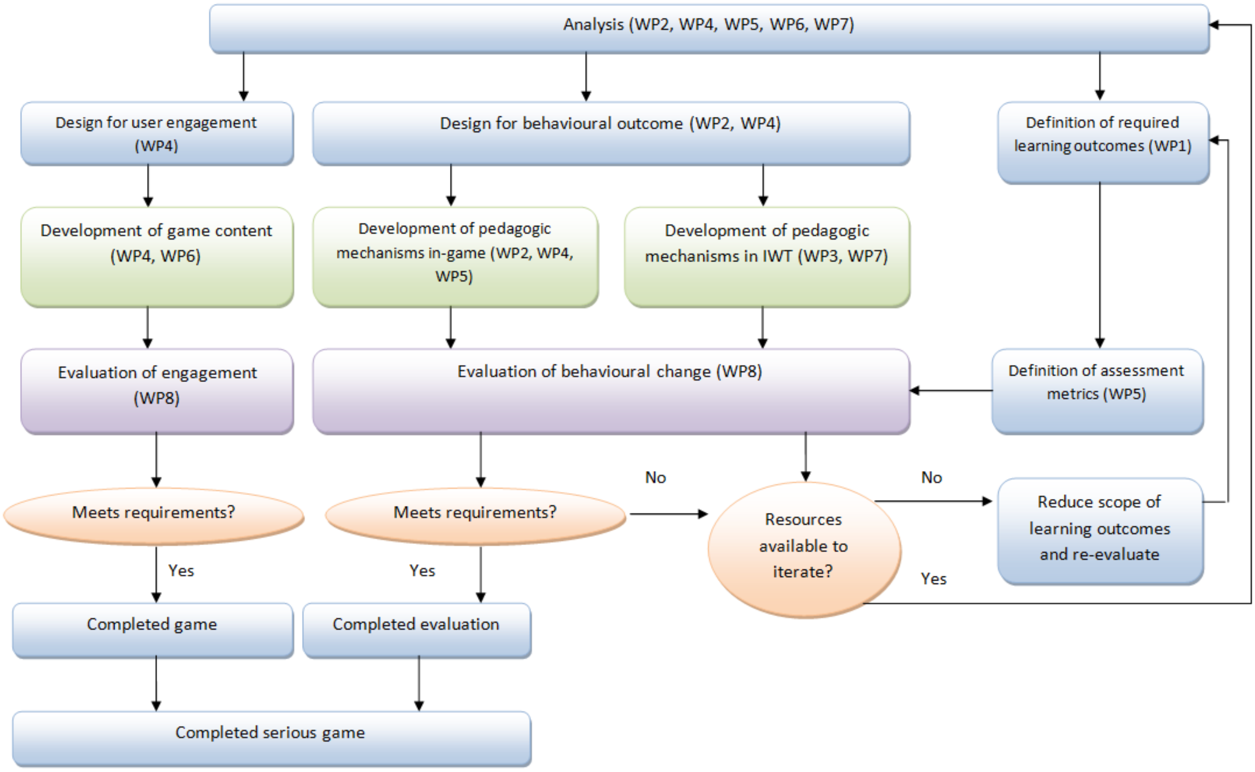

Figure 7: An overall development framework for a serious game within ALICE casts iterative design against a defined set of learning requirements

Analysis: We consider that in the case of ALICE, much early stage analysis, such as the use case, learner demographic, usage context, and several core pedagogic elements (such as CC-LOs and intuitive guided learning), have to an extent been defined in advance and feed in to the analysis process as constants. Furthermore, several aspects of the analysis are covered in other deliverables, and therefore it is not worthwhile repeating this content here. However, we do note the importance of rigorous analysis not only at the early stage, but throughout the development lifecycle. We consider also that the number of serious games created for civil defence, illustrated in Section 2.4, in part demonstrate the need for further interventions and innovations in this area.

Design: In the design phase, we **employ** a clear separation between the engagement and education aspects of game development, noting the tension between entertainment and pedagogy (Zyda, 2005). This has some immediate benefits in allowing core game content to be developed and evaluated with the simpler and more immediately measurable criteria of engagement in mind, such as, for example, the technology acceptance approach (Davis, 1989). Furthermore, it offsets and separates the pedagogic design into in-game elements, as well as the broader learning context, which in this case includes interactions with IWT. Yet this approach is not without its drawbacks: game content is inextricably linked to pedagogic model, and therefore each element of game content must be evaluated according to several criteria in order to qualify as separate from pedagogic design:

- **Is it realistically mutable?** The ideal serious game benefits from an unlimited budget and timeframe, and can therefore be infinitely iterated to reach perfection. However, in the real world, certain elements must be developed for which a change during the implementation process would carry unbearable costs. If an element cannot be changed, it is most critical this component stimulate engagement, because for reasons noted in Section 3, for a serious game which does not engage the learner, pedagogy is irrelevant (no players means no learning transfer). Similarly the requirements of the project dictate that some parameters, such as the learner demographic, are defined at the analysis stage.

- **Is it pedagogically salient?** (See section 5.2) Only elements of the game experienced by the user will contribute to its pedagogic impact. Underlying technologies may affect engagement, for example a poor frame rate or unstable core engine could detract from learners playing the game, but can be held separate to a degree from pedagogic design.
- **Is it possible to engineer the element to support dynamicism?** From a development perspective, it may be preferable to create the means to construct content (e.g. from XML), rather than provide the content itself. In the next section we describe a potential implementation of CC-LOs and adaptation to learner profiles sourced from IWT to facilitate such dynamicism. In this event, the pedagogic evaluation falls with the content used to generate game content (e.g. the CC-LO), rather than the algorithms used to construct the content. Therefore, to a limited degree, elements of the game can be 'offloaded' to pedagogic designers through provision of dynamic models for content, supporting the drive towards content creation tools which engage educators more readily in serious game development.

Content not meeting these criteria should fall under the pedagogic evaluation process. A benefit of this approach is that a degree of non-simultaneity can be introduced into the evaluation process: typically a game needs to be fully developed in order to be evaluated, and though our model does not avoid the need for a game to be fully-created to assess its behavioral outcome, pedagogic aspects do not need to be fully implemented to foster engagement. Therefore, the framework builds upon other approaches which have demonstrated that early-stage studies of user engagement with elements of the design (such as visual look-and-feel) can support high usage of the end-product independent of pedagogic concerns.

Development: In Figure 8 we illustrate a breakdown of the development process, using the classification criteria above, for the serious game developed within ALICE. In particular, we note the provision of scenario creation tools and information from IWT to drive the functionality to create a new scenario from a template. Hence, each time the game loads, the learner is presented with a scenario purpose-built for their learning needs. Similarly, the introduction of CC-LOs as objects created for general purpose within the game engine (e.g. a fire extinguisher), but with added pedagogic content, again tailored to the user through interface with IWT, allows for pedagogic dynamicism without requiring large investment in high-cost activities such as 3D modelling. CC-LOs may be updated at run-time allowing for collaborative aspects to be realised; learners can adapt and add to CC-LO content and compare their performance with other users, as well as consider collaboration and competition through reports produced by the game engine on completion of the scenario.

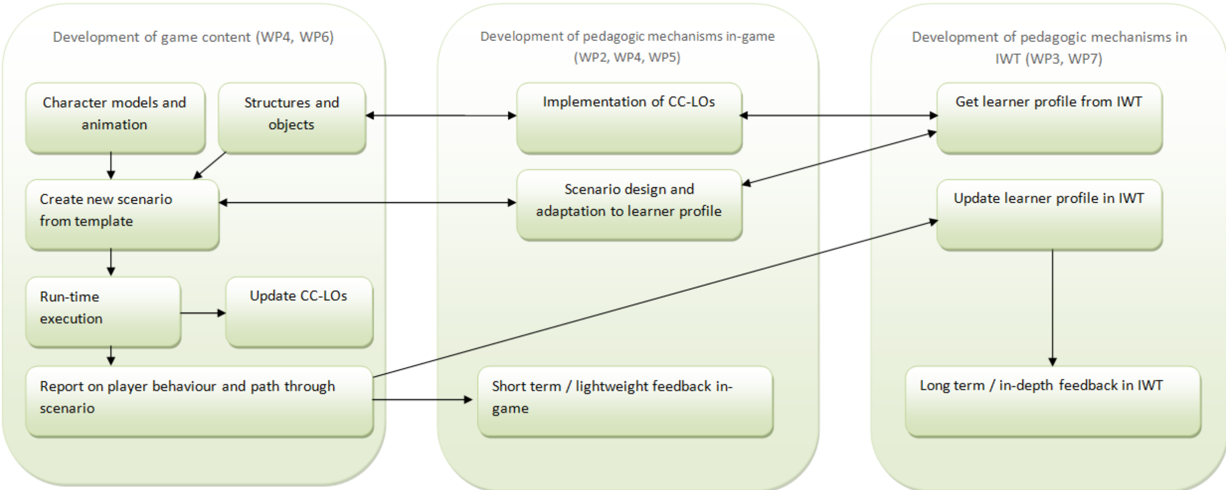

Figure 8: Breakdown of potential development activities

These reports on player behaviour, created by the game engine, are an essential component of the feedback process to learners. In Section 2 we noted the importance of effective feedback in game-based learning, and our conceptual framework takes a broad view to consider not only short term, immediate feedback in-game, but also how longer term, deeper feedback might be conveyed through the IWT system. This extends to include social and collaborative elements of learning: two learners could develop their understanding through interaction with a CC-LO during a single virtualised collaborative session, whilst their motivation is maintained by other elements at the IWT level. Potential mechanisms here could include leaderboards, online forums, or a trophy reward system.

