R&D Roadmap on Serious Games
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<tr>
<td>AHRC</td>
<td>Arts and Humanities Research Council, UK</td>
</tr>
<tr>
<td>AI</td>
<td>Artificial Intelligence</td>
</tr>
<tr>
<td>AR</td>
<td>Augmented Reality</td>
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<tr>
<td>B&amp;M</td>
<td>Business and Management SIG</td>
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<tr>
<td>BIS</td>
<td>Department of Business, Innovation and Skills - of the UK Government</td>
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<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>DCMS</td>
<td>Department of Culture, Media and Sport – of the UK Government</td>
</tr>
<tr>
<td>E&amp;M</td>
<td>Engineering and Manufacturing SIG</td>
</tr>
<tr>
<td>EPSRC</td>
<td>UK – Engineering and Physical Science Research Council, basic and applied</td>
</tr>
<tr>
<td>ESRC</td>
<td>UK – Economic and Social Research Council, basic and applied</td>
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<tr>
<td>GBL</td>
<td>Game Based Learning</td>
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<td>GM</td>
<td>Game Mechanics</td>
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<td>HCI</td>
<td>Human-Computer Interaction</td>
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<tr>
<td>GALA&amp;GALA</td>
<td>Humanities and Heritage SIG</td>
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<tr>
<td>Horizon2020</td>
<td>The European Union’s Research Framework Programme 2013-2020</td>
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<tr>
<td>ICT</td>
<td>Information and Communications Technology</td>
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<tr>
<td>IMTI</td>
<td>Integrated Manufacturing Technology Initiative, USA</td>
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<tr>
<td>IPTS</td>
<td>Institute for Prospective Technological Studies, Seville</td>
</tr>
<tr>
<td>JISC</td>
<td>Joint Information Systems Committee, UK – Central UK higher education IT services</td>
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<tr>
<td>LM</td>
<td>Learning Mechanics</td>
</tr>
<tr>
<td>LM-GM</td>
<td>The relation between Learning Mechanics and Game Mechanics</td>
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<tr>
<td>LMS</td>
<td>Learning Management System</td>
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<tr>
<td>MOOCs</td>
<td>Massive Open Online Courses</td>
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<tr>
<td>MR</td>
<td>Mixed Reality</td>
</tr>
<tr>
<td>MRLG</td>
<td>Mixed Reality Learning Game</td>
</tr>
<tr>
<td>NGI</td>
<td>Next Generation Infrastructure program, Dutch, 2004–2013</td>
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<tr>
<td>NPC</td>
<td>Non-Player Character (in a game)</td>
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<tr>
<td>NWO</td>
<td>Netherlands Organization for Scientific Research</td>
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<tr>
<td>PGLC</td>
<td>Post-Gaming Learning Community</td>
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<tr>
<td>PSL&amp;E</td>
<td>Personal, Social Learning and Ethics SIG</td>
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<tr>
<td>RCUK</td>
<td>Research Councils UK – basic research funding coordinating body</td>
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<tr>
<td>ROI</td>
<td>Return on Investment</td>
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<tr>
<td>SCORM</td>
<td>Sharable Content Object Reference Model</td>
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<td>SGREF</td>
<td>Serious Games Reusability Point of Reference – founded by GALA</td>
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<tr>
<td>SS&amp;C&amp;M</td>
<td>Security, Safety and Crisis Management SIG</td>
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<tr>
<td>SGA</td>
<td>The Serious Games Academy – founded by GALA</td>
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<tr>
<td>SGS</td>
<td>The Serious Games Society – founded by GALA</td>
</tr>
<tr>
<td>SME</td>
<td>Small and Medium sized Enterprise</td>
</tr>
<tr>
<td>STEM</td>
<td>Science, Technology, Engineering and Maths (subjects in education)</td>
</tr>
<tr>
<td>TCO</td>
<td>Total Cost of Ownership</td>
</tr>
<tr>
<td>TEL</td>
<td>Technology Enhanced Learning</td>
</tr>
<tr>
<td>TEL-Map</td>
<td>TEL Roadmap project supported by EU, GaLA.learningfrontiers.eu</td>
</tr>
<tr>
<td>TNO</td>
<td>the Netherlands Organization for Applied Scientific Research</td>
</tr>
<tr>
<td>TSB</td>
<td>Technology Strategy Board, UK – applied research funding body; now called InnovateUK</td>
</tr>
<tr>
<td>UNCTAD</td>
<td>United Nations Commission on Trade and Development</td>
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<tr>
<td>VR</td>
<td>Virtual Reality</td>
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1 INTRODUCTION
This is the third and final version of the GaLA Roadmap. It intends to provide strategic guidance for future research and development activities in the area of Serious Games (SG) and Games Based Learning (GBL).

