Project Number:	**257639**
Project Title:	ALICE: ADAPTIVE LEARNING VIA INTUITIVE/INTERACTIVE, COLLABORATIVE AND EMOTIONAL SYSTEMS
Instrument:	Specific Targeted Research Projects
Thematic Priority:	ICT-2009.4.2:Technology-Enhanced Learning
Project Start Date:	June 1st, 2010
Duration of Project:	24+2 Months
Deliverable:	**D4.2.2: Methods and Techniques for Simulative Content Creation**
Revision:	2.0
Workpackage:	4: Simulation and Serious Games
Dissemination Level:	Public
Due date:	February 29th 2012
Submission Date:	February 29th 2012
Responsible	COVUNI
Contributors:	CRMPA, UOC

PROJECT CO-FUNDED BY THE EUROPEAN COMMISSION WITHIN THE SEVENTH FRAMEWORK PROGRAMME (2007-2013)

Version History			
Version	**Date**	**Changes**	**Contributors**
0.9	07/04/11	First draft	Aristides Protopsaltis (COVUNI), Sylvester Arnab (COVUNI)
1.0	08/04/11	Review and edit pass, added case study	Ian Dunwell (COVUNI)
1.1	18/05/11	Edit pass in response to reviewer feedback	Ian Dunwell (COVUNI)
1.9	17/02/12	Update and revision to D4.2.2	Ian Dunwell (COVUNI)
2.0	29/02/12	Final edit pass addressing reviewer comments	Ian Dunwell (COVUNI)

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1 Introduction

In this document, we explore methodologies for the creation of simulative resources which facilitate an "intuitive learning" experience. We consider this challenge in the specific case of a serious game using a Virtual Learning Environment (VLE) as a backdrop for the learning process; focusing on how content at varying levels of didactic complexity can be achieved through the reuse of existing learning objects. Specifically, we analyze how complex learning objects (CLOs) can be implemented in a composable and seamless fashion. We contrast specifically the repurposing of a CLO between VLEs (semiotic reusability) to the construction of new Virtual Scientific Experiments (VSEs) as composites of existing CLOs, identifying the issues with both forms of reusability and advocating new approaches to content definition and design. We consider also the states of learning objects and collaboration, an issue of particular relevance given the ability of a virtual world to facilitate a persistent learning environment in which tens of thousands of learners can simultaneously interact. The methodologies applied in this document are explored through case-study within the context of a serious game for civil defense, developed as a prototype deliverable D4.3.2 This document discusses issues related to their implementation and suggests future avenues for research and content development towards resolution. In Section 5 the methods and techniques for simulative content creation used are explored, demonstrating how extraction of game text leads to the capacity to autonomously repurpose the game to different languages, as well as affording the educator a degree of control over the information presented to the learner and the capacity to verify and adjust in-game text. Expanding this to include more sophisticated elements such as virtual characters is discussed in D5.2.1, as well as a recommendation for future work to fully realize the potential of such approaches.

This task (T4.2) has been led by COVUNI. The content of this document represents the fulfillment of Deliverable 4.2.2 by the ALICE consortium.

2 Background

The task of developing appropriate content in general and for pervasive devices in particular, can be considered to be a difficult and expensive one. Considering the time, effort and cost, the task becomes enormous. A solution to the problem is content repurposing which refers to the conversion process by which Learning Objects (LOs) that are originally designed for a particular purpose, task, device, platform, or user, is transformed to fit other purposes, tasks, devices, platforms, or users. Content repurposing uses existing content to enable its use and reuse in different context. The majority of activities in the field of e-learning to date have focused on reuse of complete educational content items with a fixed combination of structure and content. While the value of this approach is not disputed, critical issues of deep, conceptual understanding, a sense of ownership and wider issues of cultural assimilation remain unresolved. These issues alone can determine the success or failure of educational innovations, regardless of technical robustness, accessibility and quality of content. Thus, it has been argued in the literature that fully supported opportunities for educators to 'repurpose' learning objects through a participative design process is the path most likely to lead to the elusive goal of reuse of digital learning objects by a critical mass of teachers (Gunn et al., 2005).

Repurposing learning objects means transforming these learning objects originally created for a specific educational or non educational purpose in a specific educational or non educational context in order to fit a different new purpose in the same or different educational context. Term repurposing is often mistakenly used instead of the term reuse. Consequently, the term repurposing needs to be differentiated from the term reuse which principally refers to the reuse of a learning object ”as is” (Meyer et al., 2006, Meyer et al., 2008). The ALICE definition of the term repurposing perceives the repurposed learning object as consisting of the original object and its dynamic, cumulative meta-data. This may include learning objectives, expected outcomes, means of assessment, proposed educational context, etc. There is a variety of situations where repurposing of learning objects is required. These situations, referred to as “repurposing contexts”, can be of a pedagogical nature, a technical nature or both (Kaldoudi et al., 2010). Educational content repurposing and learning object repurposing is what any teacher, lecturer and educator is regularly engaged in when creating new material. Usually, when an educator sets the context and goals of a new educational experience, he/she will review existing content and/or search for new related content and then organize and repurpose the content to fit the new educational experience. Therefore, repurposing becomes a central requirement in traditional education in general and in technology enhanced education using virtual material and environments in particular.

The structure of an educational content item that is repurposed may not necessarily change, but the key differences should be identified, described and organized in terms of a variety of tags, including time evolution, and other attributes. In order to allow for content repurposing, we have to view content in terms of autonomous items that are described via appropriate metadata. The purpose or the goal of each content item in a particular learning context should be stated, including the learning context itself, learning approach, the audience, learning objectives, relationships to other content items and delivery context. Apart from the straightforward and sometimes simple requirement to create new learning objects for different educational contexts, common needs that push for research towards the field of learning objects repurposing include the following (Kaldoudi et al., 2010):

- automatic repurposing of learning objects;
- tracking of a learning object evolution in order to (a) give credentials to original authors and sources, and provide information that may have implications for the resource's quality, validity, specificity, etc; (b) record and resolve intellectual property rights on content as it is being

repurposed and reused; and (c) update a learning resource, when its parent resource is updated, changed, terminated, etc.; and

- provision of a different approach in learning resource search and retrieval via associations created during repurposing.

Traditionally, content repurposing is a term often found in multimedia content research, where the repurposing of a multimedia object mainly refers to changes necessary to accommodate different and heterogeneous display devices (Singh, 2004). In this frame, an interesting approach uses the biologically inspired metaphor of an ant colony to manage automatic multimedia content repurposing in a network of heterogeneous devices (e.g. PDAs, Laptops, Cell phones, etc) and their heterogeneous network connections (Hossain and El Saddik, 2008). In this case, repurposing refers to the format of the multimedia data which is automatically changed and repurposed to a different display device, i.e. it is repurposed to a different technological platform. A similar work proposes a framework for building tools for the automatic repurposing of multimedia learning documents (Meyer et al., 2008). When repurposing is addressed in a broader sense, considerable research work has targeted the automatic process of learning object repurposing. A representative example refers to the common case of creating a new slide presentation out of a repository of related presentations (Metros, 2005). In this work, the text of the PowerPoint (slides, notes pages, etc) is extracted and stored as text. Text is then parsed and augmented with tags which are used to annotate each word with its syntactical form. This approach allows dynamic extraction of similar learning objects (LOs), query by example and document-level similarity checking (at document, at topic and at a slide level).

A central issue in related studies is the model used (if any) to describe the content, the level of aggregation and packaging of an educational item. Indeed, the structure and composite nature of a learning content item is still open to interpretation (Knight et al., 2005, Polanyi, 2003, Blatsoukas et al., 2008, Jovanović et al., 2005). Some research on ontologies has been conducted to address this issue. An ontology can be represented as a structured vocabulary of concepts related to each other forming the conceptualization of a domain (such as a thing, an activity, a phenomenon, or a subject domain); important also is the agreement this structure represents of the concepts in a certain domain. The ALOCoM (Najar et al., 2005) ontology is such a representative example of an attempt to provide an explicit vocabulary and a conceptualisation of the structure and aggregation level of learning content. It defines a learning object as a collection of content fragments and content objects, although it does not specify the role and position of a learning object in the learning content hierarchy. This ontology is then used to build a framework that disassembles slide presentations. These components are re-organized into more meaningful object types (e.g. definitions, examples, references, introductions, summaries) in an automatic way. Similarly to the ALOCoM work, the TRIAL-SOLUTION project defines an ontology for learning objects that includes mathematical categories like definition, theorem, proof or example, with the goal to create and deliver personalized teaching materials that are composed from a library of existing documents on mathematics at an undergraduate level (REHASH, 2005). The perspective of domain specific ontology for learning object management is commonly adopted. A prominent example is the ARIADNE project, which has put a lot of effort to enable educational content sharing and reuse, however resulted in a complex and hard to use system, as it basically reflects the metadata standard rather than the characteristics, aims and requirements of the end user (Ellaway et al., 2005)**Errore. L'origine riferimento non è stata trovata.**. Achieving the content sharing and reuse through the ARIADNE project requires ontological agreement on how content is defined and shared.

The learning object model (LOM) and Sharable Content Object Reference Model (SCORM) are established mainstream standards for learning object and sharable content representation. At the core of the SCORM system is the use of XML documents to markup educational content, enabling it to be validated and repurposed across different media and approaches to representation. It therefore provides a low level technical standard allowing compatibility and interoperability between learning object management systems (LMS). Many projects such as those listed above have built upon this standard or suggested alternative approaches, though the mainstream acceptance of SCORM implies that SCORM-compliance, even in systems which are technically or paradigmatically different, is a requirement for immediate widespread content accessibility. A key research challenge, particularly with novel approaches to sourcing information or creating new interaction modalities and interfaces, is ensuring this compliance is maintained alongside innovation. With particular regards to ALICE, the notions of dynamic and collaborative learning objects, which may evolve over time, is necessary to weight against the compatibility and composability of these objects. Hence, either learning objects must not be accessible during a virtualised collaborative session, or must support compliance at all steps of their evolution over time. Significant investment has been made into exploring repurposing reusable learning objects for use in other contexts over the last few years, including projects such as REHASH **Errore. L'origine riferimento non è stata trovata.**(REHASH, 2005) and ACETS **Errore. L'origine riferimento non è stata trovata.**(Ellaway et al., 2005), which explored the value of repurposing from opposite extremes; the former repurposing a large collection of existing assets, the latter encouraging teachers to seek their own resources where they could – which in practice means the internet. A significant outcome of both projects was that teachers and students required easy access to resources or they did not bother to use them.

Similarly, over the last decade many investments in technology-based initiatives have had mixed results as high quality courses and resources developed in one institution were often not adopted or accepted in other institutions, like for example, the Teaching and Learning Technology Programme – TLTP (TLTP, 1992-2000). More recently, the RePRODUCE programme of funding by the Joint Information Systems Committee (JISC), UK, has produced a number of positive outcomes. The RePRODUCE programme funded 20 UK projects to develop, run and quality assure technology enhanced courses using reused and repurposed learning materials sourced externally to their institution. The programme successfully demonstrated that repurposing involving a number of like-minded institutions actually produced useful learning resources that truly were reusable. This is something that the mEducator BPN project is ambitious to build on and explore further on a much larger scale (Kaldoudi et al., 2010).

Recently, research is starting to draw from Web 2.0 notions and technologies to provide a different approach to content repurposing issues. For example, social tagging has been proposed as an alternative approach to content organization, search and retrieval in educational content repositories (Dahl and Vossen, 2008)**Errore. L'origine riferimento non è stata trovata.**. Another similar approach is exploited in the MURLLO (Management, Use and Repurposing of Language Learning Objects) project, where Web 2.0 technologies are employed to create an integrated framework for effective repurposing of reusable learning objects. In this approach a wiki is proposed for the seamless authoring and repurposing of learning objects (thus allowing storage of content and all its versions), while additional services allow metadata creation for its learning resource and support searching (Wang et al., 2007). Web 2.0 notions are also employed by mEducator partners to give a different perspective to educational content repurposing, by creating social networks of educational learning objects where, amongst else, repurposing history and inheritance are used as basic social relationships among educational objects in order to drive object organization, retrieval, evaluation and reuse (Kaldoudi et al., 2009a, Kaldoudi et al., 2009b, Dovrolis et al., 2009). The FP7 ROLE IP project is also relevant here both in terms of the content generated, and its advances in tool compilation and integration.

At the start of the twenty-first century both teachers and learners now have access to an unprecedented range of digital resources with the potential to be used in many teaching and learning situations, and ranging in complexity from multimedia courseware packages designed to engage students for several hours of study to single images and text files. Despite this, the perception and evidence suggests that teachers make relatively little use of them and opportunities for reusing digital resources to improve the quality of the student learning experience are missed. The strategy of simply making resources available to students without contextualising their use, embedding them into practice and assessing them has not worked (Tavistock, 1996). Both teachers and learners are generally fairly conservative and it seems that they will only embrace innovative teaching opportunities as long as they require minimal time commitment to explore and evaluate what is available, and involve little effort to implement. There is therefore a clear mismatch between the expectations of the proponents of reusable learning objects and the experiences of most learners and teachers at the 'chalk face'.

Reusability in terms of three-dimensional objects was introduced by Singhal and Zyda (1999) as *'composability'*. In this definition, Singhal and Zyda address an issue common to virtual worlds, the need for content to be redefined and re-created. This is a core issue in virtual worlds, particularly as graphical techniques and hardware capacity evolve to support increasing levels of visual fidelity. That said, this issue is not one limited to rendering alone: physics engines and simulations have similarly evolved to support higher level of functional fidelity. For an object to be realistically modelled within a physical simulation, properties such as mass and friction coefficients must be introduced, and content defined purely in terms of geometry must therefore be edited by hand, a lengthy and time-consuming process. A truly composable object should not be constrained either in terms of its visual fidelity or its capacity for interaction, yet this raises difficult design questions. One possible route is to define the object in the highest resolution possible, though this has obvious drawbacks in terms of file size, particularly since 3D content can include both complex geometry and large textures. A multiple discrete level of detail approach (originally Clark, 1976) results in difficulties defining sufficient levels of detail to suit all purposes, without resulting in time-intensive work by hand to adjust geometry. Automating the approach to mesh decomposition (Hoppe, 1996) can allow for lower resolution versions to be created autonomously, but rarely yields as satisfying a visual result as undertaking the process by hand as a result of the cognitive aspects of perceiving a three-dimensional model, and the difficulty in anticipating and understanding the cognitive process when deconstructing a mesh into a lower-resolution instance. Therefore, whilst some first steps towards creating composable content can involve attaching XML or a similar content representation format to geometry, or inserting markers to guide progressive decomposition, this still falls short on the overarching need for ubiquitous content. Research must address this gap to ensure efficient development and reuse of three-dimensional content through both refined approaches to automating level of detail, and efficient mechanisms to represent content which is functionally as well as visually rich.