Evaluation: Our analysis on the literature in Sections 2 and 3 led us to note the desirability of a separation between the assessment of engagement and behavioural change. We classify our learning outcomes in terms of behavioural change since this is the ultimate goal of any form of evacuation training (Chittaro and Ranon, 2009), particularly since, as described in Section 2.4, lack of knowledge is seldom the cause of suboptimal performance. We show in Figure 9 a potential breakdown of the analysis using a range of methods suitable to the context: in terms of engagement, this can be assessed through qualitative work at all stages which brings together members of the target demographic. Returning to the technology acceptance approach (Davis, 1989), focus within these groups around perceived usefulness, including questions such as “what would you think about playing a video game to practice evacuation?”, should be tempered by an understanding that the motivation of learners might be principally the gameplay rather than the underlying serious purpose: e.g. the question “do you think a game about evacuation would be fun?”, could garner a different response to queries about serious purpose, yet both could lead to high engagement.

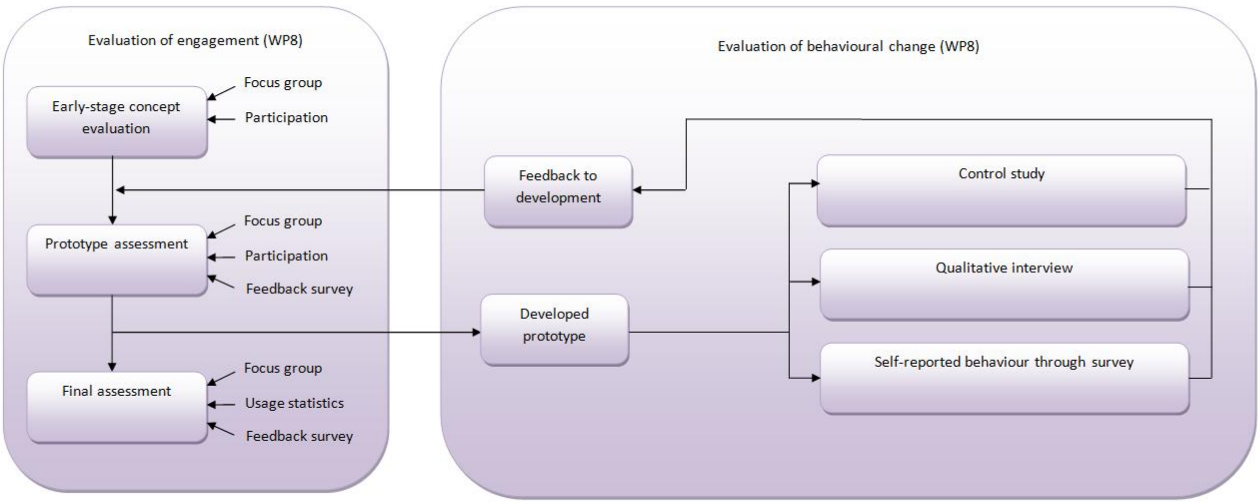

Figure 9: Breakdown of potential evaluation activities

Returning to the notion of participatory design, studies have suggested that participatory design is particularly effective with young age groups when developing serious games (Nousiainen, 2009). We suggest that participation can play a particular role in assessing engagement, since learners are typically able to answer very easily is something is “fun”. However, querying learners if something is educational is likely to result in a mixed response, requiring substantially more self-reflection amongst learners (Zyda, 2005). Participatory design in a serious gaming context must be carefully orchestrated so as to ensure the balance between gameplay and instruction is not compromised by learners more interested in developing a fun game than an instructional intervention (de Freitas, 2006). Surveys can provide a useful means to offset participation and focus groups and facilitate an inductive approach comparing multiple measures of potential engagement. Finally, direct usage statistics from the game engine can offer insight into the amount of time learners spend in game, and when combined with profile information from the IWT system, can allow usage to be linked to traits of learners such as age, gender, and ability.

With respect to the evaluation of behavioural change, we suggest three principal mechanisms may be viable:

- A **control study**, focused on comparing a group of learners with access to the game to one without. Though, it should be noted, to avoid a placebo effect, other trials have used a control (non-serious) game within the control group (Kato et al., 2008). The metric used in a control study should ideally be an objective measure of performance (e.g. time taken in a real-world evacuation drill), rather than a self-reporting survey, due to the deviation between reported and actual behaviour highlighted in Section 2.4.
- **Qualitative interview** should not be overlooked in any behavioural assessment, since it has the potential to gain deep insight into a small demographic, and can therefore by preferable where resources constrain ability to perform large-scale quantitative study.
- Analysis of learner perspectives through **self-reported survey** is also used in serious game evaluations; it can be used in a control study context as noted, but is not a preferable metric of learners due to the limitations of self-reporting in assessment.

In the next section, this report moves on to consider how intuitive guided learning might be specifically supported and implemented in pedagogic terms.

6 A pedagogic framework enabling Intuitive Guided Learning

Since an Educational Game is generally a combination of games and education, it seems appropriate to explore both dimensions for ensuring learning effectiveness researchers are still exploring multiple perspectives in designing games ranging from psychological theories, learning theories to game design theories basis. The field of education is still relatively new especially in local scenarios; hence, many localised studies are needed in order to generate more knowledge in educational games in the areas of educational game design, develofpment as well as its effectiveness among our students. As noted several times previously, the educational games research domain needs more empirical studies on its effectiveness towards education. Even though many researches on educational games have emerged lately, appropriate directions still lack to provide a less complex design that match with pedagogical requirements and multimodal perspectives. Our main intention is to develop an educational games design framework that combines these aspects: game design flow, multimodal perspectives, pedagogical requirements. The added value of the proposed conceptual framework is the capability to offer an environment strongly immersive where there is a mix between context’s element and high level cognitive process development.

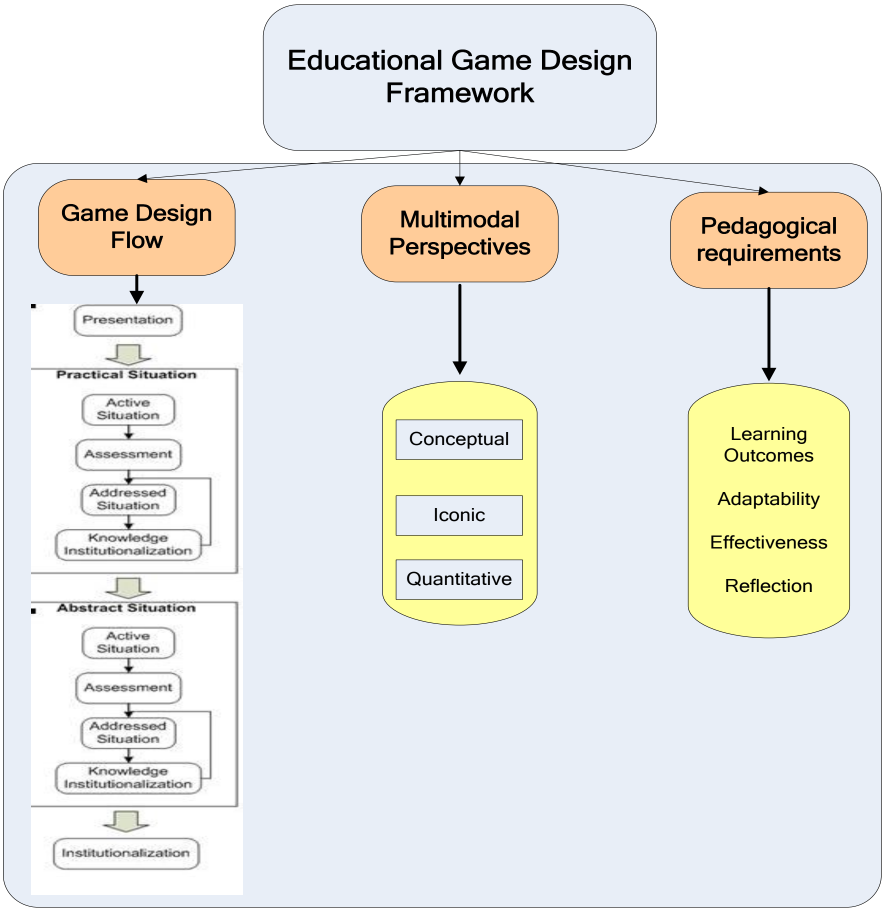

Figure 10: Proposed Educational Games Design Framework

The three factors, that define our framework, are mutually related. Indeed, the construction of an educational game must both answer to the pedagogical requirements and respect what it's defined in the corresponding perspectives (conceptual, iconic, quantitative). The first factor *Game Design Flow* has as focus the sequence of steps needed for building a game. The sequence is characterized by four macro-phases that allow passing from a concrete experience (*Practical Situation*) to a more abstract experience (*Abstract Situation*), in order to develop a level of understanding that allows the learner to transfer the acquired knowledge to other problem-solving situations and domains. The Game Design Flow discusses in detail three primary design goals that must be supported in order to enable students to learn. First the learning environment must support the acquisition of the domain knowledge necessary for understanding the model that drives the simulation. Second, it must support learners in discovery inquiry and experimentation skills, and at the same time attempt to correct common misconceptions and mistakes that may arise from prior knowledge. Third, the environment must provide adequate metacognitive, support to help learners' develop the ability to set goals, plan and execute solutions.

The first goal is realized through the *Presentation* phase that provides the description of the different steps of the game; the available technological features thanks to which the learner will be able to interact; a generic description of the concepts underlying the Educational Game. The second goal is obtained through the *Practical Situation* phase within the learner is submitted to an iterative cycle of hypothesis generation, assessment, regulation of learning and the acceptance of acquired concepts. The third goal is related to the generation of a metacognitive knowledge important for preparing the student for future learning. This it's obtained through the *Abstract Situation* phase where the simulation environment must allow the learner to think about the implications of this newly discovered model. In this phase will be developed the ability of learner to transfer the acquired knowledge to other situation. Indeed, this phase is characterized by a set up of the activities on an advanced level of abstraction.