The GaLA roadmap addresses the role that SG research and deployment will have to play in order to meet the long-term challenges as described in the previous roadmaps (D1.5 and D1.6), taking user, industry and academic needs into account. In particular, the roadmap is intended to complement and integrate recommendations from other stakeholders and working groups in the field of SG. In some cases, there is still a lot of research that has to be carried out before a solution supporting the realisation of the vision can be transferred into large scale pilot applications and finally be realised as market innovations. This depends both on the maturity of the technical solution as well as on the maturity of the market and the users.

The scope of the GaLA Roadmap is defined as follows:

1. To identify the main challenges related to the utilisation and deployment of SG and GBL that need to be overcome in order to increase the sustainability of the SG sector.

2. To describe how these challenges will be practically overcome, in terms of research, development and pre-competitive deployment expected in key areas.

Whereas challenges refer to the long-term scenario, identified with the year 2030 in policy documents and thus serve as a basis for our vision, the innovations will be mapped onto a shorter horizon, up to 2020, which is the timeframe of the GaLA roadmap.

This version of the roadmap is a continuation of the work we carried out in the previous two roadmaps and uses the same approach and frameworks as described there (D1.5, D1.6). This document synthesizes main challenges identified and prioritised within the different technical committees (devoted to research) and special interest groups (looking at the deployment of SG in a specific application field) as well as on SG in corporate training. Each of these groups has developed a more detailed report including state of the art and gap analysis. This has resulted in detailed descriptions of each challenge and also to the development of timelines for mapping of the different research and innovation activities. In order to keep the information readable, all details on SOTA and Gap analysis are kept in the specific sub-roadmaps for each area, whereas this document just present the key challenges. The sub-roadmaps are all available on-line so that the users of the roadmap can find the information they may be interested in easily. This deliverable, D1.7, is a synthesis of these sub-roadmaps and is meant to be used as an overview document. It presents for each sub-roadmap the prioritised challenges on timelines that will be necessary to keep in order realising the vision. All Roadmaps will be continuously updated.

It has been stated already in previous GaLA documents (D7.1, D7.4, D4.9) that there are huge barriers for market penetration and market uptake and that the SG industry faces great challenges in order to stay in the market. The reasons for this are many, but two important aspects are 1) the maturity of the product and the market 2) the willingness and opportunity of the market to pay. Thus, in order to identify the main risks related to innovation uptake, work package four, with its business perspective and knowledge of the market, has carried out a risk analysis, described in chapter 5.
Figure 1 shows the process for the GALA R&D roadmap.

![GALA Roadmapping Process Diagram](image)

**Figure 1: Roadmap steps carried out**

As the previous roadmaps are available online, we have not repeated the framework we used for the classification of the challenges, but only repeated the vision, which is to be found in chapter 2. Chapter 3 outlines the main challenges related to research and development from a general perspective. Chapter 4 looks at the challenges from a deployment perspective according to the special interest groups of our six application areas (Business and Management, Engineering and Manufacturing, Health, Security and Crisis, Humanities and cultural Heritage, Personal and Social learning and Ethics) as well as from the perspective of corporate training. As stated above the SG field suffers from a low market penetration, and thus Chapter 5 contains a risk analysis regarding innovation uptake. The conclusion is in chapter 6.
2 Vision

By 2030, SGs are anticipated to become a useful and reliable tool for learning and training. Educators and trainers will, according to user-specific needs, be able to select the most suitable games for achieving precise learning objectives by utilizing catalogues and databases of SGs. Authoring tools will promote the customization of contents and learning procedures, and will be widely used.