Reuse of simulations similarly has reach into learning applications. For three dimensional environments this is in part related to the aforementioned issue of composability, though simulative elements such as virtual patient models, or crowd dynamics, can be embedded into a serious game or other learning content to provide depth of content or immersive backgrounds. Alternatively, simulations external to the 3D world can be rendered or otherwise visualized in an immersive form. Within ALICE, we consider the application of a model of crowd simulation initially developed for use within a virtual reconstruction of Ancient Rome (Dunwell et al., 2010), into an evacuation context, reusing a point-of-interest system to create an evacuation by specifying exists as critical points of interest and evolving pathing AI from this basis. In this case the simulation is used to introduce both immersivity, and support learning, as the player may be afforded the ability to interact with virtual characters and these characters may form the basis for an effective feedback loop. Finally, serious games may also be repurposed across contexts and learner demographics. The e-VITA EU project considered the use of serious games for intergenerational learning across Europe (Pappa et al., 2010); demonstrating the many challenges faced when creating a serious game suited to a range of audiences. As different cultures not only have differing levels of experience and attitudes towards leisure games, but also differing expectations and perceptions of education, creating a game which successfully appeals across cultures is a difficult task. Repurposing techniques offer a potential solution, allowing a game to be modified, allowing a game to be customised to suit the needs of different audiences, though again introduces a need for increased rigour at the design phase to extrapolate and identify the elements of the game salient to cultural repurposement. This typically runs deeper than language alone, and can extend to visual elements of the game – at the simplest level, signs may need to be represented in different languages, but at a deeper level virtual character animations may need to be adapted to reach different cultural norms regarding expression through body language.

In summary, though the capacity exists to repurpose three-dimensional content, simulations, and games, careful consideration needs to be given to the costs involved, and in particular research needs to address how to reduce these costs through the provision of technologies and schema enabling more rapid and ubiquitous content creation. Furthermore, tools need to be provided that automate the processes required to represent and manipulate composable content which minimising the need for technical expertise and design input. In the next section, we explore the definition of a 'complex' learning object (C-LO) within ALICE. These objects form a critical part of the component chain required to create effective, repurposable simulative and virtual content, combining pedagogy with representation to reach specific learner demographics, whilst retaining the scalability and extensibility required to reach different audiences through repurposement.

2.1 Definition of a complex learning object

In the field of e-learning, independent units of educational content targeting specific needs have been termed as 'learning objects' (LOs). It is often cited that the term 'learning object' was first popularized by Wayne Hodgins in 1994 when he used it in the title of a CedMA (Computer Education Management Association) working group called "Learning Architectures, API's, and Learning Objects" (LOM, 2000).

The IEEE Learning Technology Standards Committee chose the term "learning objects", to describe small instructional components, and provided the following working definition:

> *"Learning Objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning. Examples of technology-supported learning include computer-based training systems, interactive learning environments, intelligent computer-aided instruction systems, distance learning systems, and collaborative learning environments. Examples of Learning Objects include multimedia content, instructional content, learning objectives, instructional software and software tools, and persons, organizations, or events referenced during technology supported learning"* (Wiley, 2001, Polanyi, 2003, Friesen, 2004).

During the past few years, a striking number of formal definitions have been proposed in the literature. One can find a number of publications elaborating on the definition of the term "learning object", reviewing and discussing various proposals and actually concluding that current definitions and practices of LOs are (at best) confusing and arbitrary, for example (Wiley, 2001). As a working definition Wiley (2001) proposed that "any digital resource that can be reused to support learning" which goes along with Polsani's suggestion that in order for any digital object to acquire the status of a LO it should be wrapped in a learning intention and be reusable (Gunn et al., 2005). In more detail, Barritt and Alderman (Barritt and Alderman Jr., 2004, p. 5) argue that the "promise" of learning objects is that they can be leveraged, linked, or copied by multiple e-learning content authors, integrated into a limitless number of training courses and development programs, as well as be available for distribution via a range of media types and delivery channels.

The idea of learning resources in general and learning objects in particular being used and reused in different contexts (repurposed) has led to the creation of the concept of the 'reusable learning object' or RLO. The term is in widespread use although it seems that there in not an agreement among practitioners of exactly what defining properties an RLO or an LO. Such definitions range from the very broad of:

"any digital resource that can be reused to support learning" (Wiley, 2001) to a more precise: *"...any grouping of materials that is structured in a meaningful way and is tied to an educational objective"* (Johnson, 2003).

The concept of *learning objects* has been developed to facilitate fast and effective retrieval of the vast amount of online learning resources and to ensure that interoperability is achieved amongst different web-based and offline learning systems. A learning object can be seen as a piece of self-contained pedagogic data which can be used and reused in many different contexts and which has a set of metadata descriptions to facilitate search and retrieval (IEEE, 2004). This reusability allows substantial reductions in the cost of developing online educational resources (Downes, 2001) and since learning objects and learning resources in general can be repurposed for different courses or disciplines, this can further reduce the development cost (Smith, 2004). Learning objects, especially digital learning objects, can also include metadata, which is information about the learning object itself. Including metadata with a learning object is necessary if we want to facilitate its search, identification and location by search engines and online repositories. Metadata specifies details such as the purpose or the goal of each content item in a particular learning context should be stated, including the learning context itself, learning approach, the audience, learning objectives, relationships to other content items and delivery context, the copyright and use terms, the author and his or her affiliations, technical compatibility details, cataloguing information, and so on.

In the last few years the popularity of games and its widespread use especially amongst the younger generation has increased educators interest concerning their use in teaching. Serious games and simulations alongside existing teaching and learning practices have become attractive complex learning objects. Existing examples can be broadly classified into the re-use and repurposing of existing virtual spaces into a serious context, such as the use of Second Life as a problem-based learning environment (Savin-Baden, 2007) or the development of bespoke serious games (for example TruSim's *Triage Trainer* or HopeLab's *Re-Mission*). To transfer those games into different contexts or to address different learners or learning objectives, can be time consuming, costly and typically requires specific technical capabilities. However, a range of projects have explored means to address these issues; the MEDULLA project aimed to offer new methods for creating, sharing, mixing, and displaying digital assets for online virtual worlds (Fox et al., 2010).

Considering the complexity, time, effort and cost of developing a digital game in general - and a serious game in particular - the potential that such a game can be repurposed, enriched and embedded effectively and adaptively into educational practices and curricula is worth exploring. This includes updating or changing serious games to reflect new functionalities, adjustments to different pedagogic objectives, technologies, representational fidelities, cultures, contexts and learners. Such repurposing and reuse, therefore, is a desirable activity, reducing organisational resource consumption and opening up new opportunities for learning, maximising the capabilities of existing learning objects. Therefore, being able to reuse and repurpose game content avoids the need to recreate bespoke content from the ground-up, and offers potential to efficiently adapt serious games and game elements to wider audiences and application areas.

According to the New Media Consortium (Smith, 2004) at the minimum, a digital learning object consists of content and an interface. The content is made up of assets, which are the resources that make up the learning object such as images, sound, animation, text passages, videos, etc. The interface is the part of the learning object with which the user interacts. It consists of the graphic design, the navigational components, and all the other controls that the user sees and interacts with. An interface may be as simple as a single web page that presents text and images, or as complicated as a virtual world or a simulation. Therefore, Complex Learning Object (CLO) can be defined as any digital entity, where the contents are either made up from more than one asset (such as images, sound, animation, text passages, videos, etc.) or when their interface (representation, fidelity, interaction etc.) is complex, meaning it is either a virtual world or a simulation. Further, a CLO is a learning object that is composed of one or more other learning objects. Usually complex learning objects are built from simpler ones and contain complex learning objectives.

CLOs are objects that can assist implicit learning. Implicit learning is nonepisodic learning of complex information in an incidental manner, without awareness of what has been learned (Seger, 1994). CLOs with the plethora of information they contain, provide such rich learning experiences to the learners that they often can learn part of the presented information without awareness.

2.2 Need for repurposable content

Repurposing means transforming a learning object or resource initially created for a specific educational purpose in a specific educational context in order to fit a different new purpose in the same or different educational context. Therefore, the term repurposing needs to be distinguished from the term reuse which refers to the reuse of an educational resource ”as is” (1966). The ALICE repurposing definition views the transformed learning object as consisting of the original object and its dynamic, cumulative meta-data. This may include educational goals, expected outcomes, proposed educational context, means of assessment etc. There is a variety of situations where repurposing of educational content is desired. These situations, referred to as “repurposing contexts”, can be of a pedagogical nature, a technical nature or both. Although not formally addressed as such, educational content repurposing is what any educator is routinely engaged in when preparing a new educational experience, including the educational content. Customarily, when an educator sets the context and goals of a new educational experience, he/she will review existing content and/or search for new related content and then organize and repurpose the content to fit the new educational experience (Kaldoudi et al., 2009b). Therefore, repurposing becomes a central requirement in education at all levels.

The structure of learning object that is repurposed may not necessarily change, but the key differences should be identified, described and organized in terms of a variety of tags, including time evolution, and other attributes. In order to allow for content repurposing we have to view content in terms of autonomous items that are described via appropriate metadata. The purpose or the goal of each content item in a particular learning context should be stated, including the learning context itself, learning approach, the audience, learning objectives, relationships to other content items and delivery context. The additional dimension of reuse introduces the potential for learning objects to be used in different settings to those for which they were originally created and used. The reuse of educational resources is clearly not a new one; academic libraries for instance are built around the reuse of books, journals and other forms of publication in support of teaching and research. However, web technologies seem to have opened up new ways of creating, exchange and reuse educational resources and to have broadened the potential for reuse far greater and closer to individual teachers and students than ever before. Many courses now require from their students to create e-portfolios, websites, wikis, blogs etc. as part of their curricula activities and especially as part of their assessment. Reuse and repurposing of materials may play a significant role in any of these activities. Reuse is not just about opportunity; it is, for instance, already a major issue for those students and staff who are publishing material on the web that everything they publish should be cleared for use (in terms of intellectual property rights, consent and so on). The importance of 'getting this right' is reflected in the increasing number of activities and organisations based around these issues, such as JISC's digital rights management (DRM) studies in the UK and the work of the Creative Commons group worldwide .

Reuse and repurpose are powerful cultural characteristics, relating to recycling, economy and efficiency, 'sustainability', as well as more general concepts of common purpose and interoperability. It is an attractive and compelling prospect that the digital age will bring the benefits of all human knowledge and experience to every desktop in the world for the benefit of every user. One reflection of the power of the idea of reuse and repurpose as an educational theme is the large number of projects based on the creation, exchange and reuse of learning materials (Ellaway et al., 2005). Despite the excitement and apparent activity around the reuse and repurposing of learning objects, many educators have not yet engaged with the concept. This is despite very significant investment in raising awareness, developing and widening access to digital resources (e.g. Computers in Teaching Initiative (CTI); Teaching & Learning Technology Programme (TLTP); Learning and Teaching Support Network (LTSN)); metadata hubs such as BIOME (OMNI) at Nottingham, and access to national collections (digital repositories) of learning resources such as Bristol Biomedical Image Archive (Ellaway et al., 2005). Each of these projects carries with it the enthusiasts and the early adopters but persuading the vast majority of teachers to engage with these resources at more than just a superficial level (i.e. informing students of their availability over the network) has always been an issue (Mayes, 1995).

To transfer such games and environments into different contexts or to target different learners or learning objectives, is time consuming, costly and usually entails particular technical capabilities. Considering the complexity, time, effort and cost of developing a serious game, the potential that such a game can be reused, repurposed, enriched and embedded effectively into educational practices and curricula is of great value. Repurposing and reuse of learning objects and especially complex learning objects can reduce organisational resource consumption and open up new opportunities for learning, maximising the capabilities of existing learning objects. Therefore, being able to reuse and repurpose complex learning objects in general and serious game content in particular avoid the need to create and recreate bespoke content from the ground-up, and offers potential to efficiently adapt such objects or elements to wider audiences and application areas.

2.3 Repurposing and pedagogy: Intuitive guided learning

Pedagogical approaches in education range from the conventional delivery like lecturing to more active learning methodologies. All of these educational approaches require the same content to be used and presented in a different way, e.g. a power point presentation for the conventional teaching approach should be repurposed to be presented as, for example, a list of questions and answers or a collection of interactive teaching files in the case of a more active learning experience.

In terms of autonomous learning for example, the materials used in presentations and traditional lecturing are expanded by supplementary information when repurposed to allow independent, self-directed learning. Furthermore, if using virtual environments synchronously and/or asynchronously is part of the selected delivery approach, the way the learning objects are provided, would affect the repurposing needs. Under a given pedagogical approach repurposing may be needed, when a learning object is used to achieve different goals or to assist in achieving a level of competence. The pedagogic approach defines also the qualities of feedback and evaluation. Repurposing these may present requirements in terms of how the evaluation is carried out and who provides the feedback (teacher, system or peers). Moreover, the timing of evaluation as well of the issue of synchronous or asynchronous have to be considered. A common reason for repurposing is to address different educational objectives in terms of difficulty or educational level. In this case content needs to be adapted to match different pre-requisites and consecutively different learning outcomes. In the follow sub-sections, various dimensions of intuitive guided learning are explored and their relationship to repurposing analysed. This leads to the definition in Section 3 of a range of methods for simulative content creation through semiotic or brick-based reuse techniques.

2.3.1 Intuition

Intuitive processes are generally assumed to be automatic activations of (semantic) networks. Intuition is part of that 'knowing' referred to by Polyani (Dane and Pratt, 2007, Davis and Davis, 2003, Sinclair and Ashkanasy, 2005) when he argued that 'we know more than we can tell'. An intuition is a recognition or judgement that firstly appears instantly, without much rational thought, secondly is very difficult to articulate, thirdly is usually based on well grounded prior knowledge and experiences; fourthly it comes together with a feeling of confidence or certainty, and finally it is emotionally charged (Reber, 1993). Klein (1998) supports that we develop our intuition through experiences in particular domains (intuition is not a generic ability; it is domain specific) which we obtain via explicit and implicit learning processes, which they lead into highly complex and subtle mental models of tacit knowledge that cannot be described, explained or articulated easily. These mental models are stored in long term memory together with a number of very complex rules (not easily verbalised) for how to achieve specific goals (Soto and Allongue, 2002). Intuitions enable us to solve problems, take decisions, achieve insights and generate discoveries and creations in many domains.

2.3.2 Neuroscience

Intuition is synonymous with instinctive signals often referred to as 'gut feelings'. Neurological research has identified an awareness that operates below our level of consciousness and which may serve like a physical 'alarm bell'. The neurologist Antonio Damasio (Damasio, 1994) argued that unconscious processing accompanied by physiological 'somatic markers' force our attention on positive or negative outcomes, which manifest in our conscious awareness as a 'gut feeling' (they called this the 'somatic marker hypothesis'). Jung-Beeman et al. (2004) has identified brain regions that are implicated in those insights (eureka moments) where the pieces of a problem that it has been impossible to solve falling into place often after a period of unconscious processing. Similarly, Le Doux (1996) has examined the role of working memory in feelings, emotion, unconscious processing and human consciousness itself. Satpute and Lieberman (2006) found that high-experience domain judgments (i.e. high familiarity) produced activation in a network of neural structures involved in automatic social cognition while low-experience domain judgments (i.e. low familiarity) produced activations in a network involved in effortful social cognition and propositional thought. It seems as though the physical locations of intuition are being uncovered.