In such a context the *Multimodal Perspectives*, characterizing the second factor of our framework, influence the Practical and Abstract Situations. In the specific, they impact on the game construction through the definition of the following scenarios:

- *Conceptual Scenario* will outline the experiment's evolution through a qualitative description including feasible interactions, expected results, a link to involved concepts (organized separately in a domain ontology) and, eventually, a link to related objects and resources;
- *Iconic Scenario* will be defined using an object oriented paradigm taking into account static aspects of the system (the subject and the object of the experimentation and its constraints) and a picture of the dynamic ones (state transitions as results of the specific actions);
- the *Quantitative Scenario* will include the mathematical model and/or the law underlying the simulation experience and necessary to its execution and evolution.

This factor is important for querying different perspectives of an Educational Game. For instance, an Educational Game could be retrieved by its objectives, its expected results, its single parts (the finer-grained objects composing the whole model), its graphical objects (possibly 2D or 3D shapes), its execution rules (possibly a mathematical model, a graph or a topic map, etc.), its elementary actions (transitions that conduct from a simulation admissible state to another admissible state). On the *Pedagogical requirements* factor, the focus is on how much the game will meet learning outcomes. For this objective, the game will be designed associated with a learning topic according to the needs of an individual student or student (sub) group. Pedagogical requirement are related to adaptability, effectiveness (motivation) and reflection for learning. These aspects are essentials and interconnected among them in experiential learning contexts. Concerning the adaptability, the expected heterogeneity from a social and motivational perspective as well as from the digital literacy level must be taken into account.

So, the adaptability concept is referred to the following aspects:

1. **Services and e-learning environments**: E-learning environment and services adaptability is needed to facilitate the matching of individual user needs and preferences with learning resources that meet those needs and preferences caused by any circumstance like learners' devices, environments, language proficiency or abilities.
2. **Learning activities:** An e-learning environment includes a large set of learning activities, which are usually made of set of learning objects. The learning activities will be this learning objects are presented to the learner should be done according to preferences, knowledge and skills of the learners to whom the learning activity is presented. In order to best respond to individual or group learning needs (changing content, way to present it, sequence, supporting activities, etc.).
3. **Personalised learning experiences**: Personalised learning environments are needed to enable learners to interact with resources when it is most appropriate for them. Therefore it is important to create a set of tailored (according e.g. to learners profile) solutions that help raise learning ability and improve the learning experience. E.g. at different locations and times learner should be able to connect to resources, peers and people at the institution and beyond, that are most suitable for them

In terms of effectiveness, the educational game design framework must:

1. **promote effectiveness and quality in teaching**: this is an overall pedagogical requirement, meaning that he use of technology must have an implicit added value for learning. This relates to the quality and effectiveness of the teaching process;
2. **promote and support personalised learning**: it is important to promote and support personalised learning, according to students learning domain, preferences, styles and other

related needs (e.g. accessibility);

3. **reduce the workload** (teachers, tutors, students and others): this requirement relates to the need of supporting all individuals involved in the learning activities or environment.

The framework must also induce reflection by supporting the process in which students link the feedback on their actions to the topic goal. This is important for promoting the overall understanding of the learning activity and for enabling students to reflect if they are performing the specified tasks or applying the learned concepts correctly.

7 Experimental method and results

The main aim of this section is to describe the functional, pedagogical and technological requirements of the Serious Game (SG) developed in the WP4 context and experimented into real life situations.

This is done to test and improve the defined methodologies and technologies.

7.1 Analysis of a Serious Game for Civil Defence Training in School

In this scenario, students of a course held in a secondary school were asked to deliver a complex learning resource (Serious Game) in order to learn the behaviour in an emergency situation (like a fire in a building).

The SG experimentation requirements are been analysed from different perspectives taking into account an "eLearning Cube" framework. (proposed by Paul Held, FIM-NewLearning, 2005)

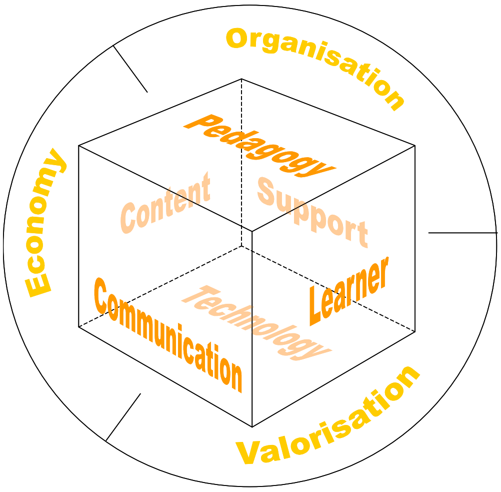

Figure 11: "eLearning" Cube Framework

For the learner perspective:

- gender, age, number, prior knowledge, cognitive style, learning style, motivation, aptitude to the game.

For content:

- learning objectives, knowledge creation, explicit/tacit knowledge, interactivity type, different levels of actions in the game.

For technologies:

- networks, bandwidth, hardware, software, authoring tool for editing and playing the game

For didactics/ pedagogy:

- experiential learning approach, quantitative/qualitative learner/learning evaluation.

For communication:

- communication styles, synchronous and asynchronous approaches, numbers of senders and receivers (one to one and peer to peer)

For support:

- machine support, ITS, human support, tutoring, technical support, embedded support, (virtual) community support.

The **Organisation shell** contains all actions to be taken, the embedding, quality management, course/learning management, quantitative/qualitative system evaluation.

The **Economy shell** would contain all aspects of learning and training economy (time, money, effort...), economy of scale, fix and variable costs, preparation and running costs.

The **valorisation shell** would contain the question: what is the outcome/added value (besides the learned) for the learner, how will the learning influence later life, career, certification, portfolio ..., and what is the outcome/added value for the organisation (exploitation, evolution, new opportunities, ...).

7.2 Serious Games Requirements

This section provides a summary of generic requirements that are been extrapolated from the specific experimentation activities.

7.2.1 Pedagogical Requirements

Developing any kind of e-learning environment or specific service gives rise to a number of pedagogical considerations. Any virtual learning activity must synthesise the functionalities of a computer-based system, including communication and cooperation facilities, with adequate pedagogical and didactical methods for e-learning. Both aspects must be considered, developed and adapted in accordance with the needs of the learners, users and organisation using/providing the learning environment. Accordingly, the pedagogical requirement must reflect in a first place a combination of users requirements (all persons and organisations with a specific role within the e-learning environment) with the educational objectives (defined by institutional programmes, teacher, etc.) and pedagogical awareness. In a second step pedagogical requirements must take in consideration the technical opportunities but also the constraints. This process requires a careful and intensive dialog between technical researchers, pedagogy experts and persons in charge of the learning environment deployment

The pedagogical requirements emerged from the SG analysis and specification process.

The main focus of the Serious Game is to increase effectiveness and quality in e-learning supported educational processes. In a first specification process the SG stated the need to support constructivist, experiential and collaborative approaches to learning as a way to improve effectiveness in the e-learning teaching and learning process. Furthermore the SG looks for ways for improving the quality and variety of teaching and learning that are not being achieved using current methods, tools and services.

Finally, it is important to stress out that technology is as good and powerful as it can be hidden from the learner.

Aspects related to the adaptation of contents and didactic methods (and approaches) according to learner's preferences have been tested and evaluated in the real contexts. The activities have been focused on individualised learning with additional collaborative activities (synchronous and asynchronous) for supporting the educational process.

The following table shows the pedagogical requirements derived by the experimentation activities leaded in the WP8:

Requirement	Explanation
Effectiveness	
Promote effectiveness and quality in teaching	This is an overall pedagogical requirement, meaning that the use of technology must have an implicit added value for learning This relates to the quality and effectiveness of the teaching process.
Reduce the workload (teachers, tutors, students and others)	This requirement relates to the need of supporting all individuals involved in the learning activities or environment . Reduce the workload of teachers in order to (related to reusability) reduce the authoring and administrative burden on teachers /tutors, thus allowing them to give more time to individual students educational needs.
Promote effective ways of learning	One of the main innovations and advantages on using technology enhanced learning environments is the increment of effective learning, which can be improved by supporting personalised an individualised learning as well as by promoting the effectiveness of group-working
Promote and support personalised learning	It is important to promote and support personalised learning, according to students learning domain, preferences, styles and other related needs (e.g. accessibility)
Adaptability	
Adaptive services and e-learning environments	E-learning environment and services adaptability is needed to facilitate the matching of individual user needs and preferences with learning resources that meet those needs and preferences caused by any circumstance like learners devices, environments, language proficiency or abilities.
Learning activities adapt to the needs of an individual student or student (sub-) group	An e-learning environment includes a large set of learning activities, which are usually made of set of learning objects. The way this learning objects are presented to the learner should be done according to preferences, knowledge and skills of the learners to whom the learning activity is presented. In order to best respond to individual or group learning needs (changing content, way to present it, sequence, supporting activities, etc.).
Personalise learning experiences to learner / groups	Personalised learning environments are needed to enable learners to interact with resources when it is most appropriate for them. Therefore it is important to create a set of tailored (according e.g. to learners profile) solutions that help raise learning ability and improve the learning experience. E.g. at different locations and times learner should be able to connect to resources, peers and people at the institution and beyond, that are most suitable for them
Individualise learning experiences learner / groups	This requirement is very important in order to address the needs of an individual learner by adapting the learning environment to the individual requirements. This is important to uniquely identify learners, promote mass customisation of content, monitor, support and assess learners individually and effectively
Interactivity	
Learning resources and objects must be investigated by the learner according to his preferences and needs	Learning resources and objects must be investigated by the learner according to his preferences and needs. The use of meaningful interactive learning resources that are responsive to learners, allowing them to actively participate in the learning process arises interest and generates motivation providing a more engaging experience for the learner.
Navigational elements (to extern and intern	Navigational elements such as hyperlinks are needed to investigate other internal and external resources, supporting the active learning process.