Not only will SGs be used to motivate students to explore new topics, but also to solve exercises efficiently, practice the application of learned theory, and verify the acquisition of knowledge and skills. Complex and precise gamified simulations will be available for free experimentation\(^1\), with different degrees of guidance, to take place according to the actual user profile and learning goals. Teacher supervision and guidance as well as peer competition and collaboration will be targeted and integrated in games through appropriate mechanics.

SGs will feature intelligent user interaction (UI) through natural means such as voice and gestures. Such user interaction will facilitate access to information and services, reduce sensorial overload, and realistically simulate the actual conditions of use (e.g., haptic forces for manual works). Several SGs will also support interactions in the physical-world.

Real world interactions are key in supporting knowledge transferability, field practice, training and verification. They will take particular advantage of mobile computing and communication technologies, with ever thinner, more ergonomic and lightweight tools, such as tablets and sensor-enriched Internet-enabled objects. Advanced neuro-physiological sensors will allow for a better monitoring of the user and understanding of his status and behaviour. Exploiting continuous information from user monitoring and stealth assessment, the game will be able to adapt in real-time the content, presentation and difficulty modalities to the different user needs and preferences. Adaptability will be enabled by an extensive use of tools dedicated to the design, configuration and adaptation of SGs. This way, teachers and trainers will be able to specify the adaptation rules and modalities according to their different educational strategies.

Learner assessment will be accurate along several dimensions and in real time, enabling immediate (depending on the player’s needs and the educator’s goals) and formative feedback.

SGs will be built as dynamic sets of mesh services supporting the reliance of big data. A comprehensive framework of services (including learning analytics, dialogue management, virtual characters’ emotion management, etc.) will be available in a cloud, featuring extensive and fine-grain interoperability, for efficient and effective development of SGs. Semantics will play an important role in this regard. All services will yield an easy-to-use authoring tool, so that pedagogy and domain experts will be able to include their knowledge into new instances of various SG formats easily. This will be defined in order to make the development of SGs much more efficient. In general, methodologies (and related supporting tools) will be available for supporting design, in particular by suggesting and supporting proper mapping among game mechanics, learning goals, user profiles, content typologies and information sources.

\(^1\) This does not mean that the usage is for free, but that the player has a high degree of freedom to experiment.
Thanks to such development support tools, the new generation of serious games will take place in highly realistic and information-rich environments, including interfacing databases and real-time information repositories, where quests/investigations can be initiated and experiments performed safely and accurately. This will lead to new learning scenarios, featuring collaboration and competition.

Currently, good strategy SGs typically target planning, problem solving, and hypotheses verification. However, better support is needed for higher-order thinking (e.g., strategic thinking, evaluation of alternatives, analysis and interpretation of events, preparation of research questions), and for creativity stimulation. We expect that this will be achieved through very accurate simulation environments (with properly designed gamified upper layers), combining several detailed system models from heterogeneous sources. Advances in Artificial Intelligence (AI), in particular concerning the simulation of (single) human behaviour are needed, in order to allow creation of living worlds, populated with realistic or at least credible non-player characters (NPCs). These NPCs are especially necessary for complex environments, in particular related to human sciences and the impact of technologies. The difference between a fictional digital environment and actual reality will need to be addressed throughout the educational process, in order to avoid misunderstandings and misuse of tools and knowledge.

We expect that high-quality SGs will feature mechanics that favour real-world interactions with other people, in particular between the teacher and other students, as human relationships are key in a balanced educational process. It is important that education-oriented SGs are able to support the growth of a person under the guidance and supervision of an adult. Training-oriented SGs are much less demanding in this formative aspect (personal growth), and will not need an additional layer of complexity, as they simply target a transfer/verification of knowledge.