2.3.3 Guided learning

Guided learning refers to the constructivist notion of learning where the teacher or educator is a facilitator assisting the learners guiding to make their own sense of the content. Within this context intuition can play an important role buy guiding learning to explore aspects of the content that would not be possible only with rational and a well structure approach. Furthermore, the notion of guided learning is very closely related to the idea of social construction. The theory of social construction is based on the work of Bruner (1961) and Vygotsky (1978). Put it simply, the theory argues that a group is capable of performing better than an individual. While knowledge can be created jointly by learners working together this knowledge can be gradually internalised and applied by the individuals. The difference between what individuals can do alone and what they can do with the assistance of more capable peers or the teacher, was called by Vygotsky (1978) as 'the zone of proximal development'. Peers or the teacher in essence assist the learning process by scaffolding the learning process into smaller more manageable parts. Scaffolding helps the learner to connect prior learning with new learning. It involves the teacher or the peer guiding learning through interactive direct teaching and also by confining the tasks set to provide focus and support. Limiting the scope and liberty of the activity usually reduces vagueness while at the same time it maintains the level of the challenge, enabling the educator to manage the pace and process by which learners take increasing control of the task and therefore the whole learning.

The theoretical principles underpinning guided learning can be summarised as follows. Learning is a social activity in which talk is a fundamental part. As a result, knowledge is jointly constructed and achieved primarily through the scaffolding. Scaffolding provides support and focus through a gradual transfer of responsibility and control of the task and the learning process to the learner. The use of metacognition is an essential part of guided learning approach. Learners are consciously using metacognition by reviewing learning strategies to assist their learning. Metacognition is particularly important with tasks which are hard, and enables pupils to accept that learning involves uncertainty and difficulty. Language, thinking and learning are interrelated during the learning process and motivation is essential. Dweck (2000), has identified two main kinds of motivation to learning: performance orientation and learning orientation. Learning orientation (goals) reflect a student's desire to acquire new knowledge and skills. On the other hand, performance orientation (goals) reflect a greater focus on confirming or demonstrating ability (Dawson et al., 2009).

During guided learning, learning is structured into distinct episodes that follow a clear sequence which increases gradually in cognitive demand. Teaching is designed to outpace rather than follow development while both teaching and learning are interactive, well structured and promote dialogue between teacher and learners and amongst learners themselves.

2.3.4 Intuitive guided learning

Intuitive guided learning also refers to the constructivist notion of learning where the teacher is a facilitator in the learning process, guiding the learners to make their own sense of the content. However, intuition plays a very important role in the process. As it has been mentioned before, intuition is a skill that arrives rapidly, without much rational thought, is very difficult to articulate, is usually based on well grounded prior knowledge and experiences; it comes together with a feeling of confidence and it is usually emotionally charged (Reber, 1993). In essence the learning process is guided by intuition when learners seem unable to find a solution to a problem or task. Intuitive guided learning though takes place in very rich environments and virtual worlds seems to be very suitable.

By saying "rich" we mean that the learner can extract high quantities of information and that this information can be acquired in numerous ways (Swaak et al., 1998a). Additionally, simulations have been characterised compared to expository instruction such as textbooks, which are of a relatively low transparency). However, the less transparent the simulation on a given field, the less of a direct access to the variables and relations of the field is available to learners (de Jong and Van Joolingen, 1998). Learning with simulations bears aspects of discovery. Discovery requires learners to infer knowledge from the information given and this is where intuition can guide the construction of knowledge based on the prior knowledge and the knowledge acquired from the given information. This is essential, as in discovery situations a coherent knowledge base is not directly available and knowledge is to be inferred and therefore intuition can guide the learning process within such rich environments.

Research that has focus on studying learning processes with simulations have identified that learners may encounter problems when learning with simulations (Friedler et al., 1990, Glaser et al., 1992, Njoo and de Jong, 1993, Veenman et al., 1997, de Jong and Van Joolingen, 1998). The notion of “believability”, connected in turn to the sense of “presence” individuals feel in a virtual space (Slater et al., 2009), includes the capacity of a simulation to adapt and respond to user input, in particular its holistic ability to adapt to worst-case scenarios or extremes of user behaviour. Furthermore, it has been hypothesised that learning from simulations and thus virtual environments might lead to a more intuitive, difficult-to-verbalise form (Swaak et al., 1998b).

The goals of learning with simulations and virtual worlds are often different compared to learning with traditional mediums. Some “traditional” learning settings result in learning objectives given to learners at the beginning of the learning experience, in simulations and virtual worlds the learning objectives are frequently expressed less explicitly and less clearly defined (Swaak et al., 1998b). Though this is not ubiquitously the case, and certainly a skilled educator will adapt the pedagogic approach to the learner and context, it remains true that virtual environments can support a wide range of learning settings. Therefore, it is hypothesised that by self-initiated and self-directed learning with simulations and virtual environments may result in a type of knowledge which can be characterised as intuitive knowledge according to Swaak and de Jong, (1996) or intuitive familiarity according to Bruner (1961) and therefore assist intuitive guided learning. Furthermore, other research on interacting with complex simulation systems points more towards the notion of implicit knowledge (Berry and Broadbent, 1988, Broadbent et al., 1986, Hayes and Broadbent, 1988) which is difficult to articulate.

Implicit knowledge or intuitive knowledge (Fischbein, 1987) is knowledge that is hard to articulate. Furthermore, intuitive knowledge is immediately available or not available at all, and can only be acquired after inferring knowledge in rich, dynamic situations (Swaak and De Jong, 1996). Virtual environments provide learners with those rich experiences and because of their low transparency require learners to infer knowledge often intuitively and guide their learning through such rich environments. Therefore, the results of learning from simulations may very well have an intuitive quality. When people make what they regard as 'intuitive' judgments or guesses they are, in fact, using considerable knowledge about the particular situation within which the judgments or guesses are made, and typically find themselves unable to articulate the nature of that knowledge...(Reber, 1993)

3 Methods for reusability

Reusability is a significant attribute of a design that can save time and money at the same time as it improves the application's quality. Reusability enables virtual learning object designers to use a virtual entity pattern initially designed for a virtual world A to be used in the design of a new virtual world B. There are technical as well as pedagogic challenges in doing so; different virtual worlds support different levels of content fidelity and methods for its representation, and a single unified format for representing such content remains elusive (Zyda, 2005). It is important to note that this section focuses specifically on reusability, rather than repurposement, the key distinction being that reusable content remains static across a transition in context, whereas repurposed content encompasses the broader process of modifying this content which may hence be dynamic between contexts. We review two potential approaches: a 'brick' approach, which achieves reusability through the compilation of learning objects into single resource, and a 'semiotic' approach, which considers the underlying meaning of objects (and hence how technology can support this understanding through semantics), and subsequently enable repurposing where more simplistic approaches to identifying and sourcing resources, such as a keyword search, might prove ineffectual.

3.1 Brick techniques

The most common metaphors—including LEGOs, molecules, and bricks and mortar—provide an extremely interesting view into individuals' underlying beliefs about teaching and learning (Wiley, 2007). Researchers share the notion of LOs as a "brick" to build learning content through aggregation. They are classified according to a hierarchy of aggregation levels, which is based on its size and the pedagogical information attached, according to the granularity (Rodríguez-Artacho and Verdejo Maíllo, 2004). The brick-and-mortar metaphor characterizes learning objects as small chunks of content which, being a variety of shapes and sizes, are difficult to assemble in a meaningful way without some kind of contextual glue to hold them together and give the aggregation meaning. This metaphor stresses that learning objects are "bricks held together and made meaningful by a contextual mortar" (Wiley, 2005). Therefore, in the complex learning objects content, one can build on top of other learning objects by extending existing learning objects with new content or use parts of existing learning objects to create new ones.

3.2 Semiotic techniques

Charles Sanders Peirce's (1931-1958), theory of signs and his concept of information, represent an model for LOs. Peirce (1931-1958) developed the field of semiotics which is the formal doctrine of signs. Semiotics is the science of methodical sign classification, analysis of their structure and relationships, and explains the ways in which signs grow and evolve. Learning is part of a general semiotic process where the learning materials are being used as signs that are interpreted in instructional situations (1931-1958). The principle goal of education is to create habits of thought and action. Habits can be defined as the process of recognizing, interpreting and connecting signs in a significant way and acting accordingly.

Semiotic techniques in learning objects can be characterised as the techniques in which the analogy of language as a system is extended to development of learning objects. In the semiotic sense, learning objects and other educational resources are signs whether they be text, graphics, audio, animation, or otherwise (Damjanovic et al., 2005). In that sense, learning objects combining single knowledge units into meaningful learning material are similar to language where individual words and sounds are combined into meaningful messages. Therefore, one can argue that Vygotsky's (1962) notion of the "influx of sense" applies to learning objects. In language, the meaning of words and sentences is affected by the meaning of word that proceeds and follows an individual word. As a result, proceeding and following words can significantly change the meaning of a word or a sentence. In learning objects, the arrangement of educational resources creates a context in which the resources affect each other's meanings and therefore the learners understanding of the material (Damjanovic et al., 2005).

People recognize patterns of information and organize them to generate meaning. Such collections form the languages for human communication. Some of the basic semiotic principles and techniques, are the notion of sign, connotation and denotation, syntagm and paradigm.

A Sign

A sign is anything that can be used to express meaning (Peirce, 1931-1958). Signs take the form of words, images, sounds, odours, flavours, acts or objects (Chandler, 1995). The sign consists of two parts:

- A signifier - the form in which the sign appears,
- A signified - the concept (mental content) represented by the signifier.

In other words, the sign is a recognizable combination of a signifier with a particular signified. In learning objects, a sign takes the form of text, image, sound, animation etc.

Connotation/Denotation

Connotation and denotation are not two separate things/signs. They are two aspects/ elements of a sign, and the connotative meanings of a word exist together with the denotative meanings (Peirce, 1931-1958, Chandler, 2007). Connotation represents the various social associations, cultural implications, or emotional meanings associated with a sign while denotation represents the referential meaning of a sign. Denotation refers to the literal meaning of a word, the dictionary definition (Damjanovic et al., 2005).

Syntagms/Paradigms

Syntagms and paradigms provide a structural context within which signs make sense (Peirce, 1931-1958, Chandler, 2007, Chandler, 1995), in essence they determine the ‘value’ of a sign. Syntagms represent a combination of things/signs in a sentence. A syntagm is an orderly combination of interacting signifiers forming a meaningful whole within a text (Damjanovic et al., 2005). In language, a sentence is a syntagm of words while in regarding learning objects, a learning object is a syntagm of “bits” while a complex learning object is a syndagm of simple learning objects.

Paradigm represents a selection of things/signs (Chandler, 2007). It is a set of associated signifiers/signifies, which are all members of some defining category, but they are significantly different from each other. In natural language, there are grammatical paradigms, such as verbs or nouns, homophones or synonyms. I learning objects, there are text, images, sounds, animations etc.

3.3 Learning objects and state

Another characteristic element is to consider all the states in which one or more objects can be - the state space, in terms of a sequential dynamical system (SDS). An SDS system comprises a set of states in which an object can (co)exist. In ALICE, we introduce the Virtualised Collaborative Session (VCS) as a means for evolving learning objects over time. In this approach, we analogise learning objects to programming objects within an object-orientation metaphor. Hence, learning objects are given static ‘classes’ and dynamic ‘instances’ which evolve over the duration of the VCS. This notion implies some important considerations:

- Where a learning object may be instanced, the potential exists for multiple instances of this object to exist simultaneously. Therefore, and again drawing on the object-orientation metaphor, where possible elements should be identified as static (identical irrespective of instance), or dynamic (unique to each instance). Static elements have the advantage of being immediately repurposable and unconstrained by the existence of the object(s) within a virtualised collaborative session, but have the drawback of not being mutable by a learner; or, rather, a mutation by a learner will result in the object changing for all participants. Therefore a simple level of access control may suggest the educator or facilitator have access to static elements, whilst learners have access to the dynamic components, effectively taking ownership of a single instance of a learning object.

- At the end of a virtualised collaborative session, multiple instances of learning objects must be reconciled to create a single reusable object. Dynamic elements may have evolved to add content to a learning object in the form of learner comments, remarks, logs, results, and configurations, and these must be transitioned back into a learner profile on the LCMS, or the instance of the learning object must be transferred in whole, in effect extending the VCS. Therefore, if we define the termination of the VCS to be the point at which the learner ceases to interact with the learning object and never returns to it, rather than single learning sessions, it becomes more straightforward to suggest the processes that need to occur at this stage. Learner feedback must be forwarded to the educator, and similarly this educator should have the opportunity to review the LO and make any additions or amendments. Implementing these amendments as static fields within the learning object would hence allow all learners to benefit from individual feedback, whilst still retaining control over the LO.

In the case studies of the following section, we consider both a serious game with wholly static information, embedded into the game engine via subject matter experts, and a serious game which draws its content wholly from Wikipedia, a highly dynamic information source editable by any web-user. Both these cases demonstrate the diversity technology affords in learning object definition and repurposement; the first using a game as the basis for learning object formation, and the second using the web as a basis to create learning objects for a game.

4 Case studies

This section presents two relevant case studies. Firstly, we present the repurposing of the Climate Health Impact game within the EU FP7 mEducator BPN[1]. This study demonstrates the capacity to extract learning objects from a serious game, and repurpose them linguistically and culturally, in this case translating the game from English to French. Secondly, we present the repurposing of information sourced ultimately from Wikipedia

4.1 Case I: repurposing content from a serious game

Games in general and Serious Games in particular have the power of engaging users. Considering the complexity, time, effort and cost of developing such games the potential of repurposing, enriching and embedding effectively into educational practices and curricula is worth exploring. We consider in this case specifically extracting content for linguistic, cultural and context-based repurposing. In this case of linguistic repurposing, modifying the language for a serious game (or other rich-content medium) depends highly on the game engine and structure by which content is defined and arranged. Extrapolating dialogue into separate XML files, who can annotate the structure and sequence as well as content of dialogue, and allow for expandability, provides one avenue for supporting this form of repurposing. However, simple translation is often insufficient to provide a satisfactory transition between cultures. Often, factors such as gender roles, perceived social norms, and visualisations of the environment combine in immersive environments, requiring additional affordances are made to perform effective cultural repurposing. Extracting these elements is often a less straightforward

[1] http://www.meducator.net/

process than working with dialogue alone, as visual elements may not be so readily modified without introducing substantial cost overheads. In this case study, we demonstrate how a game engine may be deconstructed to allows such repurposing, through note that a continued requirement of emerging serious games is greater capacity for content to be extracted and modified without requiring reversion to source code.

In terms of the extraction of learning objects from serious games, though the potential exists, and is demonstrated in this case study, to create an encapsulated learning object from the content contained by a serious game, far greater potential exists when considering the inverse; that is, inserting a learning object from another source within a serious game. This is largely the focus of the second case study, which looks at the use of web-based metadata within the virtual environment. However, within this first case study, it is worth noting the capacity for educational content to be removed from a game and reconstructed. For games based in simulation, wherein this content can take the form of physiological models, vehicle dynamics, or interactive characters, potential exists to extract and repurpose to suit different user interfaces, as well as broader repurposing which addresses different learner demographics, contexts, pedagogies, and representational media.

The case studies are based on the Climate Health Impact (CHI) game[2] developed by the UK Company PlayGen. However, instead of repurposing a single learning object this case study refers to repurposing a complex learning objects created by many simpler ones.

4.1.1 Context of the resource

The game was designed to give biology students a better understanding of the health impacts of climate change. It focuses on identifying diseases and understanding the policies that could be implemented to help us adapt. Players assume the role of a biomedical scientist and policy maker aiming to prevent and reduce the impacts of diseases spreading throughout the world due to climate change. By correctly diagnosing symptoms and methods of transmission for diseases, the player is able to research treatment for diseases and begin helping casualties. By placing specific policies in affected areas they are also able to slow the spread of disease, and by doing so to reduce fatalities. Climate Health Impact links to the A Level Biology curriculum for OCR, AQA and Edexcel, enabling it to be used effectively in the classroom as well as at home.