sources)	
Resource interaction	Resource interaction it is needed to promote an effective use of learning resources and facilities integrated in e-learning environment, e.g. unit of learning linked to communication and collaboration resources (e.g. forums, instant messaging, collaboration services, etc.).
Reflection	
Support the process in which students link the feedback on their actions to the topic goal	Important for promoting the overall understanding of the learning activity and for enabling students to reflect if they are performing the specified tasks or applying the learned concepts correctly.
Provide meaningful intrinsic feedback	Provision of meaningful intrinsic feedback is important for influencing effective learning outcomes
Formative assessments	Formative assessment will allow skills and knowledge acquisition to be noted, reflected upon, and developed in a continuous manner.
Support offline activities	This is important for learners that in certain situations, due to different reasons, do not have internet-access.
Tutor / teacher can easily provide further supporting LOs	This is a very general pedagogical requirement, which is important for every pedagogical session. It promotes the quality of learning, supports individualised learning, increases motivation and enhances learning outcomes
Didactic	
Present of the content in different modes	Presenting the content in different modes facilitates the transfer of knowledge and skills in long-term memory
Promote intrinsic motivation	This is an essential thing for learning, only a motivated learner is able to learn
Promote active investigation of the learning resources	Active investigation of learning resources arises interest and generates motivation, resulting on a more engaging experience for the learner and a deeper learning understanding.
Promote confidence	Decreases fears, increases motivation and promotes learning.
Allow learners to apply the new knowledge in real-life situations	Important for promoting learning transfer and confidence
Inform learners about the relevance of the learning activity (e.g. real life situations)	Important for increasing motivation and confidence
Monitoring	
Teacher / tutor can track the individual progress of the learners, can monitor discussion threads, check assignments	In an e-learning environment the teacher (or tutor) is not always present while the learning is performing certain activities . Therefore it is very important that the tutor/teacher has access to different activities of the learner to monitor his/hers progress, and if necessary provide further support. The stages at which the tutor has access to defined learning activities must of course be communicated ahead to the learners, in order to avoid incertitude and

return, etc	fear of being observed.
Learner can track his/her own progress	The learner himself gets information on this activities path, has access to his
Build learner profiles upon explicit (e.g. tests, questionnaires) and inferred sources (behaviour).	This is important to have a ore truthful profile of the learner

- **Effectiveness:** the quantitative and qualitative data, used in the experimentation context for analyzing the SG results, have shown that the SG has allowed the efficient transmission of lesson learned inside the learning experience on the theme of the risk management.

- **Adaptability:** The learning path is delivered taking into account learner previous knowledge and preferences. In such a way personalized courses has been delivered allowing each learner to learn only required concepts through the most feasible learning resources.

- **Interactivity:** A peculiar characteristic of the SG delivered by each student is its interactivity. Indeed the learner can manipulate the scene of the game through specific buttons of Play, Stop, Restart, and fix the specific point of view of the game.

- **Reflection:** The game includes an assessment phase that induct the learner to reflect on the game's purpose. A tutor is also foreseen in order to help him in the discover of the specific learning knowledge.

- **Didactic:** The learning objective has been shown in different modalities: as a game resources for experiential student and as a .pdf file for the control game in order to facilitate the transfer of the knowledge and the skills in the context of the risk management.

- **Monitoring:** The teacher or tutor can track the individual progress of the learner, through a specific report associate to the SG resource.

7.2.2 Contextualisation of the Educational Games Design Framework through the SG

The defined Serious Game allows to validate the Educational Games Design framework quoted in the previous section:

- **Phase 1: Presentation, Experiment**
  A specific message has introduced the student to the game related to some instructions before to start the interaction with the game
- **Phase 2: Practical Situation**
  Active Situation
  - scenario involves
    - execution modality of the simulation.
    - other parameters involved.

Assessment (related to the specific scenario)

- Students will fill out questionnaires immediately after the SG is over.
  - Questionnaires aim at figuring out both:
    - Level of user experience and overall satisfaction
    - Level of intrigue
    - Level of collaboration –and communication- achieved
    - What exactly did the students learn from the SG
- **Phase 4: Abstract Situation**
  Inductive discovery of various phenomena
- **Phase 3: Knowledge Institutionalisations**
  The correct relations between the variables in question are presented by the tutors via the com channels

Accessibility

The developed SG allows for learner/tutor access to it at any time, from any place.

Experiential aspects

SGs promote experiential learning (learning by doing) by allowing users by themselves or through collaboration with others to test and run a SG, changing a number of parameters to affect the experiment behaviour and results, and thus learn in the process.

Personalisation aspects

During a SG session, all students get the same information, perform predetermined experiments by utilizing the SG tool and are led through the process by the system in a non-personalized manner. However, personalization aspects are applicable in cases of prior or afterwards access to SG content through the use of the respective online e-learning services. Execution of a SG at other time instances than the actual experimental class session, are personalized based on learner or group of learners profiles. That is, a leaner may be guided in a different manner through re-executing the experiment online, or through retrieving information about it based on his preferences and competencies. Material is displayed to the learner based on his preferred style.

8 A methodology for intuitive guided learning

In this section, we combine the conceptual work described in Sections 2-6 with the experimental outcomes in Section 7 to propose a concrete methodology built around the notion of enabling an "intuitive guided" approach to learning. This is novel in two respects: firstly in the definition of the "intuitive guided" pedagogic approach, which draws upon established psychological theories to posit this method as particularly salient to emerging generations of learners, and secondly in the methodology it proposes for enacting this in practice. As a result, we consider carefully the experimental outcomes in Section 7 to propose how technology might be used to facilitate intuitive guided learning, and outline the requisites of effective experience design under this technique.

8.1 Why use an intuitive guided approach?

A key motivator behind the use of an intuitive guided approach is the increasing tendency for users to demonstrate an intuitive approach to learning (Kolb, 1984). Under such an approach, learners explore possibilities and potentials through correct and incorrect actions, and as such require environments and technologies which are non-linear and non-sequential in nature. A causal factor of this shift is the emergence of digital devices and technologies with high tolerances for user error, coupled to intuitive interfaces. In an environment where gaming is increasingly the norm (ISFE, 2010, Pratchett, 2005), it is natural to explore pedagogies based around non-linear and engaging experiences, addressing the increased disengagement of students with traditional and more didactic methods of instruction.

Inclusivity, however, must also be considered: under Kolb's typology (1984), other types of learner exist: assimilating learners might not approve of the high degree of input required for game or simulation based learning; drawing from other models of learning style (Felder and Silverman, 1988), a number of key principles are suggested. Table 1 demonstrates a mapping of these principles to learner types and serious game design considerations. It can be observed that two of Felder's considerations are addressed substantially by the integrative approach of the ALICE platform, and in particular by WP7's integration techniques which allow games to be structured and sequenced identically to other learning objects. Therefore a clear benefit of the ALICE platform can be seen in these two areas. The remaining areas imply a certain approach to serious game development; the traits suggested here to be efficacious include using the game to enable learners to apply and rehearse knowledge, rather than as the principal source of knowledge acquisition. The reasoning here is that the low levels of Bloom's established model (Bloom et al., 1957), knowledge and comprehension, are well addressed by direct and didactic learning approaches; to teach a fact, presenting this fact to learners didactically can be a highly effective approach (Pollak and Baker, 1988). Game-based learning might therefore be best considered in the higher levels of the model, which begin with the application of knowledge by the learner, and proceed through levels of analysis and synthesis. If we consider games which exclusively support intuitive learners, then key to their design and development are simulative components of action-reaction. Important for efficacy are internal consistency within these simulations, as well as facilitation of learning underlying principles though either a blended method or other form of knowledge transfer: in effect this principle is stating that the lowest levels of Bloom's model must be met prior to gameplay.

Learner type	Teaching Method (Felder, 1996)	Serious Game Principle
Sensing, Inductive, Global	Teach theoretical material by first presenting phenomena and problems that relate to the theory (sensing, inductive, global).	Use the game as a vehicle for the application and rehearsal of knowledge rather than a primary method of knowledge acquisition.
Sensing, Intuitive	Balance conceptual information (intuitive) with concrete information (sensing).	Abstraction in games should be complemented by consistency in action-reaction.
Visual	Make extensive use of sketches, plots, schematics, vector diagrams, computer graphics, and physical demonstrations (visual)	Apply and consider visual elements fully.
Sensing, Intuitive	To illustrate an abstract concept or problem-solving algorithm, use at least one numerical example (sensing) to supplement the usual algebraic example (intuitive).	Simulate and visualise action-reaction as well as conveying the underlying process through a blended approach.
Sensing, Global	Use physical analogies and demonstrations to illustrate the magnitudes of calculated quantities (sensing, global).	Demonstrate the outcome as well as the process in-game.
Inductive	Occasionally give some experimental observations before presenting the general principle, and have the students (preferably working in groups) see how far they can get toward inferring the latter (inductive).	Present problems beyond the learner's zone of proximal development (Vygotsky, 1978) and support them in expanding this zone through blended or social approaches.
Reflective, Active	Provide class time for students to think about the material being presented (reflective) and for active student participation (active).	Utilise feedback and scaffolded reflection in a substantive manner both within and outside the game.
All	Encourage or mandate cooperation on homework (every style category).	Facilitate cooperation on homework through the provision of social and collaborative technologies (e.g. Intelligent Web Teacher and WP7 within ALICE)
Sequential, Global	Demonstrate the logical flow of individual course topics (sequential), but also point out connections between the current material and other relevant material in the same course, in other courses in the same discipline, in other disciplines, and in everyday experience (global).	Support a structured and sequential presentation of game based learning content, again as facilitated through Intelligent Web Teacher and WP7.