Achieving all points described above requires the exploitation and development of advanced technologies in fields such as Artificial Intelligence, Human-Computer Interaction, modelling and simulation, neurosciences, virtual reality, etc. The user and stakeholder needs in the various target application domains (e.g., education, business, manufacturing, healthcare, etc.) will need to be carefully elicited and addressed. In addition, accurate and detailed studies are needed that go into the design of game formats, mechanics and dynamics and that are able to effectively join educational and entertainment goals (a very difficult balance to achieve) into meaningful and compelling wholes (i.e., the actual SGs).

This vision represents a significant complement to the current educational possibilities, which will need to be preserved. As games typically tend to favour procedural knowledge, and gamification has possible risks (typically related to extrinsic motivation and development of a utilitarian/hedonistic/competitive mentality), both must be addressed together within a balanced educational environment. Based upon this vision four key challenges were defined in the first roadmap (D1.5):

1. How ‘values’ of serious gaming can be operationalised, researched and determined. In many cases, this will be in terms of ‘effectiveness’ – goal achievement – or ‘efficiency’ – resource effectiveness - especially in the key application areas, which are education, training and learning. These however might not be the only, or most appropriate, ones when games are utilized for persuasion or complex systems. Frames, research theories and methodologies are a necessary means to achieve this.
2. How knowledge and insights into the value of serious gaming can be iterated back into the learning process itself, in order to improve the learning, ex ante, on-going, or ex post. Seamless (stealth) assessment (Shute et al., 2009) and tools that support this are an important means to achieve this.
3. How to feedback the acquired knowledge and insights on the value of serious gaming, and the iterative improvement of the learning process, into the design of innovative game-technology and the game-principles that allow us to deliver these values even better in the future. Even though many game mechanics are available we do not know much about how these work when it comes to learning. In addition, further exploitation and development of advanced technologies in fields such as Artificial Intelligence (AI), Human-Computer Interaction (HCI), Modelling and Simulation (M&S), Neurosciences, Virtual reality (VR), etc., is needed.

4. To continuously reflect on the values of serious gaming itself, and how we are perceiving and achieving them. This is a meta-challenge that refers to the understanding of our value systems upon which we base the utility of serious gaming. Here, the science and discipline of Serious Games can demonstrate its maturation. Reflective theories in sociology, political science, cultural and design sciences and philosophy are the means to achieve this.

Based on these, the challenges are clustered into priority areas to which the GALA research activities will contribute to advance towards the fulfilment of the vision in the long term. Short term contributions to the Vision have been delivered by the GALA project, but many research and development topics will occur after the GALA project has finished.
3 Research challenges
This section describes the research challenges identified within the technical committee experts’ groups and which have been validated at various events (see annex A). For a detailed description of the State of the art, see D2.4 and it sub-reports as well as the sub-roadmaps delivered by the TCs for specific domains.

The main objective of this section is to describe the research challenges identified within the different technical areas (e.g. learning analytics, neuroscience, learning and serious games mechanics, personalisation, HCI, psychology, interoperability and total cost of ownership). The WP2 Technical Committees updated the SOTA of their fields (see WP2. D2.4 reports) and based on that we (i.e. WP2 stakeholders as well as additional researchers) derived more detailed challenge descriptions and corresponding timelines. After the update of the SOTA we revisited the TC specific challenges identified in year 3 and presented in the second roadmap (D1.6) and updated those accordingly. Within a focus group involving the TC leaders the specific challenges from a research perspective have been discussed to find out similarities and dependencies, and these have finally been synthesized. The TC research topics are very different, but we were able to identify four main themes to which they could be clustered to provide a better orientation. These themes are design, evaluation and assessment, total cost of ownership and disruptive and emergent technology. Not all research areas have challenges for each of these themes. The challenges are presented related to their research field, since it is most likely that a researcher specialised in for example neuroscience will need to look at both challenges related to design as well as to evaluation in his work.