4.1.2 Description of Serious Games

Fourteen diseases are included in the game. A panel on the right is used to keep track of the diseases the player has found, and those which are currently being researched. Researching a disease requires the identification of its name by searching the Internet on the basis of a list of symptoms, and then examining its propagation vector –how the disease is spread across populations. Once a disease and its vector have been identified, additional information is provided regarding the treatment and the causes of the disease.

4.1.3 Repurposing Description/Type

Climate Health Impact (CHI) game was designed to give biology students a better understanding of the health impacts of climate change.The repurposing activity took the form of repurposing to a different language intended to target a French speaking audience.

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[2] The game is available online at http://playgen.com/climate-health-impact/

4.1.4 Process of repurposing

Repurposing to a different language involved the translation of every text displayed in the game. First, the game was made generic to ease the future translations. In essence, it means that instead of translating every text directly in the interfaces and the dynamics, all the text-related content was centralised in an XML file as new content, along with the existing already separated content. The Adobe Flash based interfaces have been edited and the static text fields (tags, titles, buttons, etc.) replaced by dynamic fields (to be replaced at runtime by the actual texts). Foreign fonts have also been embedded on those interfaces to ensure the future compliance with Greek or other non-roman character languages. The dynamics were edited to load all the content from the XML file at runtime and fill the correct fields on the interfaces. These three first steps were similar to applying the recommendations provided at the end of this document, although those recommendations should be followed at the design stage. Finally, the content (new content as well as existing content related to the diseases) was translated using a simple text processor. The translation was facilitated by the fact every piece of content was separated from the Flash interfaces and the dynamics, and therefore without requiring any programming skills.

Figure 1: Screen shot from the Climate Health Impact game

4.1.5 What are the main issues you encounter?

Due to the technical nature of game content, the educator has to keep in mind that a limited knowledge about how games are designed and programmed is still a limiting factor for everyday repurposing of game content. Conversely, game developers should realise the potential of anticipating the increasing demand from educators who consider serious games content as a relevant source of educational material. The role of researchers therefore is to provide game developers with recommendations and frameworks that would enable this turnover at the lowest cost.

The first issue encountered is the access to source files. Invariably, a game is delivered as a set of compiled files, as opposed to the source files used by the programmer during the project. Compiling those files has the effect of translating the initial human-readable scripts and objects (game dynamics can be written in many languages such as C/C++/C#, Java or ActionScript) into machine language that can be understood and executed by the computer, but not any more by the developer. Compiling is a necessary step towards the ability to play the game on the computer, but it also provides a means of protecting the sources. In addition to the game dynamics, the interfaces can be delivered as compiled file as well. At least was it the case for the web-based game used in the case studies where all the interfaces were delivered as Flash SWF files. Adobe Flash is an authoring tool that helps designing graphics component. It manipulates FLA files but those are delivered into their compiled version (SWF). Although some software allow the user to de-compile a SWF file into a Flash source file, it may not work properly and re-compiling the source file into a new SWF file that can be integrated back in the game can be tricky.

Even if the educator is allowed to access the source code and can therefore perform changes in the game, editing a dynamics script or a flash-based component requires decent programming skills (which one can assume an educator does not have). For these reasons, these case studies they have led us to formulate different recommendations that readily apply out of this context. Having the content separated is really important in order to facilitate the repurposing of a game. A general recommendation would consider minimising the elements which need pushing programming skills or access to the source files. For example, regarding the interfaces, it is possible to have Flash considering a text field as a variable (a Dynamic Text Field in Flash terminology) by assigning it an identification name. Consequently, the same way content is loaded into the interfaces at runtime, the interfaces labels, buttons or titles can be separated as well in a separate file, preferably in XML, and loaded by the game dynamics. Another aspect of this generic implementation concerns the multiple locales to take into account. By default, Flash elements designed in English will only accept standard Latin characters. As a result, translating the game into other languages (such as French in our case study) reveals the inability to display accentuated characters.

These recommendations have been successfully applied on the CHI game primarily of the case studies. As an extension, the same recommendation applies, to a lesser extent, to the game dynamics. In some cases, they can be considered as content and stored in separate files, provided appropriate ways of representing them are found. Scenario-based games provide a perfect illustration. Usually, the scenario of such a game is scripted inside the game dynamics and therefore inaccessible for repurposing after being compiled.

4.2 Case II: mining dialogic interactions from the semantic web

In this case study, we consider the repurposing of unstructured information from the web, created through peer collaboration via Wikipedia, into a learning environment. To achieve this, we use a chain of web services including GeoNames and DBPedia to extract information in a semantic form, construct learning objects, and embed them into a large-scale virtual world. In a recent paper (Dunwell et al., 2010), the authors explored the use of the semantic web to create and implement learning objects within a large-scale virtual environment. In this case, the environment used was built around the Rome Reborn model (Guidi and Frischer, 2005), a model which, as shown in Figure 2, encompasses the city of Ancient Rome within the Aurelian Walls. Populating this model with learning content is a significant challenge due to the size and complexity of the environment: though a subject matter expert may be able to annotate such an environment by hand, the process would be both time consuming and costly. As the environment represents one with real-world locations, albeit during a different time period, the authors considered an approach linking the environment to the real-world via geocoding. By taking three reference points within the model, and accurately determining their real-world latitudes and longitudes by reference to Google Maps[3], a transformation matrix was created allowing a virtual point within the model to be translated to a real world latitude and longitude. As the web provides a host of services for providing data based on geographic coordinates, this proves a useful first step in opening up the model for input from a wide range of web-based sources.

Generic information sources, whilst in many cases relevant, must be filtered according to pedagogic objectives. In the case of learning on Ancient Rome, it is important for any information point generated from latitude and longitude to contain information which is historically salient and filtered according to factors such as date and topic area. Considering one of the most generic peer reviewed information sources on the web, Wikipedia[4], and its semantically-annotated relative DBPedia[5], created through regular dumps of the Wikipedia corpus into semantic analysis software, the potential exists for this information source to be used as a basis for forming learning objects autonomously. Cautions must exist for educators: a degree of review and validation for content is required, and therefore as with any repurposed or autonomously sourced learning object tools must be provided to allow educators control over the use and ability to correct content. However, the benefits are obvious: a geolocated point can be translated into a search of DBPedia, with semantic annotation used as the basis for filtering (e.g. retrieving articles only on “ancient” Rome, or flagged with appropriate historical dates).

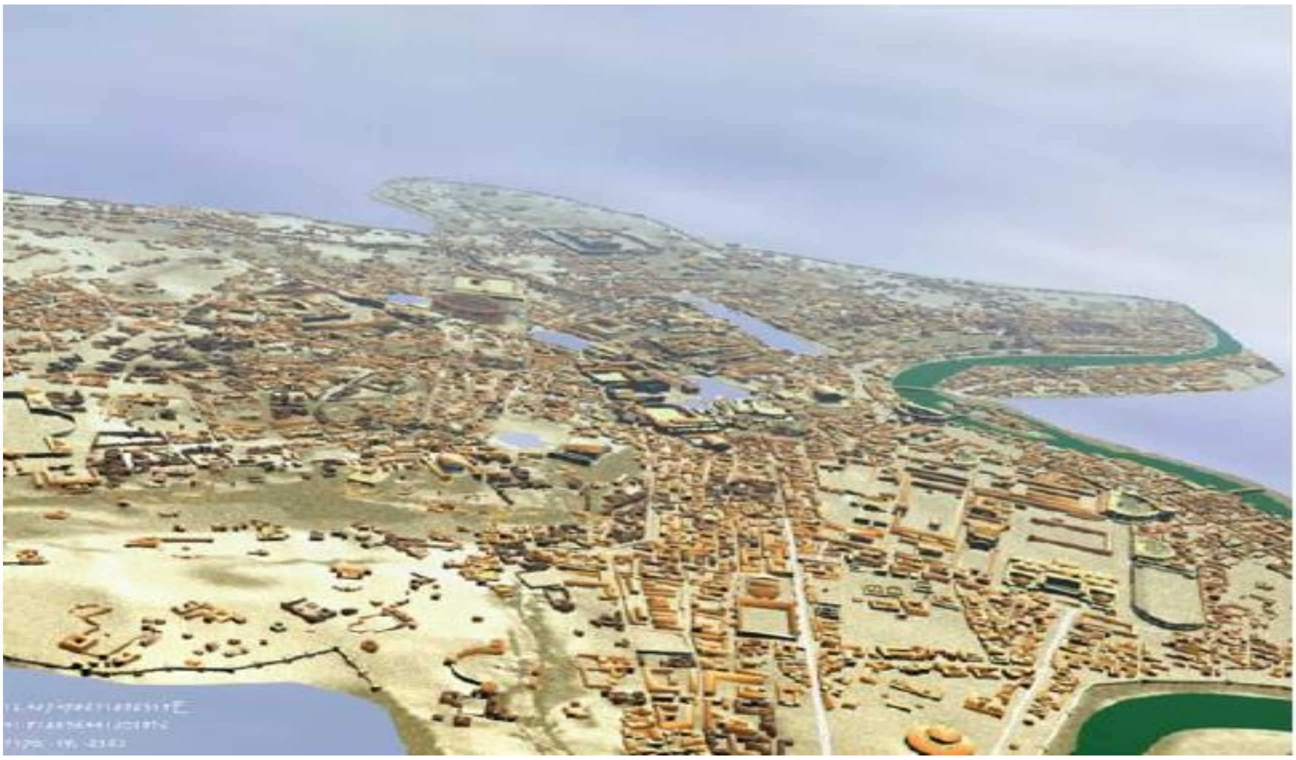

Figure 2: The Rome Reborn model

[3] http://maps.google.co.uk/

[4] http://www.wikipedia.org/

[5] http://dbpedia.org/About

The architecture used to create this solution is shown in Figure 3. The GeoNames[6] service is used to bridge to Wikipedia, in turn creating a link to DBPedia. This is then used to drive the annotation of the environment, a functionality provided to the user through both display of information points, and a "where am I?" request system that provides a user with information on the point closest to the viewpoint. Simple examples show the system working in practice: as a user approaches the Collosseum, they are provided with information on the point sourced from the web and seamlessly implanted within the virtual world, without needing to explicitly request the information, or with any need for intervention from a subject matter expert during the creation phase.

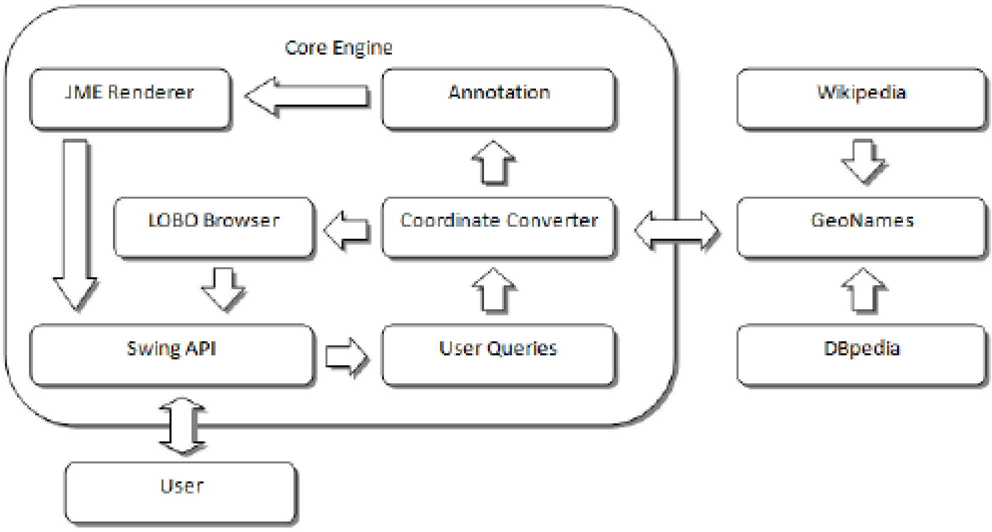

Figure 3: Prototype architecture constructing learning content from the semantic web (Dunwell et al., 2010)

The approach presents a number of key considerations for autonomous creation of content for virtual environments, using both brick and semiotic approaches: the role of the educator, extent to which content creation can be automated, and need for progression beyond simple provision of information, towards provision on learning objects that embed pedagogy and assessment. In this latter case, the need exists for information to be structured and developed, and as learning object representation extends to an ever increasing corpus of information, the potential is emerging to apply the technique described in this case study, which operates on simple text summaries of articles created ultimately by peer-review on Wikipedia, to more complex learning objects and collaborative contexts.

[6] http://www.geonames.org/

5 Simulative Content Creation in ALICE: A Game for Civil Defence

5.1 Introduction

In Section 5, we describe how concepts such as those demonstrated through the previous case studies in Section 4 have been expanded on to create a proof-of-concept expansion on the state of the art within ALICE. In Section 5.2, we classify sources of simulative content based on the activities required to reuse them effectively, or construct them from scratch. In particular, we draw out the pedagogic aspects underlying this use and reuse of content, and its specific relevance to serious games. Our model presents the consideration of construction versus reuse; noting that for any given application some combination of the two will likely be required. However, in the longer-term, adoption of standard approaches and schema for defining content has the potential to lead towards solutions that require developers only to interconnect various components whilst remaining mindful of pedagogy, a scenario which, if fulfilled, would allow educators to play a key or sole role in the creation of a serious game.

The section goes on to demonstrate these principles through the working prototype delivered in WP4 of ALICE. We show a variety of technologies and techniques in practice, creating a school environment from blueprints and schematics of a real world building, and populating it with objects and characters sourced from online repositories. The use of a modern game engine allows aspects such as rendering and physics to be implemented at a level approximating the state of the art in entertainment games, whilst allowing the retention of low-level of control over game mechanics and content. Such functionality is further demonstrated through the implemented ability to extract individual components from the game, construct a semantic web search or bridge to other web services from their properties, then reinsert autonomously acquired content back into the game. In the proof of concept, this is shown through the translation of in-game text using the Google Translate service, though the core underlying approach could equally be used to search for content such as posters and videos with which to populate the virtual environment. We outline this technique and discuss its implications for both ALICE, and future work within the area.

Our summary of methods and techniques for simulative content creation highlights the value of this area as a means to create sophisticated learning environments in a rapid and pragmatic fashion. However, the approach lacks learner and tutor-centricity, and therefore must be undertaken alongside careful consideration of the value of the resulting game and environment. Repurposing and reuse have the potential to allow greater adaptivity in learning environments, for example replacing instructional posters within the game world with a selection chosen from the semantic web based on traits of players such as their country of origin and age. However, tools facilitating such adaptivity must be mindful of the needs of educators and their ultimate key roles as selectors and editors of educational content. Including educators in the repurposing pipeline is demonstrated in a user-friendly fashion within the ALICE prototype, providing simple plain text files of translated content for educators to further edit to suit their needs. However, significant future work will be required to identify how best to include educators in approaches to asset sourcing and retrieval for serious games, and broaden this area to include and capitalise on similar, more general advances in learning object repurposement.