Table 1: Mapping of learner types to teaching styles (Felder, 1996), and subsequent implications for game-based learning

8.2 Technology as a facilitator

A key rationale for considering an intuitive guided approach to learning is the enabling role technological developments have played in allowing immersive, exploratory learning environments to be visualised and interacted with by learners. Virtual worlds can now encompass large areas of terrain or detailed structures, and allow real-time interaction and navigation of these environments. Appropriate use of these technologies can allow learners to gain new perspectives, insights, and reflect on various solutions to a problem (Anderson et al., 2010, Annetta et al., 2006). These technologies are increasingly facilitating the implementation of pedagogic approaches which explore less didactic approaches to instruction, for example social or experiential learning. In the case of social learning, a particular dimension of the learner experience advanced by technology is the ability for peers to communicate in a variety of forms, such as using chat or web forums, and not requiring physical co-presence to interact. This has a subsequent impact on learners' sense of identity (Bricker et al., 2008), with the ability to develop new identities on web forums or in a virtual space impacting collaboration and competition (Ward and Tiessen, 1997). Similarly, for experiential learning, the ability to recreate scenarios with increasing levels of fidelity positively impacts learning transfer (Allen et al., 1986), particularly when compared to classroom or tabletop activities

Evident, therefore, is the fact that the evolution of technology is enabling a far broader range of pedagogic and instructional approaches to be considered and implemented than were previously viable. It is for this reason that research must focus on evaluating independently these emerging technologies and contrasting them to existing approaches. Yet such contrast is challenging to achieve in certain terms; the individual characteristics of tutors and learners can have a strong impact on the efficacy of any learning programme (Smet et al., 2010), and reaching context-independent results confirming the validity of one technique over another is subsequently a difficult undertaking. In lieu of this evidence, it is centrally important to consider and develop for tutors as well as learners. Learner-centric approaches to serious game development, or indeed any technology-assisted or -enabled educational process may risk overlooking the benefits of including the tutor in the information flow of the system (Egenfeldt-Nielsen, 2005). In the particular case of feedback, it could be asserted that technology feeding back to a tutor, who can then validate, verify and deliver this feedback to a learner in a supportive and probing form, is likely to prove more effective than providing summative feedback to the learner themselves. A particular benefit of such an approach is the oversight the tutor is subsequently empowered with, being able to identify common areas amongst students where knowledge is lacking or behaviour is incorrect.

This does not mean direct feedback to the learner from the game need necessarily be discarded, rather that the role of technology as a facilitator should be taken in literal terms - it eases, rather than replaces, conventional interactions between students and tutors. A Socratic method of instruction, whereby individual student and tutor interactions are the principal form of learning transfer, is restricted in use by pragmatism and available tutor time, rather than an inherent advantage possessed by other, more complex theories of instruction. In implementing intuitive guided learning, this particular principle comes to the forefront. Implemented within ALICE are virtual characters with dialog driven AI (D5.1.2, D4.3.1, D4.2.2), yet the most sophisticated AI can only hope to emulate to a limited degree the support and emotional involvement that can be afforded by direct student-tutor interaction. Yet an increasing need exists in European society with demand for learning and limited resources for teaching to provide these solutions which allow large-scale distributed learning which gains in accessibility what it loses in efficacy. In the next section, we describe how technology facilitates the construction of an intuitive guided learning experience.

8.3 Constructing an intuitive learning experience

In this section, we reflect on the case study work within ALICE creating a game for civil defence. Individual simulative components of the game and their construction and reuse are covered in detail in D.4.2.2, therefore, in this deliverable we focus on the relationship of the game to intuitive learning, leading to our definition of an intuitive learning pipeline in Section 8.4. Table 2 reviews how the principles presented in Section 8.1 are reflected in the ALICE prototype. Notable from this is that all styles of learning presented in Table 1 are considered, though a priority is placed on supporting the aspects most relevant to intuitive learners. Important also is the introduction of the learning content management system at the heart of ALICE (Intelligent Web Teacher or IWT) to support principles which cannot readily be supported by the use of the game alone. The use of simulation and simulative content is capitalised upon heavily to enable these characteristics, and it can therefore be asserted that any game which would seek to implement an intuitive approach as described by this deliverable should include some simulation of environment, action, or experiment, though this may be abstract rather than realistic in form. Abstraction has merits in making complex concepts and structures more readily accessible to learners, though the trade-off is an increased need for scaffolding of subsequent reflection and application of these concepts in real-world applications (Kolb, 1984).

Essential then at the first stage of constructing an intuitive guided experience is a consideration of the degree of abstraction, achieved by relating the capacity of learners for proximal development (Vygotsky, 1978) to the complexity of the task. Though not a comprehensive solution consideration of Bloom's domains (Section 2) may be a useful undertaking to create a broad-stroke understanding of task complexity and suitability for a more abstract approach to instruction. The crucial design activity here is a decision over whether the complexity of the scaffolding or learner guidance that would be required to support a more abstract approach is validated by either the increased learning transfer that would be expected to result, or the reduced cost associated with a less complex simulation. However, whilst it is true abstraction can be used as a pragmatic necessity - for example, a real-world evacuation scenario would allow a great deal of freedom of choice to the individual evacuee, and supporting all potential behaviours within a game or virtual world would be prohibitively complex (Chittaro and Ranon, 2009) - such pragmatism should be carefully managed against required learning outcomes. This early stage activity should consider fully the appropriateness of a game as a method for learning, and its role within the wider blended context rather than as a standalone solution.

Another useful design activity is a consideration of the items presented in the first column of Table 2 for the individual implementation of intuitive guided learning being undertaken. Difficulty in conceptualising these elements for a given solution is potentially indicative of subsequent complications in the design phase and may suggest a game-based approach is not ideal for the given task or problem presented to learners. Game-based learning may not be precluded in this case, though its scope and application should be reconsidered. In the example in Table 2, facilitation of cooperation and structured and sequential presentation of game content are offloaded to the responsibility of the IWT platform. In more complex game-based learning approaches, it would be equally valid to offload elements of this design to a tutor's role, or additional pedagogic and technical elements. The ultimate goal of this exercise is to identify the relevance of the task to game-based learning, and express in a validated pedagogic fashion the underlying design and objectives. As can be seen from Table 2, in the case of the prototype devised within ALICE, such an exercise is straightforward, primarily a result of the close synergies between evacuation training, simulation, and subsequently serious games (Chittaro and Ranon, 2009).

Serious Game Principle	Practical Implementation in ALICE WP4 Prototype
Use the game as a vehicle for the application and rehearsal of knowledge rather than a primary method of knowledge acquisition.	Direct knowledge of evacuation principles and procedures is assumed prior to gameplay. Players rehearse and apply this knowledge in a simulated evacuation.
Abstraction in games should be complemented by consistency in action-reaction.	Elements of the game deviate from realism due to either the limits of the simulation (e.g. fire does not spread), or to extend the scenario to create a more challenging evacuation than would likely be experienced in practice (e.g. a large number exits are blocked). However, core mechanics leading to success and failure, such as the avoidance of smoke, yield consistent results in response to player actions.
Apply and consider visual elements fully.	A high-fidelity solution is used which implements a 3D virtual world with lighting effects, shadow, and detailed content. The intent is to provide a game recognisably similar to entertainment games.
Simulate and visualise action-reaction as well as conveying the underlying process through a blended approach.	Actions such as crawling through smoke result in reduced exposure and increased time to suffocate
Demonstrate the outcome as well as the process in-game.	The ultimate outcome of the evacuation can be either success, or failure as the player is overcome by smoke. In both cases, feedback is given on performance.
Present problems beyond the learner's zone of proximal development (Vygotsky, 1978) and support them in expanding this zone through blended or social approaches.	As a single scenario, problems will only be beyond proximal development if the learner lacks knowledge. Hence to score highly in the game they will need to expand this knowledge. Integration with IWT makes supporting material readily available; in the longer-term adaptivity to individual learner profiles could further enhance the ability to present problems outside the ZPD.
Utilise feedback and scaffolded reflection in a substantive manner both within and outside the game.	At the end of each round of the game, the player is presented with summative feedback on performance. Integration with other ALICE technologies (WP5) creates more detailed and extensive feedback outside of the game.
Facilitate cooperation on homework through the provision of social and collaborative technologies (e.g. Intelligent Web Teacher and WP7 within ALICE)	IWT integration provides access to social technologies such as forums (WP3) and collaborative wikis (WP5), which learners can use in informal learning contexts. Provision of complex collaborative learning objects (WP3) further enhances support for collaborative learning.
Support a structured and sequential presentation of game based learning content, again as facilitated through Intelligent Web Teacher and WP7.	Encapsulation of the game as a Learning Object provides the foundation for a method for structuring and sequencing game-based learning objects whilst integrating them fully with existing non-game based learning content objects.

Table 2: Mapping serious game development principles for intuitive guided learning (Table 1) to practical implementation examples in the ALICE WP4 prototype.

8.4 The intuitive learning pipeline: designing for efficacy

In the previous section, a range of initial considerations for the implementation of an intuitive guided learning approach were presented. Assuming these considerations validate the use of a game-based approach to creating an intuitive-guided learning experience, in this section a pipeline for constructed a game based around intuitive-guided learning principles is introduced. In defining this pipeline, both experimental results (Section 7) and overall methodological considerations from background literature (Section 3) are applied. Through the pipeline the roles of learner and tutor are encapsulated in an iterative cycle drawing upon established methods of software development (Boehm, 1986). Unique is the segregation of game and pedagogic design and the emphasised need for early iteration towards the subsequent integration of both these components amongst game and instructional designers. Before technical development works starts, agreement should be sought from both instructional and game designers that the solution will likely fulfil both the requirements of engaging game and effective instructional tool. However, as described in Section 8.3, blending may be applied or careful scoping of game-based elements so as to define their use for conveying specific elements of content or as a motivational tool.

Emphasis is also placed on the development of an early prototype with which to assess learner response. Quality in assessment of this response is crucial (see Section 4). Positive self-reported response may not reflect an effective learning solution, as a game may be enjoyed without having pedagogic value. Similarly, a more negative response from learners could be indicative of comparisons to entertainment games, an arena in which a serious game is likely to struggle given limited development budget and greater freedom in design. In a context where a game is deployed for use in learners' leisure time, this is a principal concern; however, for classroom education, engagement may be better compared to existing resources rather than entertainment media. This example demonstrates the impact context can have on the efficacy and learner response to a solution. Comparing perception of usefulness and usability amongst tutors and learners can be an important indicator of subsequent uptake, though ultimate metrics of learning transfer for more complex cognitive goals is universally difficult to assess. Given the difficulties in creating valid samples for quantitative approaches such as control studies, a consequence of the impact of individual tutors, sites, and interactions between groups, qualitative methods are likely to prove the most pragmatic methodology for this assessment.