3.1 Game and Learning Mechanics
The main topics were derived after coordinated efforts to analyse and identify SG mechanics among the GaLA members active in WP2, several SIGs and industry contacts. A general consensus from these discussions is that the uptake of SGs wanes due in part to limited evidence of its effectiveness and pervasiveness (compare chapter three on deployment). With pedagogy the attention leans towards revealing the contents of the ‘black box’ that have the potential (along with actor-actor and actor-educator interactions) to determine where gameplay has the greatest influence on learning. Establishing these
associative patterns would provide insights into which mechanics can be used to encourage particular ways of learning and assessing given a curricular content. Also critical is the need to consider interoperability and reusability (See section on TCO on specific reusability challenges).

The sub-roadmap on serious games mechanics\(^2\) identifies the key challenges and sets out a time-plan for how they can be met by the serious games community. The four main topics identified and described in detail in the SGM roadmap are summarised below.

### 3.1.1 Pervasive GMs for pedagogical practices and knowledge transfer

The transition between instructional design and actual game design implementation remains a major knowledge gap in SG design. Given that SGs are trending to mobile platforms it is all the more important to study pervasive game mechanics based on the type of the application domain. Developers will need to pay attention to the future user/client constraints and desires, and understand the effects of game mechanics (or for that matter pervasive serious game mechanics) in multimodal environments for learning.

Having researched to how the ludo-pedagogical mechanics are designed and for what SGs are used we have identified a key need to continue research to map the impact of SGMs, leading on to pervasive GMs for SGs and several challenges to be overcome. There is also a need to develop prototype serious games using the methods proposed as a proof of concept.

Figure 3 shows the timeline for pervasive SGMs applications that would eventually be applied in the construction/generation of SGMs implementable to SGs. The research activities are divided into different categories (see colour code key to the right of the table): research and development, demonstration (of prototypes, early systems), regulatory and standards (development and compliance with), and market introduction. Research and development cover basic research to prototype development. Demonstration includes piloting in end-user organisations and showcase applications/ integrations with corporate systems. Regulatory and standards includes the development of standards, the development and compliance with regulations and laws (e.g. data protection, health and safety, etc.) It also includes codes of practice and best practice. Finally market introduction means selling on the open market of SGs. This implies that they are commercially ready – i.e. robust and reliable, have facilitator training, and are promoted through marketing campaigns.

Pervasive SGMs focus on all aspects of designing game mechanics that seamlessly blend with pedagogical practices. The impact on SG design concerns architectures that support blended learning and interfacing such as BYOD (Bring Your Own Device). Research will be needed to understand whether such SGs and technologies are effective, benefit learners using them and for companies developing them. Thus experiments and effective measures need to be developed and conducted in parallel to provide an evidence base. The advances in this field is related to improved knowledge as such and therefore not directly transferred into a product.

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\(^2\) ADD LINK to gaming lab document.
### 3.1.2 Curating, designing and implementing SGMs to meet accreditation and educational policies

This is one of the most important topics due to a growing shift in using games to support the delivery of formal education. Consolarium\(^3\), a game-based learning (GBL) initiative of Education Scotland involved teachers across Scotland exploring and disseminating the efficacy of using computer games in terms of their positive impact on teaching and learning. Other initiatives include the Institute of Play’s\(^4\) Quest to Learn Middle School in New York, North West Learning Grid’s DiDa program in England and Futurelab’s Teaching with Games project\(^5\). Games are more likely to be used if they can be seen to inspire, or there is a direct link

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\(^3\) [http://GaLA.cisco.com/web/strategy/docs/education/Consolarium.pdf](http://GaLA.cisco.com/web/strategy/docs/education/Consolarium.pdf)

\(^4\) [http://GaLA.instituteofplay.org/about/](http://GaLA.instituteofplay.org/about/)

to the curriculum and teachers play an important role in the adoption and effective use of a game-based learning approach (Bourgonjon et al, 2013).