5.2 A reusability-oriented classification of simulative content

Classifying simulative content in terms of its repurposability is a useful exercise to undertake before considering methods and techniques for simulative content creation. With respect to this deliverable, we consider content creation to be either in terms of bespoke development from limited first principles (e.g. using tools such as 3D Studio Max[7] to model content and objects, and coding associated physical or behavioural simulations); creation through reuse and combination of existing simulations (e.g. combining a physical simulation with existing 3D models to create a simple game teaching ballistics); or creation through pure reuse (e.g. using a simulation created for on-the-job training as an educational tool for trainees). Many games intrinsically reuse elements of simulative content without explicit consideration of the process. Physics engines are commonly shared between 3D engines; if not at the code-level then at a conceptual level in terms of their design and implementation to provide real-time behaviours for objects falling under gravity or responding to impacts. Similarly, elements of character animation, such as ragdoll physics and animation blending, are implemented through similar methods in a wide range of modern game engines. Reviews of such elements, their incorporation and reuse, and relevance to serious games have already been conducted (Petridis et al., 2010). Therefore, the focus of this section is on specifically relating these methods to pedagogic concerns, as well as identifying, in educational terms, key principles for constructing and reusing simulative content.

Such principles must ultimately be derived from underlying educational need. A temptation with modern game engines, which provide capacity for high fidelity content inclusion at low cost, is to implement a wide range of features and functions without specific heed to their educational impact. This is particularly complicated by the fact the pedagogic role of elements such as fidelity is still relatively unexplored in educational terms; some studies have suggested focussed fidelity on elements of particular salience under a cognitive model of learning, rather than a blanket approach to high-fidelity might be more educationally beneficial (Jarvis and de Freitas, 2009). Certainly under established models relating cognition and learning (Bloom et al., 1957), a danger of cognitive overload could be perceived from feature rich, exploratory games. Yet an exploratory (de Freitas and Neumann, 2009), or experiential (Kolb, 1984) approach to learning has been shown to work well in a simulator-driven learning environment (Raybourn, 2007), and thus it could equally be argued that the 'ambient fidelity', e.g. the fidelity of the surrounding environment extraneous to the learning objectives, can also play a key role in sustaining the engagement of learners. Developed examples such as Triage Trainer (Knight et al., 2010) have demonstrated substantial investiture in the backdrops and environments in which pedagogic content in deployed and arranged, and though few studies have attempted to evaluate the link, a logical one could be expected between how visually compelling a game appears, and its intrinsic appeal to learners.

In Section 5.2.1, we explore in more detail techniques for simulative content creation. This leads to our consideration of two core approaches: construction of new content, and repurposing of existing content. Ultimately, the decision is grounded in cost-efficacy: given an unlimited budget and timeframe, a bespoke and highly iterative approach would undoubtedly yield the most effective solution. However, in more pragmatic terms, the gains that can be achieved through the reuse of content, game engines, and assets often make them desirable and highly relevant techniques for serious game development.

[7] http://usa.autodesk.com/3ds-max/

5.2.1 Key techniques for simulative content creation

Before describing techniques for simulative content creation, it is important to first define what is meant by “simulative content” in the context of this report. Notably, in game development parlance, the term “asset” is used interchangeably with “content” to describe a discrete element of a game. These are typically demarcated in technical terms: for example individual .3ds files for 3D models, .mp3 files for audio content, or .jpg files for textures. There is often a danger when attempting to relate models of content definition designed from a technical standpoint, to one from an educational standpoint: for example, a static 3D model may have little educational value, and nor may its associated texture; yet when combined they may represent a visually recognisable artefact for cultural heritage interpretation. Even then, unless combined with a visualisation engine capable of supplying users with the tools they need to easily navigate and view the object, their pedagogic value may be nil. Furthermore, simply including an audio file, technically a very simple asset, may add a narration to the exploratory visualisation that dramatically increases its pedagogic value. However, this may not mean the majority of the pedagogic value is encapsulated in the audio file, as without the associated visualisation, the narration may prove confusing, unengaging, or meaningless.

From this simple example, it is easy to see a definition of “content” is not as straightforward as it may initially seem. Clear parallels can be drawn to the learning object metaphor, and indeed we have demonstrated in early stage prototype work (D4.3.1) how a game might be defined as a learning object within the Intelligent Web Tutor platform. Even so, it is perhaps beneficial to consider how games may themselves serve as *content managers* for learning objects, blending more fully into intelligent tutoring systems to provide a platform or vehicle for incorporating learning content. An educational video, for example, might be given more relevance and salience when combined with a gameplay mechanic when encourages learners to view it through a system of in-game rewards; an approach demonstrated through games such as MeTycoon[8]. In Figure 4 taken from the ALICE prototype, we demonstrate the inclusion of safety posters within the virtual space; these adhere to the common definition of learning objects as encapsulating fully their pedagogy and functioning in a standalone fashion for learners:

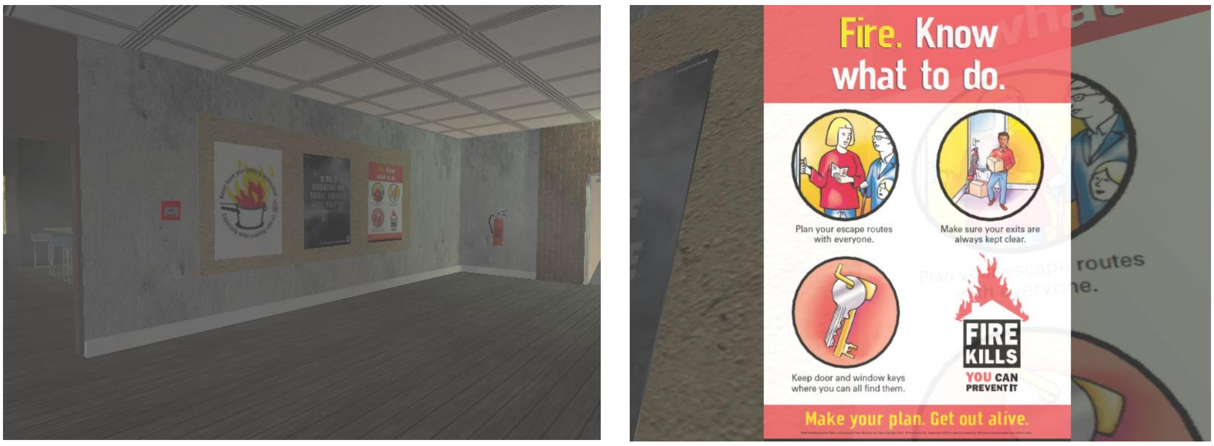

Figure 4: Learning content objects (fire safety posters) in ALICE demonstrating (left) how they can be included within the virtual space and (right) how additional mechanics may optimise pedagogic value

The illustration in Figure 4 also demonstrates a further complication when including external learning content in a serious game; without explicit motivation on the part of the learner to view and experience this content, they might be overlooked as background material (Brydges et al., 2010). Therefore we

[8] http://metycoon.org

explicitly scaffold learning engagement by rendering the poster over the screen in an easily readable format as the learner approaches. Encapsulating these elements, due to their engine and application specificity, is a difficult task, and the resulting object may have little value outside the immediate application. Similarly, unless coupled to research exhaustively exploring the best deployment of the object in the virtual world under all feasible game dynamics and pedagogies, it would be difficult to justify an automated selection and implementation process. Hence, we must turn once again to the role of the educator: by providing the images in a separate folder, they can easily adapt or replace them at a content level, whilst the implementation within the game itself remains constant. This is one example of the combined repurposing of existing learning content with new simulative aspects defining how it is realised within the virtual world of the game. Noting that games may benefit from abstraction (Wier, 1958), or even fundamentally require it (Vygotsky, 1978), a benefit of this approach is it places no constraint on how the resource is ultimately realised within the game. The trade-off, of course, is that the removal of such constraints places the emphasis on preserving its pedagogic value through the transition as this is no longer guaranteed.

Returning to the overall definition of “simulative content”, we can see from this example that content should be defined and demarcated in terms of its pedagogic value and repurposability, rather than its technical boundaries. It could be argued that any self-contained simulation of a real world event or process has intrinsic pedagogic value in allowing a learner to observe the process or event; therefore such simulations would fall under this definition. Furthermore, static objects such as images, though readily defined in terms of technical boundaries (e.g. their file size and format), would equally be valid content items, provided their pedagogic is wholly encapsulated as would be the case with an educational poster or resource. By comparison, excluded from this definition would be images that explicitly required the presence of an educator to explain and convey their meaning to learners. In our previous example of cultural heritage visualisation, whilst the model, textures, and audio *individually* would not be considered content under this definition, the combined resource would be. Thus, a key advantage of the definition put forward is that it reinforces the operation of our methods for construction and reuse on the pedagogic level, reinforcing parallels to guideline definitions of learning objects (Smith, 2004). In the long term, even greater transparency may be possible, automating the conversion process wholly and transitioning serious games to the role of content and learning managers: in the immediate scope of this deliverable, we may now describe construction and reuse in a pedagogically-grounded fashion.

5.2.2 Reusing existing simulative content

In the discussion of the previous section, a range of example sources of simulative content, such as cultural heritage visualizations and physical models were described. Following the definition of content provided in the previous section, an important first distinction is to identify whether content is pedagogically-defined, and may therefore be reused in an educational context, or lacks pedagogic structure, in which case it must first be *repurposed* into a valid learning content object. Repurposing methods are described and have been explored in-depth for more general learning objects (Singh, 2004), with dimensions such as community involvement (Wang et al., 2007) considered as methods for enabling large-scale repurposement. However, in the case of serious games, given the difficult balance between instruction and education (Zyda, 2005), some degree of design input is likely to be required to achieve pedagogic scaffolding whilst simultaneously catering to the need for a compelling gameplay model. Hence, for these repurposed simulative content objects, converting them effectively to learning objects is likely to imply limitations in users, context, and representational medium is implied by the serious game’s design (de Freitas and Oliver, 2005). Furthermore, if a gameplay model is inherent to the pedagogic structure around the content object, it may limit composability (i.e. the ability to construct new simulative content as a composite of existing simulative content components).

Simulative content already pedagogically defined represents a far simpler case for reuse. As outlined in Section 5.1.1, even simple elements such as safety posters can be constructed into content for simulations, and by extension form subcomponents of simulative content, in a technically straightforward manner. In this context, we might consider the wider range of resources which, whilst not intrinsically simulative themselves, could be used as valuable educational resources within a serious game. Examples here might include more conventional learning objects containing image-based, textual, or video resources which could feature within a virtual world simulating an event. As such, these objects might be placed around the periphery of the experience to immerse the learner amongst pedagogic content. Previously in this deliverable (Section 4.2) we have described work to annotate a virtual model of Ancient Rome with information mined from the semantic web; there is little reason against why this could not be generalized more fully into models for creating serious game content for learning object metadata. Following an immersive learning paradigm (Warburton, 2008), provided an overarching pedagogy such as an experiential, social, or situated model is in-place, surrounding or immersing the user amongst content derived from other sources is possible in a unique form within a virtual world, given its capacity to add substantial background information. Subtle techniques such as cognitive or narrative cues may then be applied to guide the intuitive learner around the environment (Mott et al., 2006), or modify their affective state (Knez and Niedenthal, 2008).

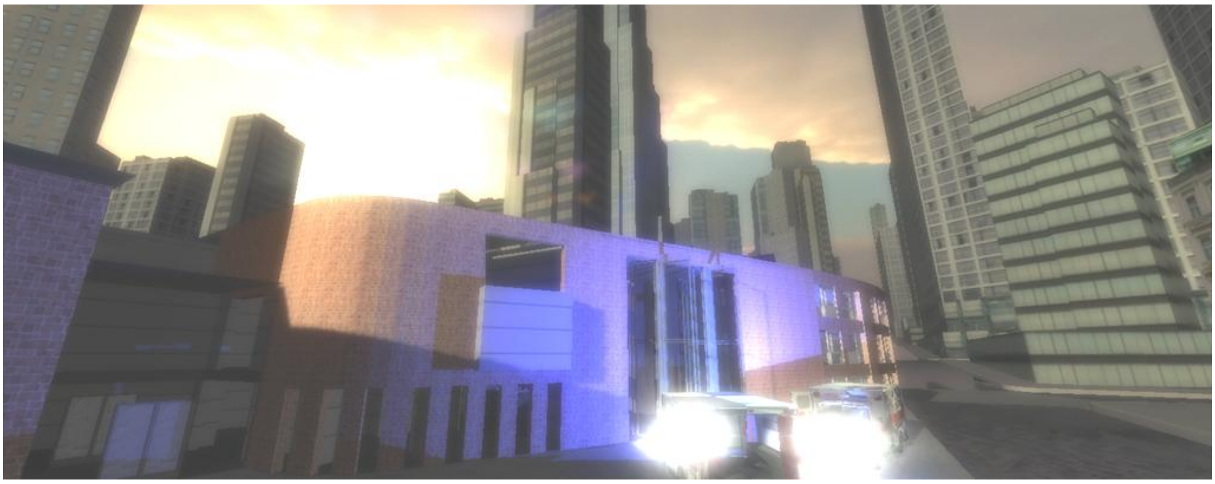

Figure 5: Procedural generation provides a rapid way to create a plausible backdrop for the game

Procedural generation of content is also worth of consideration as a method loosely coupled to the notion of content reuse. In Figure 8, we show how a city backdrop is implemented within the ALICE game through the use of the CityEngine[9]. Here the simulation *creates* the asset, building the backdrop based on a simple set of parameters and learnt knowledge of how cities are structured and evolve. The result is a large-scale, visually plausible environment for the game. Pedagogically, the value of this activity is indirect, through could be suggested to be beneficial in increasing immersion, and therefore presence (Slater et al., 2009) under a cognitive model of learning (Bloom et al., 1957). Similarly, factors salient to technology uptake, such as perceptions of usefulness amongst users, might be enhanced by a higher-fidelity solution (Davis, 1989). Immersion and flow (Cziksentmihalyi, 1997) have also been explored and shown to be impacted by game structure and fidelity (Nacke et al., 2009). Thus, whilst higher fidelity might have limited direct impact, its indirect impact through these other methods is worthy of consideration.

[9] http://www.esri.com/software/cityengine/index.html

5.2.3 Constructing new simulative content

As with any learning object, an essential first exercise in construction is to identify the overall pedagogy, its requirements, and subsequently determine the required content. In the case of a simulation, this is likely to follow an experiential (Kolb, 1984) or exploratory (de Freitas and Neumann, 2009) cycle which underpins the majority of simulator-driven approaches to training (de Freitas, 2006, Mautone et al., 2008). In the virtualization or abstraction context common to game-based learning, whilst experience and exploration occur in this virtual context, learning outcomes are expected to be applied to the real world. This implies two fractures which must be overcome by the learner: the first between exploration in virtual space and reflection on its implications for real space; and the second between the concepts learners form as a result of the experience, and their return to a virtual context to test them. Without careful scaffolding, examples have shown that learners can learn to overcome the game by circumventing learning requirements, for example with the MathBlaster serious game, learners were shown to develop strategies to win by rapid, random shooting, rather than careful selection of targets to solve mathematical problems (Binsubaih et al., 2008).