Section 3 introduced the notion of the game as a research instrument, and this is also strongly advocated by the intuitive guided pipeline introduced in this section. Again the role of the tutor is considered here in their ability to interpret the data captured. This can be essential in defining the methods used in the completed solution for capturing and reporting learner progress in a form which can be supported effectively by an informed tutor. Raw data formats such as XML may prove unsuitable for this task, requiring visualisation tools, text outputs, or other automated forms of reporting to be considered. Simultaneous development of these tool as a method for the assessment of efficacy required for effective iterative development, and as a component of a finalised solution for game-based learning, is a worthwhile consideration. A final consideration at each stage of iteration is the need to relate back to the initial learning requirements and consider if subsequent iteration is a valid approach for fulfilling these requirements. If this is not the case, then reducing the role of the game and investing more in supportive technologies or alternative methods may prove the most efficacious route to a learning solution.

An effective methodology should not only consider guidelines for best implementing it in a game-based fashion (Table 1), but also how to ensure its efficacy through techniques such as those shown in the development and evaluation methodologies put forward in Sections 3 and 4. Fundamentally this must be an iterative approach which seeks to analyse and learn from the responses and acceptances of learners and tutors.

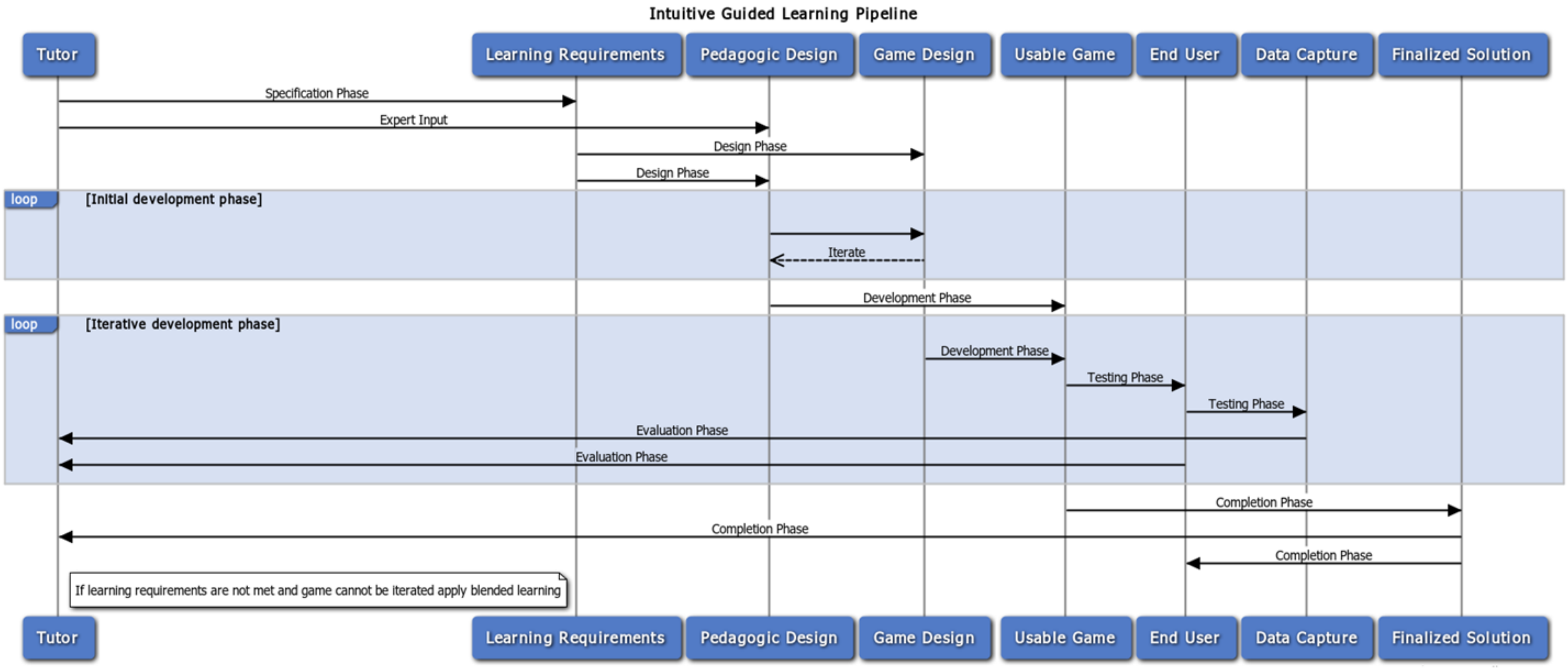

Figure 12: An Intuitive Guided Learning Pipeline for Serious Games

9 Implementation Guidelines

In Section 8.4, we note the need to design for an efficacious learning experience, else risk delivering an approach which offers little benefit – and considerably greater cost – than a more traditional pedagogic approach such as classroom instruction. Ensuring this design requires careful consideration at all stages of best-practices for implementation, delivery, and blending. Drawing on experiences within ALICE, we hence outline in this section the key considerations in implementing an effective intuitive guided learning experience.

9.1 Understand intuitive learners

From Jungian theory, intuitive learners emphasise possibility in their learning, considering a range of ideas and possibilities when addressing problems, and exploring potential outcomes (Jung, 1921). Abstraction, imagination, and prediction all feature heavily in intuitive learners' behaviour. Traits of these learners commonly cited (Jung, 1921, Kolb, 1984) include:

- Preference for abstraction and theoretical work
- Tendency to examine phenomena at a macroscopic level
- Appreciation of new challenges and situations
- Preference for short session work and segregation of tasks

Immediate parallels to the sandbox open environments games might provide can be observed, as can the appreciation intuitive learners might have of the abstract ways in which games can present pedagogic content (Brdiczka et al., 2005). Areas of education such as mathematics have particularly benefitted from the use of abstract and immersive virtual environments for intuitive learning (Lai and Sourin, 2011), as have other numerical and scientific disciplines such as mathematics (Squire et al., 2004). Hence, it is straightforward to map the preferences of intuitive learners as expressed by both Jung and Kolb to the characteristics of serious games. However, more essential is the consideration of the subsequent response of intuitive learners, and how games might be better designed to capitalise on these strengths whilst remaining inclusive. Consider for example the contradictory traits of sensing learners:

- Focus on immediate actions and reactions
- Learn through observation of surroundings
- Use of experience and knowledge to solve problems
- Practical and rational approach to activities

An interesting observation here is that the sensing type of learner relates directly to Kolb's experiential model (Kolb, 1984), which is frequently applied as a basis for simulation-driven education (Mautone et al., 2008). They learn through experience, reflecting and developing knowledge to increase their skills. Contrast this to the intuitive learner, who emphasises more adaptivity and improvisation to address new challenges rather than relying on learnt processes and causal chains. Both learners might be supported by a serious game implementing a virtual world which allows exploration coupled with problems that can be solved by the application of learnt knowledge, though does a benefit exist in favouring one approach? Critiques of the learning style theories presented by Kolb are numerous (Reynolds, 1997), with particular evidence considering whether these manifest themselves through teaching style as opposed to intrinsic traits of learners (Pashler et al., 2009). If, as the meta-analysis of Pashler et al. suggests, evidence fails to support the typology being inherent to learners and hence no measurable benefit emerges from the tutor adapting delivery to suit the type of each student, then difference instead must emerge from intrinsic contextual or representational benefits for a given approach.

Understanding intuitive learners, then, is less a case of focussing on the group of students who will respond well due to a measurable typology, and instead appreciating the capacity all students have to learn through an intuitive approach. Emphasis within the approach for intuitive guided learning advocated by this deliverable must therefore be placed on creating solutions which capitalise on the suitability of games to deliver intuitive learning whilst acknowledging the capacity of learners to respond to an intuitive model to a greater or lesser degree. Inclusivity hence becomes less a matter of supporting a sensing approach to learning, and more one of realising the intuitive approach as effectively as possible so as to reach all learners in a meaningful fashion. To this end, heed should be paid to the general principles of technology acceptance (Davis, 1989): games must be perceived as both useful and easy to use. Ease of use relates to the design of the game and its user interface, and is relatively easy to assess through user response and performance. In particular linking learnt knowledge to game performance pre- and post- hoc provides an ideal vehicle for assessing whether knowledge of learners is accurately reflected in their performance in-game, and if not, considering the relationship this might have to ease of use and the ability of learners to demonstrate this learnt knowledge.