Game mechanics (GMs) are well understood and established in the context of entertainment games. Game mechanics which are Pedagogically-driven GMs are still however a research domain in its infancy. Evidence of the effectiveness of SGs, while vigorously studied tends to focus on application usability, often within a small or localised population of students. A usability study alone however, does not reveal which underlying mechanics, technology and pedagogical paradigm would befit accreditation and educational policies.

Figure 4: Timeline for evidence of SGMs to meet accreditation and educational policies
The field of learning theories and pedagogical paradigms is itself extremely broad and complex. We do not know if SGMs can be regarded as a value-added entity leading to the accreditation of present courses. However, SGMs could be the fundamental link that map the mechanics of Pedagogy & Learning to Game Mechanics (LM-GM) to meet accreditation and educational policies.

We also do not know whether SGs justify their cost in the ramp up towards accreditation purposes. Numerous conjectures are made in the literature regarding SGs and learning theories, pedagogical paradigms and approaches, and few attempts have been made so far to systematically relate these different fields. Research into SGs as a whole, and specific games in particular often makes mention of constructivism, experiential learning, and discovery learning etc. in a fairly liberal manner, often without specifying what definition of the theory or paradigm has been adopted or how it is actually realised in the particular game or practice.

To avoid the clear risk of getting endlessly entangled in the attempt to characterise, structure and represent it in its entirety, it is evident an alternative is required to provide deeper insights into serious game design patterns and instructional/pedagogy-driven design elements.

Figure 4 identifies several topics that need to be covered for achieving evidence of SGMs to meet accreditation and educational policies. There is a need to develop methodologies to evaluate the scientific relevance and value-added outcomes of SGMs. Second, there is a need to develop methods to validated and standardise measures for both SGMs and how SGs can be accredited. If these standardised measures are used then the scope of SGs and the underlying SGMs could pave the way towards a new and holistic means to meeting organisational and program/service standards by professional bodies, and provincial and national organisations. A technological society will rely heavily on using technology every time when there is a problem to solve; consequently society could forget the art of cognitive problem solving. This has implications from the not only for pedagogy but more importantly for the learner. Sole dependency on technology can be dangerous and it does not address the accreditation in educational policies.

The Open System SG (O’shea and Jay, 2014) idea implies that various bodies within the system will be operating virtuously, without corruption, with stringent information assurance regulations, with operations and materials respectful of ownership. The majority of present research in SGs is questioning how successful are Serious Games for providing the serious ends they were designed for. This uncertainty means there is still an uptake confidence problem.

The burning issues for MOOCs at present are the exploration of a viable business model and the accreditation of MOOC learning (BIS67, 2013). The biggest challenge is to overcome the hype. “Serious games and virtual environments are not a panacea in the training space.... This presents a huge challenge for government and industry as we work toward creating blended learning solutions. How do we incorporate these capabilities into existing programs of instruction while communicating with the existing IT infrastructure for learning?” (Brent Smith, vice president and chief technology officer, Engineering & Computer Simulations (ECS))

7 http://publications.cetis.ac.uk/2013/667
The research identified is well-balanced in three stages curating design methodologies, defining/establishing accompanying measures and prototyping in the form of test-beds and applications. Curating design methodologies and researching new methods can be completed in two to three years – it also consists of the design of experiments and analysis techniques. The development of measures requires literature review, collation of existing constructs from the literature, refinement of constructs, experiments to collect data based on the constructs, statistical analysis (including reliability analysis) and it concludes in a set of validated constructs for measuring the concepts (learning, commercial outcomes, etc). Longer term would be the large-scale testing of prototype applications (i.e., not just SGs but other applications where SGMs can be implemented). This work is required for the research identified in the SG Applications topic on studying the impact of SMGs for pervasive use. All of this research is high priority and should be carried out as soon as possible.