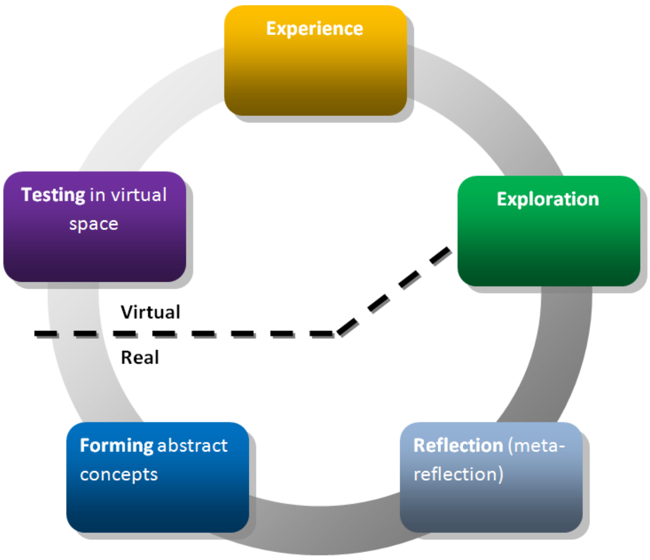

Figure 6: The exploratory model fractured by the differences between reality and simulation (Dunwell et al., 2011)

Therefore, in the construction of new simulative content, it is crucial to scaffold this fracture through careful consideration of feedback and blending, in particular identifying where autonomous or machine-based feedback benefits from input from educators on deeper levels, probing learners' understanding and reflection of core concepts (Dunwell et al., 2011). Affective and emotional approaches such as those put forward within ALICE allow a high degree of adaptivity in response to levels of emotion, but identifying these levels of emotion in an effective form initially is a challenge, as the assessment process itself may influence results (Docherty and Serper, 1990). Hence, in the short term, we cannot exclude the tutor from considerations; rather we must accommodate and target simulation driven learning approaches in a fashion which seeks to aid, rather than replace their role. An additional advantage of simulations in this respect is their ability to monitor closely learner interactions. The notion of a video game as a research instrument has been explored by recent literature, a key challenge faced here is translating low-level events such as keystrokes and avatar co-ordinates to a meta-level suitable for assessment by educators. Such translation is further complicated by the nature of intuitive learning: such learners will explore incorrect actions and their consequences as readily as correct ones, and therefore it is dangerous to associate directly the 'correctness' of actions in an exploratory environment to learner ability or skill.

Figure 7: Collection of 3D objects taken from external sources and repurposed into learning content

Within the ALICE prototype delivered in WP4, we have adopted an "achievement" based system for translating this information to the meta-level. Figure 7 shows a range of assets sourced from web repositories such as TurboSquid[10] and distributed under a free public license agreement. All these elements have the potential to be reconstructed as learning objects, but independently lack pedagogic grounding and structure. In the civil defence scenario ALICE explores, it is possible to relate these to learner actions - for example following fire exit signs, activating an alarm, or attempting to (incorrectly) use a fire extinguisher. Discussed more in D5.1.2 and D5.2.2 is the conceptual underpinning of how interactions with the objects are subsequently related to learner assessment and feedback strategies. However, relevant to this deliverable is the notion that constructing simulative content requires a supportive pedagogy, often unique to the game rather than its individual objects to be valid. Within the achievement based system implemented, various objects are assigned scores, collated to provide a coherent experience; yet if a single item were extracted and repurposed, even with the surrounding achievement system intact, it would lose meaning beyond the rule set of the surrounding game.

An alternative form of content construction as briefly mentioned in the previous section, is to composite existing simulative resources into new content objects, following the brick-based paradigm described in Section 3.1. Whilst this might require technical work around the periphery to integrate systems towards a single coherent content object, it can provide a rapid means to create simulative content. Figure 8 illustrates a simple example of this through the combination of an untextured globe model and a map of the world. Though trivial, this example provides a good demonstration of how assets might be combined to create increased pedagogic value: the map has some intrinsic value; the model less so, yet combined they offer learners the ability to gain more insight into the distribution of countries around the globe, provided an interface is provided to allow the learner to rotate their viewpoint around the object. We might also then create a game requiring learners to seek out locations or even plan strategies through a global simulation, as implemented by games such as Fate of the World[11]. Yet as we progress further down this pipeline to a learning experience, we are

[10] http://www.turbosquid.com

[11] http://fateoftheworld.net/

simultaneously reducing the repurposability and reuse potential of the end-product. This is not a problem unique to games, and in fact one reflected in the wider use and reuse of learning content; however, in the case of games it is a particularly significant challenge.

Figure 8: Simple example of resource combination: Two separate resources (an untextured 3D model of a globe, and 2D map of the world) are combined into learning content (left).

For the construction of simulative content, these considerations lead to a number of implications:

- If we are to compose content, and in doing so reduce the composability of the subsequent end-product, it is desirable to preserve content at key links in the composition chain in order to later decompose the structure for repurposing;
- Encapsulation of game-based content in terms of a learning object (LO) is, due to the nature of the gameplay model, unlikely to allow for a fine-grained approach. Notions such as 'gamelets' focus upon creating micro-games which might be easily repurposed, but even in this case each gamelet contains a self-contained gameplay model. Thus, it could by posited that gameplay model and pedagogic approach are intrinsically interrelated and cannot be separated.

Therefore, returning to the notions of brick-based and semiotic repurposability (see Section 3.1 and 3.2), clear and immediate parallels can be drawn to the use and reuse of simulative assets. Brick based methods consist of compositing content as described in this section. Semiotic methods, by comparison can be represented by a change of audience or context for delivery. In broad terms, therefore, brick methods are restricted by technical constraints, limiting the ability of designers to bring together assets seamlessly. Semiotic methods contrast starkly in that the challenge is a purely pedagogic rather than technical in nature; shifting learner and context dimensions will inevitably impact the most suitable choice of pedagogy and representational medium (de Freitas and Oliver, 2005). In Section 5.3, we demonstrate through case studies within the ALICE platform how these challenges are addressed. Before doing so, however, it is important to note two remaining concerns: the first is the preservation of intellectual property whilst repurposing; the second how performance requirements may require scalability beyond that required for learning content which is lower fidelity in nature.

5.2.4 Preservation of intellectual property rights during repurposing activities

Preservation of intellectual property (IP) is an important consideration during any repurposing activity. Online repositories of low-level technical assets such as 3D models and images commonly include a licensing agreement as part of the download process[9]. However, preserving these agreements in the case of composed assets can conflict with the need to provide assets suitable for further brick-based repurposing. For assets given a free open use agreement by their creators, considerably fewer restrictions apply; yet for other sources of IP, allowing a composed asset to be decomposable risks making these assets available for reuse without the explicit consent or knowledge of the IP owner. Whilst standard copyright law can suffice for cases where uniquely identifiable assets have been reused without permission (Kienle et al., 2008), for more complex structures, such as gameplay mechanics, little copyright protection exists; in fact the entertainment gaming industry thrives on genres which are defined in terms of mechanics reused without acknowledgement of the original source (consider for example genres such as first-person shooters, or real-time strategy). Though discussion of this in depth is beyond the scope of this deliverable, it does highlight a potential clash between the ethos surrounding learning content, and that surrounding game design, and one which inevitably require resolution as these disciplines converge to create serious games. Open source and creative commons licenses offer

Digital watermarking (Kahng et al., 1998) offers a potential solution, though mixed uptake has so far failed to result in a ubiquitous solution. Rights-enabled processing systems for graphics (Shi et al., 2006) also offer potential to resolve issues surrounding lower-level technical components. Yet these technical issues must be offset against a higher ethical consideration of the impact of fine-grained IP management on the nature of the Internet and emerging technologies (Spinello, 2003, Lipinski and Britz, 2000). Shifts towards user-generated content and increased accessibility of modelling tools (e.g. Google Sketchup) and game engines (e.g. Unity) are leading towards an environment where the amount of open content challenges traditional approaches to IP management both through volume and social norms (Cheliotis, 2009). As creation of virtual world content and games becomes increasingly accessible a pressing need exists to evolve and reconsider these approaches to accomodate the repurposing methods described in this deliverable more fully. Whilst explicitly resolving these issues within ALICE is beyond the project's remit, it is an important consideration for future work in the area.

5.2.5 Preservation of scalability during repurposing activities

Under the model previously shown in Figure 6 it is desirable for any simulation built around experiential or exploratory pedagogy to consider the relationship between simulation fidelity and quality of learning transfer. Such a relationship has been behind, for example, drives to create highly realistic flight simulators for both civil and military aviation (Mautone et al., 2008). Yet this must also be balanced against the technologies at the learner's disposal. Initial evaluation of the ALICE WP4 prototype (see D4.1.2) highlighted the difficulty in introducing a game which approaches modern entertainment titles in its hardware requirements and fidelity levels into schools where the hardware to support such titles was not present. As discussed in more detail in D4.1.2, this is a non-trivial issue and simply creating lower fidelity solutions risks replicating the problems that have led to serious games being widely considered as learning solutions: the disconnect between low fidelity didactic classroom instruction and high fidelity experiential and sandbox entertainment outside. D4.1.2 notes possible resolutions to be an increased move towards funding and supporting gaming technology introduction in-schools, targeting children during leisure time when they have access to gaming platforms, or scaling down the game to lower-fidelity versions. Of these, increased funding or shifts in spending has broad political implications and, beyond recommendation, is not considered within this deliverable. Similarly, targeting children in their leisure time is a viable route used by other interventions and learning programmes (Michael and Chen, 2005), but beyond the ALICE remit of classroom education. Therefore, we focus specifically on how scalability might be required and achieved during simulative content creation through brick of semiotic approaches.

From a technical perspective, the primary performance overheads when rendering 3-dimensional content come from both visual and simulative components. However, as visualisation is undertaken principally using dedicated graphics hardware, whilst simulation operates in the CPU (though technologies such as CUDA are increasingly enabling the GPU to be used for other operations (Che et al., 2008). Classically, therefore, the limiting factor for any environment is one rather than both of these performance thresholds. For lower specification and older PCs, or other situations where end-users cannot be expected to have high-performance hardware, a scaled solution from a higher specification system would be expected to reach a performance bottleneck in the rendering, rather than simulative capability. Completeness dictates, however, that both are relevant considerations when defining methods and techniques for simulative content creation.

- Simulation scalability must be achieved through a multi-threaded approach which is independent of the speed of code iterations; e.g. the distance a simulated object moves between frames must be expressed in terms of delta time. Consider for example these two simple psuedocode equations for an object moving through virtual space, where $\underline{p}$ is a tuple representing object x, y, z position, $\underline{v}$ its velocity, and Δt the time elapsed between frames:

  $$for\{each\ frame \quad \underline{p}_{new} = \underline{p}_{old} + \underline{v}\ (1) \quad \}$$

  $$for\{each\ frame \quad \underline{p}_{new} = \underline{p}_{old} + (\Delta t\ .\ \underline{v})\ (2) \quad \}$$

  At constant framerate, both methods would result in an object moving at constant velocity; however, if the framerate ceases to be constant, the results diverge. Significant here when considering upscaling to more complex simulation is that (1) is computationally less expensive than (2), and for a simple application or game would generate plausible result. This paradigm extends to other aspects of simulation, particularly those developed for games where user experience, rather than authenticity of simulation, is a key factor. Frameworks such as those positing multiple levels of interaction (Panzoli et al., 2010) as a method for user-centric experiences note that often a "smoke and mirrors" effect to creating plausible virtual characters can result in an experience perceived by users as more realistic than true simulation. This again can limit the usefulness of accurate simulation when applied within game environments which by their nature are user-centric and abstract.
- Performance scalability requires the ability to deliver a usable frame rate. For real-time 3D graphics this is commonly suggested to be a minimum of 20 frames per second for interactive environments (Slater et al., 2009). This is a particular concern when reusing high-fidelity assets, as high polygon counts or high resolution textures can increase hardware requirements both in terms of processing time and memory overheads. Whilst bespoke environments can be created with a target polygon count for individual components, meeting this requirement using resourced or repurposed assets may require reduction of these texture resolutions and mesh detail. Whilst methods for progressive decomposition of meshes exist (Peng and Kuo, 2005), a ubiquitous means to automate the process remains elusive, a consequence of the wide range of structures and formats in which content may be specified. Similarly, textures can be converted to lower-resolution or more highly compressed formats with relative ease; however, optimisation of a scene in visual terms might require certain textures such as emergency exit signs to be preserved in high resolution, whilst grass or brick

textures can be readily reduced or discarded. Hence intervention from a designer is required for an optimal solution, though a coarse approximation, if sufficient for learner needs, could be achieved through a combination of mesh decomposition and texture scaling.

5.3 Examples of simulative asset creation and reuse in ALICE

In this section, we demonstrate how the principles put forward in Section 5.2 are applied to create an immersive game which uses and reuses simulative assets to create an environment with minimal overheads. Though eliminating the need for human expertise during the design and development phase entirely is beyond the scope or capacity of current technologies, the application of methods and techniques for simulative content creation in ALICE are used to accelerate development and pragmatically deliver a serious game integrated with the LCMS. To achieve this, the web is considered as a source of assets, as well as available sources of information such as building schematics. With any use of web-based content, evaluation and validation is essential when integrating this content into a learning environment. Section 5.3.1 discusses how text-based assets can be decomposed from the game, interfaced with web services, then the resulting adapted text reviewed by the tutor prior to recomposition and reinsertion. Section 5.3.2 details the progression from real-world schematic to game environment, noting the complications that can emerge when attempting to repurpose large-scale content objects. The remaining sections 5.3.3-5 discuss how simulative assets can be used to create single in-game objects, characters, and the role of the game engine in providing composable technologies. Finally, Section 5.3.6 discusses the relationship between these activities and the dynamic and adaptive themes within ALICE: the rapid and efficient sourcing of simulative content using the methods put forward in this deliverable can be a useful tool in meeting the needs of adaptivity whilst also providing a high-fidelity learning environment.

5.3.1 The web as a source of assets

The web, and more generally semantic web, are an increasingly rich source of content objects suitable for composition into a game ("assets"). As virtual worlds can support text based, image based, three-dimensional, auditory, and temporal assets, significant potential exists to source and repurpose game content to annotate environments with pedagogic content (Dunwell et al., 2010). As such, it is possible to perceive through a broader consideration of learning object (LO) structure, that a game might serve as both an independent LO, but also as a container for other LOs, embedded in a game environment as images, books, videos, or other self-encapsulated pedagogic materials. By integrating these components into a gameplay mechanic, it becomes possible for a game to serve as a dynamic container for LO application and use, in-line with the brick techniques described in Section 3.1.

Web services also have potential to allow for dynamic repurposing of content. Figure 9 illustrates how semiotic reuse of material is enabled through service integration with the Google Translate service. In Figure 9, Text is directly composed into a game asset, but can also be sent as raw text to the online translation services offered by Google[12] which offer both web form and API-based methods for translating text. The raw text returned can then be evaluated and edited by the educator or tutor, being compiled into an asset by the game at run-time. This approach has several advantages over existing methods which might seek to hard-code content: firstly, neither learner nor tutor requires knowledge of the native language in which the game is constructed. Secondly, by allowing this process to operate dynamically at run-time, it is possible for the game to gain additional pedagogic value as a language learning resource. To ensure access across usage contexts, which may not assume unrestricted Internet-access, the most current version of the content is stored offline. Finally, by allowing the tutor

[12] http://translate.google.com/#

direct control over the text content within the game, they are able to apply their direct understanding of their individual learner cohort to ensure text is appropriate and intelligible for the games target users. Such involvement of the tutor in game-based learning is a central objective of the intuitive guided approach when applied to serious games as described by D4.1.2.