Usefulness can be a harder issue to address, particularly as the nature of games can lead to them being perceived as a trivial or entertainment device rather than a meaningful learning aid (Burke et al., 2010). The role of the tutor can again become essential here, as can the fashion in which the game is introduced (Kelly et al., 2007). Returning to the nature of intuitive guided learning described at the start of this section, it could prove more effective to deliver games as smaller, independent elements of a blended course, and studies have suggested greater efficacy when feedback is segregated into multiple smaller components (Jarvis and de Freitas, 2009). The appreciation of new challenges and situations by intuitive learners might then be capitalised upon to introduce the game as a novel approach to allowing them to apply their knowledge. Noting that the acquisition of this knowledge may be sourced from outside of the game, a particularly compelling case exists for the development of games which seek to provide a means for learners to apply and rehearse knowledge, rather than as a principal vehicle for knowledge acquisition. This does not necessarily imply elements of knowledge cannot be imparted within the game; rather that the overall compelling nature of the gameplay design should be built upon to allow learners to develop their skills rather than obscured by fact-based or other forms of learning at the lower levels of Bloom's taxonomy (Bloom et al., 1957). Taking these points into consideration, effective serious game design should consider the strengths of game-based learning as a medium when developing for the four traits of intuitive learners presented at the start of this section. However, learner expectations must also be managed to ensure perceived usefulness for the developed solution. Here technical considerations present themselves in the need to create inclusive solutions. In the following section, these themes are discussed in more detail, leading to the need for an iterative cycle to be implemented as described in Section .3

9.2 Match learner expectations of fidelity to the requirements of inclusivity

With between 70-99% of individuals under 30 surveyed across Europe identifying themselves as 'gamers' (ISFE, 2010), widespread reach of entertainment gaming across genders and cultures is increasingly being demonstrated. Yet along with the increased engagement with serious games this brings, learners are also approaching serious games with greater expectations of fidelity and engagement - the novelty of interactive technology can no longer be relied upon alone to enthuse and engage learners (Prensky, 2003). Whilst serious games introduced in lieu of existing instructional media may benefit from comparison to the existing low-fidelity medium rather than entertainment games, particular cases such as public health interventions which seek uptake during leisure time as an alternative to an entertainment title face particular challenges in user acceptance and engagement. Significantly, the desire to create high fidelity experiences using simulative content such as that detailed in D4.2.2 must be offset against the need to provide games which work in a scalable and cross-platform fashion where required. This can require a careful balance between providing an experience with sufficient fidelity for the learner to draw comparison to entertainment gaming, whilst also delivering this experience on a platform which can be accessed on low specification hardware. Classroom education is a particular case in point; as experimental results outlined in Section 7 suggest, dedicated graphics hardware is unavailable in many classroom desktop PC environments. Particularly as intuitive learning implies a degree of expansiveness and non-linearity in the virtual learning environment, the solution of producing a lower-fidelity game capable of running on this hardware does not completely resolve the issue. As evidence suggests, children in their leisure time are increasingly gaining access to platforms capable of high fidelity graphics, such as XBox360 and PlayStation 3 systems and this access is comparatively unrestricted by societal or cultural divides as may have previously been the case (ISFE, 2010). Hence their response to a game introduced in the classroom which has substantially lower fidelity than the games they experience in their leisure time may be restricted.

This issue is discussed in more depth in Section 10.1, from a design perspective. However as an implementation guideline, if we are to assume a degree of disengagement as a result of this technological divide between learner contexts, then a need emerges to engage learners with the lower fidelity solution through similar means to other educational materials. Manipulating the overall role of the game within the learning process is one potential avenue, with play a reward for completion or part of a reflective and critical evaluation. One emergent finding in the research of the game within Italian schools was that a prior discussion of the game with the class generated enthusiasm and stimulated discussion. Creating, rather than playing games is a valid approach for allowing learners to exercise numerical and logical as well as artistic skills (Nousiainen, 2009), and reflection on the design of a game might be used to stimulate wider and differing engagement than play. Returning to the intuitive guided learning pipeline specified in Section 8.4, iteration - also covered in the next section - requires experimentation and evaluation with learners. In a practical context, this could be undertaken in a qualitative fashion using participatory action research or a similar method, empowering tutors and learners with the ability to adapt and refine the game themselves as part of a holistic approach. Whilst further research is required to give educators and learners the scalable and usable platforms required to adapt games and game content, as technologies used to create games become increasingly accessible, this becomes a viable method for the educator to involve learners in games built around the intuitive guided learning paradigm through scaffolded reflection and blending.

9.3 Emphasise the need for a pragmatic iterative cycle

It has been reflected on in Section 3 that in lieu of the research that would be required to underpin every pedagogic element within a game, iteration and participatory design are powerful tools for ensuring an effective solution. However, this cycle must be pragmatic, and take into account the high costs associated with high fidelity game content. An animated virtual character, for example, requires not only the polygonal mesh and textures, but also for this mesh to be rigged, animations created either by hand or through motion capture, audio to be sourced or recorded, and algorithms implemented allowing them to navigate the virtual world in a plausible fashion. The use and reuse of methods and techniques for simulative content creation detailed in this report can reduce the cost associated with these activities, but they still remain relatively high when compared to adjusting other forms of pedagogic content such as static images or text. Identification and separation of these assets from elements which foster engagement, and elements which facilitate learning transfer has been suggested in Section 5, and shown to work effectively when used alongside the methods and techniques detailed in Section 8.

It is also suggested this pragmatic approach to iteration revisit and review the learning objectives for the game, rather than attempt to achieve these through an unblended, standalone game. This allows a much greater degree of pragmatism, as the developer and educator work in synergy to explore the learning outcomes that the game best addresses, and supplement weaker areas with other methods of instructional design.

9.4 Apply a relevant feedback approach

Feedback is centrally important in game based learning, as it acts between the game dynamic and the pedagogic objectives to scaffold the reflection required for effective experiential learning (Dunwell et al., 2011). Research has reported on the importance and effectiveness of a structured and feedback approach which is carefully targeted to the user (Chai, 2003). *Focused reflection* can be defined as an integral goal of the feedback process (Thorpe, 2000). This implies equipping the learner with the capacity to both identify their weaknesses and address them. Rogers (1951) defines feedback as falling into five categories. Within this model, he identifies the three most commonly used methods as evaluative, interpretive, and supportive. The two remaining levels are excluded in this context since they rely heavily on interpersonal interaction and are hence beyond the scope of current technical features. Evaluative feedback, the simplest level, consists of providing subjects with an accurate summary of their performance. This is by far the most common approach in Serious Game design; for example Triage Trainer uses this paradigm in a summary screen at the end of a session (Dunwell et al., 2011). By comparison, interpretive feedback involves developing an understanding of the user, and the higher level factors governing lower level performance. Hence, examination of learners and the capacity environments have to perform this evaluation is also an integral part of providing effective feedback. The capacity to evaluate learner progress is integral to providing any form of adaptive level-of-difficulty, and represents the substantive process of providing evaluation which is not fed-back to the user, but rather utilised in order to identify their process or dynamically modify the difficulty or nature of game content.

Automated interpretive feedback lies within the domain of intelligent agents and adaptive artificial intelligence, and is a subject of ongoing research. Supportive feedback is the most challenging form to deliver using technology, since it requires a further interpretation of performance which also incorporates consideration of the affect and motivation of the user. Rogers suggests supportive feedback need not necessarily be accurate in terms of the success of the learner in achieving goals, rather, it should increase their motivation to improve. Work has considered the use of brain-computer interfaces (BCIs) to better understand and respond to user affect, and the recent emergence of low-cost BCI technology may prove advantageous particularly when attempting to automate this form of feedback (Crowley et al., 2010). Closed environments, which restrict the freedom of the learner to specified areas of the game world, have the advantage of much tighter control over simulation variables, and thus a considerably simpler and potentially more accurate feedback system. Open environments by nature introduce substantially more variables, and thus complicate the process of extrapolating the factors relevant to evaluating learning and compounding them into effective user feedback. That said, they offer substantially more scope for making this feedback emotive and compelling – assuming a user has reached a high level of engagement with an open immersive virtual environment, seeing the consequences of this actions on other users is likely to have a substantially greater impact than seeing the consequences through a simple summary screen.

A hybrid environment approach could potentially offer a solution to this problem through the integration of both closed and open elements as demanded by the learning objectives and pedagogy. The challenge in effectively achieving this solution is the seamless integration of open and closed components in such a way as to be invisible to the user. Online games, as a comparison, often combine open 'common' areas with specific closed areas which are restricted to a small group of players; examples typically lie in the MMO genres. A potential exists for serious games to leverage a similar potential – an example would be an environment which provides an open every day area for users to interact socially and develop their skills with the user interface, but is also capable of transplanting a small group of these users into an emergency situation. It could be hypothesised that if users are allowed to develop an everyday familiarity with the environment, their subsequent engagement in an emergency situation within 'their' environment would increase.

9.5 Blend effectively with other pedagogic elements and approaches

It has been noted previously in this deliverable that effective blended learning is a key element in the implementation of many serious games (Graham, 2005). To blend effectively, the strengths of various methods of instruction should be considered and combined to capitalise on their benefits whilst ameliorating their weaknesses. Students have been shown to respond positively to blended approaches (Ulur et al., 2011), and this positive response might be capitalized upon to create more effective solutions. In particular, collaborative and social learning can benefit from blending (So and Brush, 2008), and a game might serve as an effective agent for stimulating these forms of learning whilst an underlying LCMS system such as IWT supports and enables it through web forums and other collaborative technologies enhanced through ALICE. Similarly, a problem-based technique might present learners with information up-front transferred through didactic means then use a game environment for learners to demonstrate and rehearse their understanding, or gain insights into the practical application of concepts (Donnelly, 2010).

The use of blended approaches to allow more flexible methods of instruction is well established (Jun and Ling, 2011). This flexibility must be particularly capitalized upon in the case of game-based learning to address the inherent difficulties in effective assessment of learning outcomes in higher cognitive domains as outline in Section 8. Effective blending requires consideration on both sides of the resource, as educators must be aware of the need to adapt their overall method and pedagogic approach to the inclusion of game based learning, so must developers of serious games provide the flexible tools required to allow this in practice. As demonstrated within ALICE, specification of the game as a learning object (LO) within the IWT platform, and the subsequent capacity to construct courses and attached metadata to the game as with any other LO, provides a technical platform enabling such blending. However, as with any other learning technology, engagement with end-users as well as their ability to effectively use the system is essential. Again here ALICE technologies serve to support this engagement though other techniques such as narrative and emotional techniques.

Having presented in this Section five important considerations for the implementation of an intuitive guided learning approach, the next section outlines a number of constraints and barriers which may challenge their implementation in practice. Predominantly these are considered from the technological perspective in-line with the objectives of ALICE in developing an advanced learning platform, however the European dimension is also considered, as it carries implications for how a large-scale intuitive guided approach to learning may ultimately be delivered.