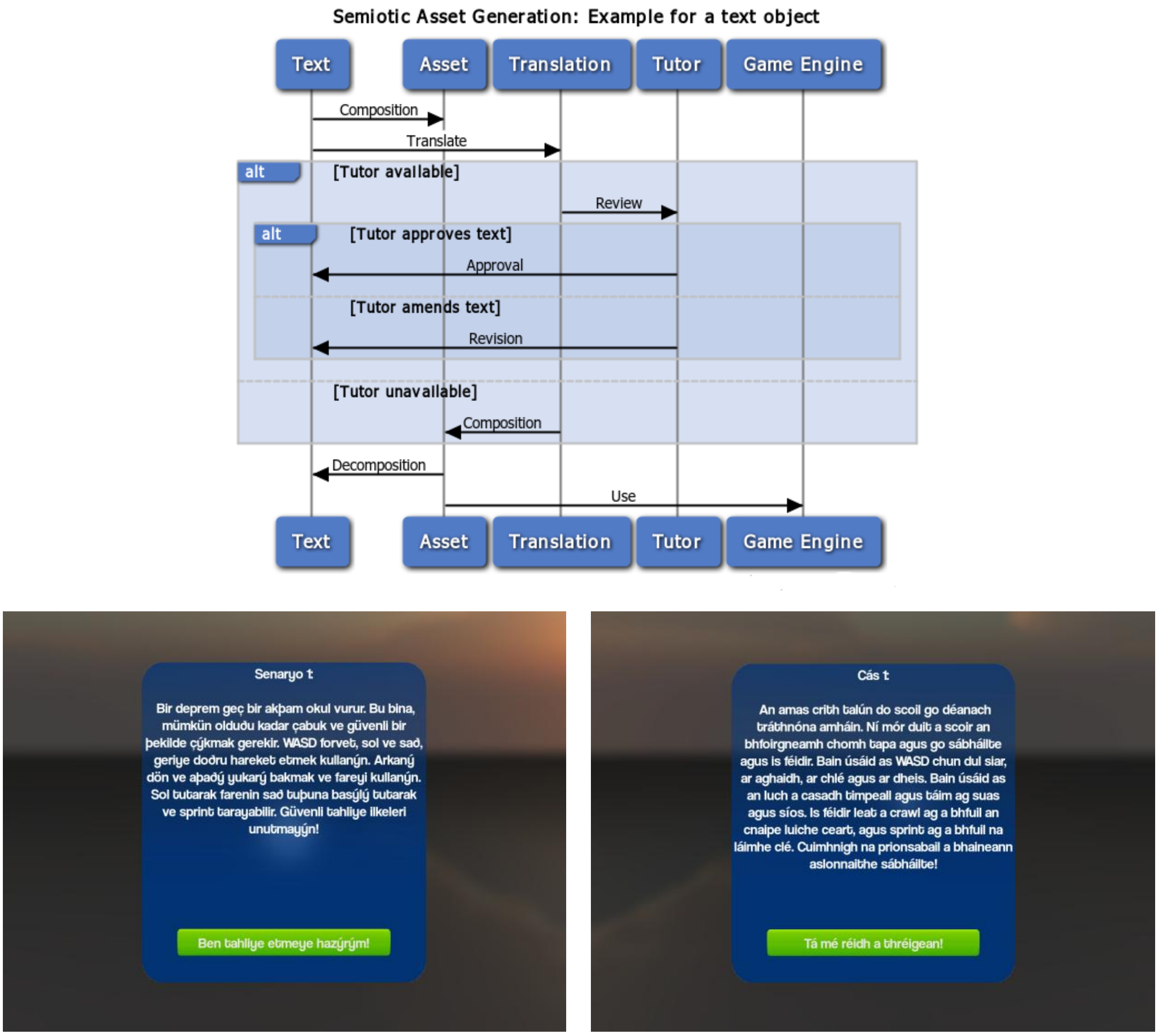

Figure 9: Example of semiotic repurposing for a text-based object in the ALICE WP4 prototype and the resulting game content translated into Turkish (Left) and Gaelic (Right). The principal limitation of this translation is the character set available for the in-game font; currently 23 different languages are supported.

With any learning resource, correct use of grammar and spelling are essential for an optimal learning environment. As automated translation cannot guarantee this outcome, data is saved into raw text files which can be opened and edited by the educator. If the tutor is unavailable the translation process is still possible, and the repurposed game will remain comprehensible, in-part due to its limited use of text beyond the scenario description at commencement. As text is fully extracted from the game and composed only as required, it is also possible for pedagogic adjustment to be easily made: for example negative feedback can be adjusted by the tutor to provide a greater degree of encouragement, or direct them to specific contextual learning resources. In the case of character dialogues, these can be completely re-written to address different topics or questions, a technique explored in more depth through integration with the dialogue engine described by WP5 of ALICE (D5.1.2). For the interface with Google Translate, rather than use a bespoke API we instead demonstrate how a direct sourcing of page content through a constructed URL can provide game content:

```
string url = String.Format("http://www.google.com/translate_t?hl=en&ie=UTF-8&text={0}&langpair={1}", input, languagePair);
string result = String.Empty;

    using (WebClient webClient = new WebClient())
      {
        webClient.Headers.Add("Charset", "text/html; charset=UTF-8");
        webClient.Encoding = Encoding.GetEncoding("iso-8859-1");
        result = webClient.DownloadString(url);
      }
```

<I would recommend here a listing caption>

It is then trivial to use a regular expression to extract the information from the returned HTML page. Sequential processing is used to read in and export to static text script files. As the learner may not have access to the Internet in a classroom context, or the web service may not be available, a batched approach is taken to translation. It may be invoked at any time, but will only update text if a valid connection can be provided.

5.3.2 Adapting real-world building schematics to a game environment

Real world schematics provide an available resource for creating plausible virtual environments. In the case of ALICE, a UK Schools for the Future blueprint was constructed into a 3D model for use within the evacuation scenario. In this Section, several key considerations when generating simulative assets in this fashion are discussed, including the use of a brick-based approach to constructing an environment around the resulting 3D model. The first stage in this process is the transition from 2D CAD blueprint to 3D visualisation. In this case, the visualisation was created for demonstration purposes rather than as a game environment. Such visualisations can prove a useful source of simulative assets for reuse in serious games; however, they are commonly created for pre-rendered and static images, rather than real-time exploration. As a result, elements such as a physical model and increased visual fidelity are required to create an immersive experience which moves beyond a simple visualisation of an environment. Figure 10 below illustrates the model as created from schematics and rendered in a real-time engine.

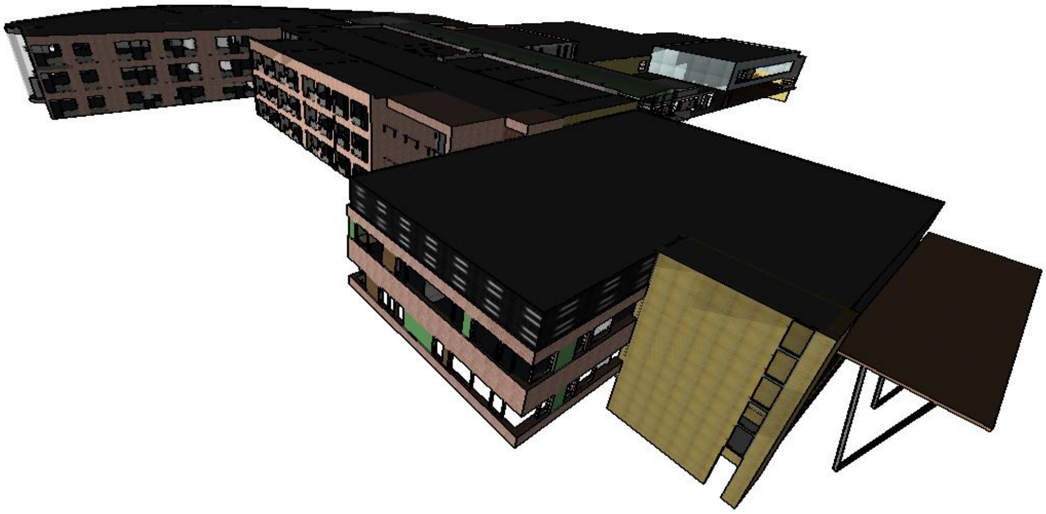

Figure 10: The school model created from schematics as a polygon mesh textured with reference images

Figures 11-15 illustrate the process for developing this asset into a game environment through a brick based approach which introduces additional assets to create a plausible environment. These assets are sourced from free-license public content repositories, or in the case of assets such as the slide presenting the project embedded into the virtual world, created through bespoke development. Similarly, shaders used are either integral to the game engine, or created using C#. Scalability can be introduced at this stage by creating a hierarchic structure for game objects, allowing content non-critical to the gameplay dynamic to be removed to reduce polygon counts and increase rendering speed. Similarly the post-processing effects and pixel lighting shown in Figure 15 can be disabled to improve performance. Approaching this in more general terms, it is possible to describe any brick-based composition technique in terms of a hierarchic content structure; whether culling for scalability is then performed by the game engine or an external script, the end result is identical. An implication here for simulative content creation is that additional metadata attached to objects at the composition phase can result in a scalable and decomposable solution. However, how this metadata is structured and defined is dependent on the game engine or script that utilises it; few general schema exist for annotating 3D content in a composable and generic form (Zyda, 2005). Consequently a degree of bespoke development is required both in application creation and scaling. Automating this process is desirable to reduce development costs and introduce more pragmatic solutions, yet relies on content authoring and management to create and define objects, as well as a progression of standards for annotation of 3D content.

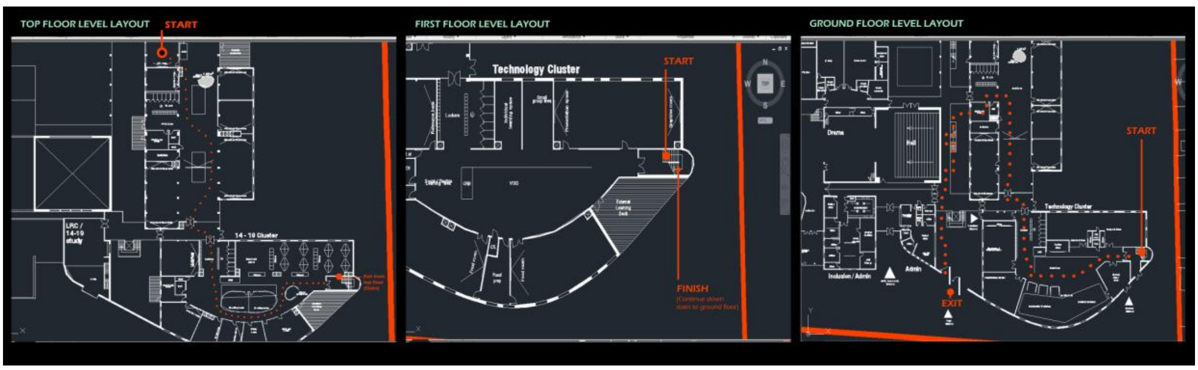

Figure 11: User paths through the scenario are designed and the model adapted to define a 'playable' area for the game

One example of this bespoke development is the definition of a scenario path (Figure 11). As the areas of the building through which the learner navigates benefit from increased fidelity, mapping this route in advance allows for increased emphasis to be placed on key areas and parts of the structure. Similarly, removal of extraneous content improves scalability on lower-end platforms. This content removal can be automated through an occlusion culling technique, or undertaken by hand.

Figure 12: The initial environment created from the 2D schematics is used for the game. Collision meshes are implemented and a simple physical model for the player camera, ensuring the player is constrained by gravity and solid objects. Light sources are positioned by the designer, noting that their choice can have a strong impact on user affect (Knez and Niedenthal, 2008). Whilst this provides an adequate environment for exploration, the lack of content limits the ability of the learner to recognise the earthquake scenario.

Figure 13: Walls are retextured using higher resolution images. Similarly the floor is retextured, using bump and normal mapping to emphasise the divisions between individual boards. To highlight the earthquake scenario individual ceiling tiles are added and given physical behaviours using the same model applied to the player; as the simulation starts these tiles fall and collide with the floor.

Figure 14: The environment is populated through the reuse of simulative assets in the form of three dimensional models and textures. A slide from the ALICE project is added to a whiteboard at the end of the room demonstrating the ability to embed and reuse images as pedagogic content. Interactive items such as the bag shown on the left are added. As the tiles added in Figure 13 fall, they collide with objects using the physical simulation to create a plausible initial layout for the environment. Post-processing effects including screen space ambient occlusion are applied to increase the fidelity of the environment without requiring modification of its content.

Figure 15:Per-pixel (deferred) lighting is applied to further increase visual fidelity. Note the impact on the evacuation sign at the far door, which gains prominence as the learner surveys the scene, as well as the slide added as pedagogic content in Figure 12. As noted in Figure 10, lighting can play a crucial role in both the affective state of the learner and their navigational choices when progressing through an environment. The process is repeated for the playable area defined in Figure 11. Occlusion culling is also applied using an octree-based technique to create an occlusion map, which reduces the number of polygons rendered at run-time, improving performance. A shake of the player's viewpoint is added as tiles fall to increase the plausibility of the earthquake.

The process described through Figure 11-15 broadly describes the state-of-the-art approach. However, this is commonly undertaken with entertainment rather than pedagogic objectives at the forefront of design. Pedagogic consideration suggests that the composition of the environment must be carefully undertaken as to present relevant content to the learner whilst ensuring they do not deviate from learning outcomes. Given the further requirement that an intuitive learning experience include exploratory or experiential elements, particular care needs to be taken to ensure a guided yet non-linear experience for the learner. Figure 16 illustrates in more detail the process underlying the visual example provided in Figures 12-15:

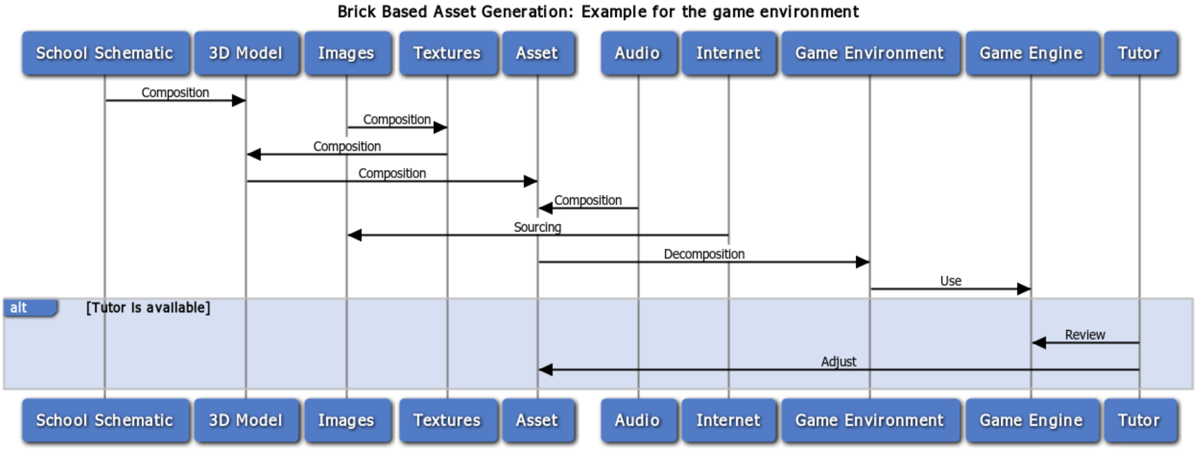

Figure 16: Example of brick-based repurposing for the game environment in the ALICE WP4 prototype

This can be typified as a brick-based repurposing technique which compiles and composes simulative assets into a coherent environment for civil defence training. However, this is not without need for bespoke development within the process to position elements and increase the fidelity of the environment through retexturing and other methods. Procedural generation techniques offer longer term promise for the creation of game environments from simple parameters, and are used to create environments such as cityscapes (e.g. the backdrop in Figure 5, generated using the CityEngine). Even in the case of bespoke development, simulative resources can provide a useful backdrop for game creation. More generally this technique can be expanded to suit any serious game built around the intuitive guided approach defined in more detail in D4.1.2. Worthy of consideration also is the nature of the environment created: closed immersive environments restrict the user by design. The intent of the closed world paradigm is to create an environment specifically to fulfil specified learning requirements, with particular attention given to minimising cognitive overload and thus optimise the time taken to deliver instructional content. Closed environments thus have the advantage of ensuring the learning experience is delivered in a set timeframe, and well as being capable of ensuring the learner does not deviate from the intended path through the learning experience. This is of particular significance to organisations seeking to achieve learning objectives in the shortest possible timeframe.

The expansiveness and scale of a closed world is directly reflected in the budget and time allocated for its development. Whereas an open environment typically has many existing assets, a closed environment must be built through either repurposing assets from other simulations or from the ground-up. The cost of a closed world is thus related directly to the amount of content contained and the level of fidelity at which it is represented. A benefit here can be seen to be the fact that individual elements can be increased to any level of fidelity as required by the learning requirements – for example, a detailed evacuation scenario may only be possible to accurately visualise using proprietary techniques, precluding its use in an open environment. Open IVEs themselves already exist as generic platforms for learning experiences. Development of learning experiences within open IVEs is thus focussed on the use of existing tools and accessible open environment technology in order to create learning experiences, which in turn form a small component of an existing expansive simulation. Open environments are often attractive for low-budget or experimental serious games since many assets already exist within the environment, and can be reutilised without requiring significant amounts of bespoke development. Open environments are often publicly accessible (e.g. Second Life), although access is usually controllable through password or user credential-based approaches. They also have in-build support for concurrent users and collaborative interaction, typically including voice-over-IP (VOIP) as well as text chat support.

5.3.3 In-game objects

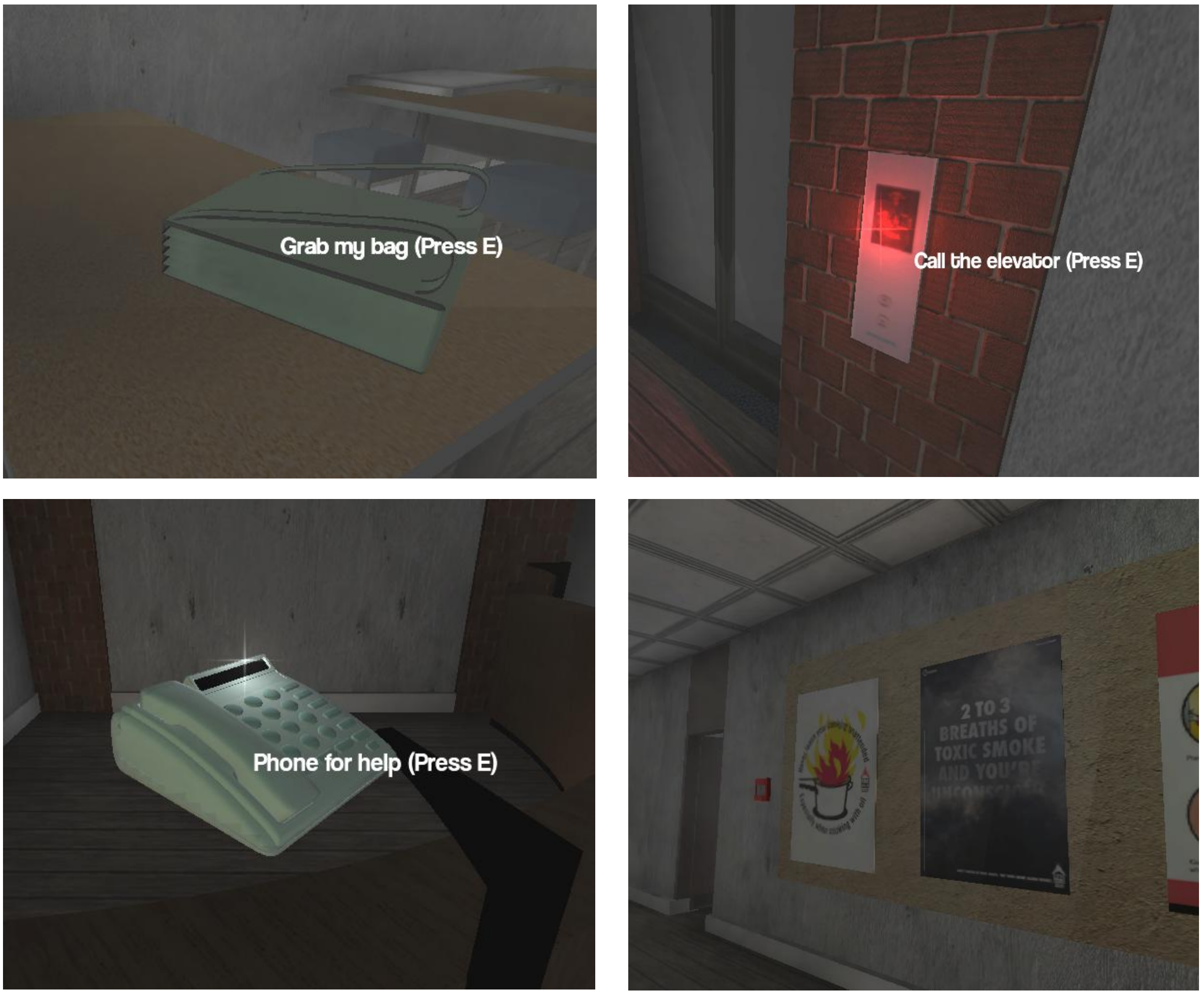

Figure 17: Differing use of 4 in-game objects: Top left - A collectable object that can be picked up by the player; Top right - An elevator call is used to test the players knowledge of safe behaviour; Bottom left - A static telephone again allows the player to perform a simple action; Bottom right - Posters displayed on the walls of the environment convey best practices.

Objects can be sourced as simulative content either as images, converted to textures, or as 3D objects as illustrated in Figure 17. More complex is the behaviours of these objects, which can vary depending on both game and pedagogic designs. Note in Figure 17 only the safety posters have intrinsic value as learning objects; the remaining content relies on bespoke development and integration into the game mechanics to gain meaning as illustrated through the available actions shown in the figure. Characters present a unique type of object in terms of both their behaviour, and the complexity of interactions that a learner may expect or require from them. Under established definitions of presence (Slater et al., 2009), it is particularly important to note the higher expectations of fidelity to be observed from learners regarding characters and their behaviour, and how implausible characters can rapidly detract from the sense of presence and immersion, which under a flow paradigm (Cziksentmihalyi, 1997) would be expected to manifest in lower levels of engagement and learning transfer. Implementing this form of simulative asset effectively requires a more open approach to implementation as shown in Figure 18.

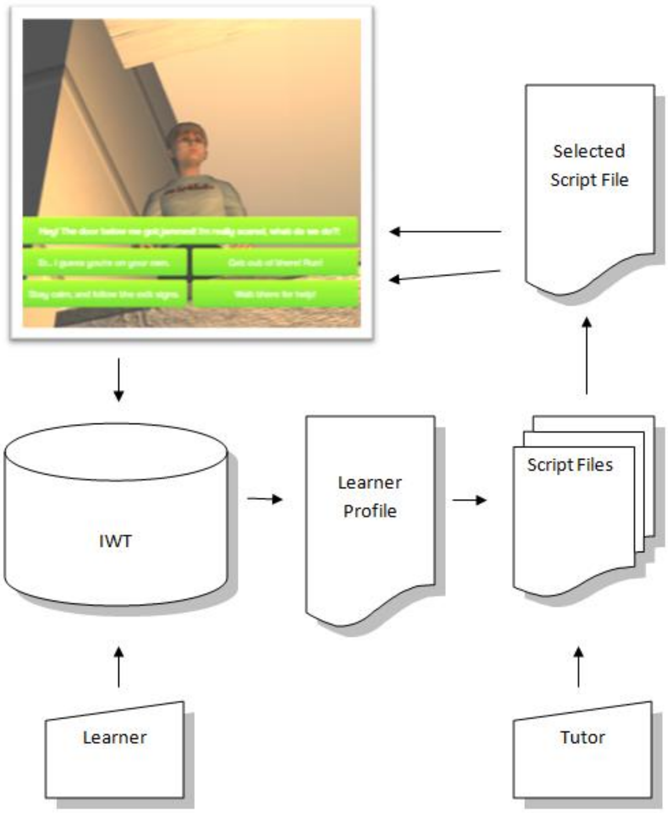

Figure 18: Interaction with a virtual character scripted and defined by learner profile passed from IWT

Multiple script files are created for the character, which can be accessed and edited by the tutor. These script files are in plain text, with no structural or semantic annotation, and therefore can be edited without expertise being required beyond that necessary to effectively write the dialogue for a character. In situations where the educator does not wish to interact with these files, static defaults provide a baseline ensuring provision of content. At run-time, they can then be selected based on learner profile. A proof-of-concept implementation demonstrates the capacity to use this facility to localise the game to the learner's language preferences, though as the scripts can be edited by the tutor without requiring expertise, it becomes possible to customise these more precisely to the state of the learner as transferred from IWT. For example, a learner for whom affecting and emotional assessment techniques were suggesting was anxious or struggling, more supportive feedback could be provided. The limiting factor of this technique is the capacity and willingness of the tutor to adjust and create script files, and link them to variables within the IWT platform.

5.4 Summary of methods and techniques for simulative content creation

In Section 5.3.1 and 5.3.4, this deliverable introduced the notion of the web as a source of simulative content. Of all the methods described in Section 5.3, this holds the greatest promise as a long-term solution to the need to pragmatically create high-fidelity simulative content for serious games. In particular, this deliverable demonstrates through this approach how content might be both sourced and muted by using web repositories and services. The ultimate goal here could be perceived as the provision of tools that effectively automate content sourcing and game creation, with the educator playing a key role in adjusting and selecting game content and pedagogy. However, expanding the demonstration of how this might be achieved for a simple text-based element within ALICE to broader use of web content and assets such as 3D models and images poses a number of challenges; this content is typically not semantically-annotated and automating searches becomes a more complex task. Furthermore, repositories for 3D content typically lack the volume of open-source and publically licensed content that might be required to create a platform capable of rapidly creating a game, and these databases are not optimised for automated or semantic search and retrieval. In this, both the accomplishment of T4.2 within ALICE, as well as the need for future work in the area become clear: a proof of concept has been created extracting game content and repurposing it using the a web-based service, but progressing this content beyond raw text is a complex, yet achievable, task.

In Section 5.4.1, therefore, it is discussed how content authors and simulation creators, who generate content through either brick based, semiotic, or bespoke techniques may advance the field by placing a number of considerations at the forefront of the creation process. Section 5.4.2, by comparison, notes the crucial pedagogic considerations and constraints that emerge when seeking to generate content for learning purposes, as without verification and validation of content sourced by automated means, potential arises for incorrect information to be presented to learners. Similarly, broader pedagogic encapsulation is a requirement for learning object definition, and if we are to create virtual content and simulations which serve as learning resources, similar methods are desirable. Finally, Section 5.4.3 builds upon the notions presented in this deliverable to discuss future considerations and recommendations to advance methods and techniques for simulative content creation in serious games.

5.4.1 Implications: how to create composable simulations?

In creating a serious game through the use of both brick-based and semiotic repurposing of simulative assets, it is possible to consider the implications for future creation of more composable simulations. Such simulations might be more easily combined or repurposed into educational contexts, building upon game-based learning principles to maximize learning transfer. Key to this are the following considerations:

- **Temporal scalability**, defined as the ability for a simulation to run regardless of available processing and hardware resources. This should be achieved by the use of deltatime functions. In the case of lower-end platforms, the limited update rate might then be corrected by dead-reckoning or similar techniques. This brings with it two key requirements:
- **Resolution scalability,** both in terms of texture resolutions and polygon counts. For three dimensional content support for shader effects such as bump and normal mapping should also be integrated into texture definitions irrespective of its end use by the rendering engine. Automated generation techniques can extrapolate surface maps from images, though as image-based techniques these methods can be prone to error. Polygon count can similarly be decomposed through automated methods, though these cannot perform the visual

compositing and analysis of which a human eye is capable. Creating scalable meshes which produce visually satisfactory results is an ongoing area of research, though specification of meshes with reduction in mind can simplify the process and improve the end result. Though the detail of these processes is beyond the scope of this Task, further detail can be found in related publications (Klein et al., 1996, Boiangiu and Raducanu, 2008, Wang et al., 2011).

- **Pedagogic scalability** can be defined as the preservation of pedagogic content and value under the temporal and resolution scaling processes previously defined. Effectively the need exists to preserve pedagogic value across platforms and performance levels as well as deployment platforms. In the case of brick-based repurposing, value should also be maintained through the integration process, which requires a degree of encapsulation of content in a transposable form. Furthermore, as a platform or simulation scales to large numbers of users, the role of the tutor or educator must remain manageable. To this end, implementation of metrics for user performance and their analysis are a central concern, as is the ability to annotate content as being particularly relevant in pedagogic terms. As an example, reducing texture resolution to minimise memory footprint would benefit from being able to identify the most pedagogically-salient aspects of the environment (such as the safety posters within the case study), and maintain their resolution.

6 Summary and conclusions

In this deliverable, the methods and techniques for simulative content creation were outlined with focus on repurposing and the reuse of learning objects (Los). Following the provision of a definition of learning objects and the literature review on repurposing and reuse of learning objects the definition of complex learning objects (COL) is provided and analysed. Then the need for repurposable and repurposed LOs is explored. The subsequent part of this deliverable is focused on the notion of intuition and guided learning where they form the basis for the description of a new pedagogical approach which is called intuitive guided learning and it is based in the constructivist approach of guided learning, where the learners can be guided by intuition to discover complex information when learning in a virtual environment. Next the methods for reusability are considered and we are discussing the brick techniques, the semiotic principle and finally the objects state. At the end of Section 4 two case studies are presented. These form the basis for the evolution of the state of the art for content use and reuse in serious games discussed throughout Section 5. Games created using this paradigm benefit from being instantly translatable to any given language, given adequate character set support, as well as empowering the educator with the ability to review and adjust game text to accommodate cultural needs as well as linguistic accuracy. The unique integration of game and LCMS within ALICE is also demonstrated to be a potential basis for further adaptivity in these dimensions, recording and reporting on the state of the learner and hence allowing content to be dynamically adapted in response, for example a struggling learner having their script adjust to one offering more supportive feedback. Together with the integration of an adaptive dialogue engine described in D5.2.1, a solution for characters and dialogues demonstrating increased dynamicism and capacity to respond to learner state is introduced. Future work must focus on how to best capitalise on this technology to serve pedagogic need, as well as exploring the ways more complex elements of the environment, such as objects and images, might be recomposed in response to these learner states, as well as more accurate methods for initial assessment of this state itself.

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