10 Practical constraints and barriers

This penultimate section introduces two key practical constraints for delivering serious games using an intuitive guided approach in practice. The first is hardware availability, and in particular the emerging gap in gaming technologies accessible during learners leisure time, and their formal education times, particularly with respect to high-quality real-time rendering. Section 10.2 considers the further implications introduced by the need for localisation and individualisation within the EU, discussing how work undertaken in T4.1 and T4.3 has demonstrated a simple linguistic solution, yet differences in how various cultures approach both learning and play must be addressed to create ubiquitous solutions. These and other recommendations for future research are covered in Section 10.3.

10.1 Hardware availability

We note from experimental results (Section 7) that a common issue raised by learners was game performance, due to limited hardware availability. Notably, the game was designed to operate with dedicated graphics hardware, but in the school experimentation took place, desktop PCs used only stock graphics cards. It is tempting to propose the simple solution of reducing the fidelity of the game. Indeed, creating a lower-fidelity version is viable and resulted in improved performance. However, this fails to address the greater problem of a disconnect between the immersiveness of gaming experiences students experience in a home context, with that which they experience in a school context. Referring again to the Interactive Software Federation of Europe's recent report (ISFE, 2010), it is reasonable to assume these learners with access to only limited hardware in schools have extensive access to modern gaming platforms outside of an educational context.

A difficult question thus presents itself: should we design experiences which, by nature, have lower fidelity than entertainment games, and therefore succumb to the very same pitfalls we seek to overcome by embracing methods such as game-based learning, or design instead for the platforms available to students outside of schools, accepting the implications of exclusivity that result? Perhaps this can be ameliorated by careful game design, for example favouring 2D games focussed on high degrees of interactivity, whilst excluding high-fidelity 3D and consequently virtual worlds and similar technologies. Yet this has pedagogic as well as practical limitations; as simulation-based pedagogy and experiential learning require the learner to reflect on experience and relate it to reality (Kolb, 1984), greater degrees of abstraction and analogy decrease its efficacy (Wier, 1958, Brdiczka et al., 2005). Similarly, as 2D games rely more on compelling yet simple gameplay models, pedagogic elements are often forced into peripheral roles surrounding a more abstract experience: consider for example PlayGen's MeTycoon[13], in which the core pedagogic elements are encapsulated as videos around a gameplay mechanic which, whilst directly related to the game's overall objective of serving as an advisory tool for career choices, is strongly abstracted from reality.

10.2 Localization and individualization within the EU

Repurposing learning objects is a particular focus of research within the EU, a consequence of both the challenges and benefits of creating open, shared platforms for learning and learning content (Verbert et al., 2005). In the particular case of serious games, scenario-based repurposing offers a basis for reuse of content whilst still allowing customisation to suit various learner needs (Protopsaltis et al., 2011). Within WP4, the specific issue of linguistic repurposing is tacked, outlined in more detail in D4.2.2. The method adopted extracts the text from the game into a raw, sequential text form, then

[13] http://metycoon.org

automatically calls the Google Translate service to translate this text into the required language. This text is then reinserted into the game, allowing for immediate localisation. As automated translation can give rise to errors, the formatted text files are also made available to the educator for open editing using a word processor. This also allows them the opportunity to reword individual elements of the game content to address cultural issues that might arise through literal translation (for example the Italian 'Ciao bella', can gain negative connotation when translated into the literal English as a greeting). Involving the educator in such a role is an interim solution in lieu of technology to automate the process fully. Machine learning approach to translation such as that implemented by Google Translate will evolve over time to offer improved services, and a benefit of the implemented architecture is that the game will similarly improve over time as these services are regularly accessed for updated, more accurate translations.

10.3 Recommendations for future research

From the discussions raised in this and previous sections, three key areas are recommended for future research:

- **Methods for integrating pedagogy and game design** are essential during the iterative process shown in Figure 12. Due to the relative infancy of game-based learning, and more generally technology-enhanced learning when compared to established methods of didactic instruction, still relatively little information exists when attempting to select a specific game design approach to address a pedagogic need. Often evaluations operate at the macroscopic level, comparing the game as a whole to an alternative method, though such studies are seldom conclusive. An advocation here would be include studies which focus on a micro-level at the individual merits of various game elements, mapping them to pedagogic elements and subsequently learning outcomes through experimentation. This would then provide designers with a useful tool set, bridging between learning requirement and game design approach. Within the intuitive guided approach presented in this deliverable, this would be an invaluable resource for accelerating the development of serious games using empirical research to validate design decisions.
- **Support for extracting and repurposing game content** is addressed in a range of EU projects including the mEducator Best Practice Network and Games and Learning Alliance Network of Excellence. Evolving the game along brick-based repurposing techniques such as those defined in D4.2.2, to include the notion of the game as a composition of learning objects, represents a move towards a hierarchic structure which blends game and content management wholly to consider how a game might act as a content management system itself. Such an approach offers the potential to provide a motivational backdrop against which more conventional approaches to instruction are embedded. However, technical challenges, including the linguistic and cultural repurposing of text, images, and more complex multimedia objects in an automated and seamless fashion requires significant further investment.
- **Technology and hardware availability**, whilst the frequent topic of industry reports (ISFE, 2010), should be carefully considered in terms of the gap between hardware availability in learners leisure and formal education times. Particularly with the increased prevalence of gaming hardware in home contexts across Europe demonstrated by the ISFE (2010) report, as well as the perceptions of educators and shifts over recent years unexplored by large-scale research, a risk may exist for an increased digital divide between home and school contexts, limiting the ability of games deployed in a school context to appeal to learners more experienced with high-fidelity content on home platforms. Researching both the extent of this divide, as well as the requirements of fidelity in serious games both for technology acceptance

and learning transfer, is necessary to inform policy surrounding investment in this emerging educational medium.

11 Summary and conclusions

In considering the definition of serious gaming in Section 2, this report noted that the definition is commonly used to describe the intent, rather than proven impact, of a game-based learning intervention. It is essential that as the field expands, development of games for new and existing application areas is matched by rigorous evaluations of efficacy, which underpin the development process, guiding and informing both game designers and educators. Emphasizing the need for careful balance between gameplay and instructional design, Sections 3 and 4 have presented means for ensuring this balance through the involvement of all parties in serious game design, including end-users. The report has sought to address the need for more generalizable and application-independent development and evaluation methodologies, and has therefore to the greatest extent possible sought to ensure that whilst the conceptual framework in Section 5 is tailored to the concepts within ALICE, it retains elements of generalizability. With specific regard to the notion of “intuitive guided learning”, this report has presented a number of important considerations for the development of serious games which seek to implement such an approach. Review of methodologies and evaluation techniques has confirmed that ensuring the efficacy of such an approach requires a careful balance of iterative and user-centric design with the practical constraints of the ALICE project. To enable such balance, we have described a methodology for the creation of a serious game within ALICE that separates engagement from instruction, providing a means for simultaneously developing game content whilst performing evaluatory work on pedagogic elements. Though we have noted the implicit links between pedagogy and all game content, by careful evaluation, this report advocates a compromise between flexibility and pragmatism, avoiding overprescribing cyclic development.

Experience from implementing this approach in practice is outlined in Section 7. The intuitive guided learning approach for serious games, as detailed in Sections 8 and 9, reflects on these findings to stress the importance of iteration and well as provide a pipeline for the creation of an intuitive guided learning approach within a serious game. The positive response from learners to the initial iteration (see also deliverables within WP2) is promising, though the need for iteration as stressed by the framework presented in this report suggests increasing efficacy as T4.3 refines the game in response to these findings. The methodology for intuitive guided learning presented in this report notes the inherent typology of learners in this definition, as well as evidence suggesting such typologies are limited in their ability to fully reflect the diversity and adaptivity of learners. However, in seeking to implement an approach which caters to all types of learner whilst emphasizing the benefits of an intuitive approach, the methodology put forward in this deliverable is suitable for application in more general contexts. Exploring such applications and further refining these models and methodologies will prove an important goal for future work. In doing so, experimental work will increasingly bridge the gap between learning requirements and game designs, allowing early stage development to make increasingly informed decisions and reducing the costs associated with iteration and evaluation.

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Annex I – Links to games referenced in Figure 1

Against All Odds	http://www.playagainstallodds.com/	Immune Attack	http://www.fas.org/immuneattack/
America's Army	http://www.americasarmy.com/	infiniTeams	http://www.tpld.net/beta/store/view/infiniteams/
Ayiti: The Cost of Life	http://www.unicef.org/voy/explore/rights/explore_3142.html	iSeed	http://playgen.com/
Code of Everand	http://www.codeofeverand.co.uk/	Karma Tycoon	http://www.karmatycoon.com/
CyberCIEGE	http://cisr.nps.edu/cyberciege/	Microsoft Flight Simulator	http://www.microsoft.com/games/fsinsider/
Darfur is Dying	http://www.darfurisdying.com/	Patient Rescue	http://www.trusim.com/
Deliver the Net	http://www.nothingbutnets.net/its-easy-to-help/game.html	Re-mission	http://www.re-mission.net/
eduTeams	http://www.tpld.net/beta/store/view/Eduteams/	Sneeze	http://www.miniclip.com/games/sneeze/en/
eLections	http://broadband.ciconline.org/elections/Default.aspx	The Enterprise Game	http://www.pixelearning.com/
e-VITA	http://www.evitaproject.eu/index.php	The Finance Game	http://www.pixelearning.com/
Floodsim	http://www.floodsim.com/	The Garbage Game	http://www.gothamgazette.com/games/garbage.php
Food Force	http://www.wfp.org/how-to-help/individuals/food-force	The Sales Game	http://www.pixelearning.com/
Global conflicts: Palestine	http://www.globalconflicts.eu/	Triage Trainer	http://www.trusim.com/
Harpooned	http://harpooned.org/	Wii-Fit	http://wiifit.com/
ICED: I can end deportation	http://www.icedgame.com/	World Without Oil	http://www.worldwithoutoil.org/