3.1.3 Intelligent, Reusable and Interoperable Pedagogy & Learning Mechanics-Game Mechanics (LM-GM)

This topic concerns assets and tools for SG design in particular intelligent SG-related learning environments where SGMs serve not only as core ludo-pedagogy mechanics but where they are interoperable over a range of SG genres. Intelligence exist in various capacities such as the ability for SGMs to inform about learning to providing the information needed for in-game analytics to evolving based upon the user state and their rate of progress. The ability to intelligently adapt or simply to be reusable across different games from different vendors would be a highly useful functionality and a significant step change in the way future SGs are designed.

Interoperability of educational technology through serious games and pervasive methods can benefit students who do not do well in the classical model of education. This topic has to be seen in close connection with the TCO research challenges mentioned below.
Personalised learning follows the pervasive concept of “recommended for you” based on tracking the pattern and history of the learner. Interoperability implications here pertain to digital courseware for assessments and resources for help, but crucially to actually adapt to a learner’s responses and change the content that is next served up. Over time, the pervasive learning environment becomes an adaptive personalised learning system suited to an individual based on a particular concept to provide uniquely tailored, completely personalised instruction. This has implications on what type of learning modalities (independent, online, group, and teacher-led) and media type (text, audio, video, simulation, gaming) are best used.

![Figure 5: SGMs interoperable and reusable standards Issues Timeline](image)

Technology infrastructure, system fidelity, professional development for teachers, content quality and assessment, are important components for which SGMs need to enable. The provision for real-time feedback is equally important for anywhere, anytime learning, not to mention the game design and its implemented mechanics. This has implications for SG designers and developers, pedagogics and content creators, among others.
Research (see Fehler! Verweisquelle konnte nicht gefunden werden.) is thus needed towards a comprehensive model, standard and framework of the interrelationships between pedagogy and gaming.

3.2 Reusability, interoperability and total cost of ownership

SG researchers and developers are aware of the benefits brought by standardisation and interoperability, and are able to access a portfolio of relevant standards, services, policies, best practices, and resources that accelerate information exchange, supporting sustainable development and deployment of SGs and other related applications (virtual reality, cyber-physical systems, augmented reality, haptic technology, etc). Reusability, interoperability and standardisation are keys to the reduction of production and deployment costs. Component and knowledge reusability will lead to more optimised design and development processes, higher quality, and a wider accessibility to SG development, reducing the number of typical challenges in SG development like time for bug fixing, lack of documentation, too high use of resources, discontinuous knowledge transfer processes, etc.

Within GaLA we have developed the SGREF (Serious Games Reusability Point of reference) which is a framework to support reusability, but this will not solve all the identified challenges (see sub roadmap on Reusability, Interoperability and Total Cost of Ownership for detailed description of the SOTA and each single challenge). The gap analysis of the current state of the art and future needs have resulted in defining three main research and development topics:

1. Large-scale Serious Games Reuse
2. Serious Games Shared Services
3. SG Development from Art to Science

3.2.1 Large-scale Serious Games Reuse

The first main challenge identified is the lack of sustainable, wide-scale SG reuse mechanisms and practices across the SG community that has resulted in increased costs, time consuming SG design and development processes, as well as in significant redundancy across activities spanning from design to deployment. Therefore, the potential gains of SG reuse remain limited. SG reuse efforts have focused mainly on technical components and source code, and they have not addressed consistently other topics such as SG reusable design, SG reuse patterns, associated SG reuse knowledge, SG reuse best practices, etc.

No in-depth analysis has yet addressed the complex issues related to the costs of SG reuse, and effective SG reuse mechanisms. SG reuse initiatives are limited, usually within organizational boundaries. Even if SG reuse repositories have started to be developed (e.g. Advanced Distributed Learning 3D Repository), no SG reuse models have been defined, preventing extensive sharing of reusable SG assets across organizations. With the emergence of cloud computing, new opportunities for large scale SG reuse have been created. Yet, to streamline initiatives that support SG reuse across the SG community and enable off-the-shelf access to reusable assets, it is necessary to define best practices and standards for SG reusable assets and knowledge. These will also create the premises for interconnecting SG environments with other disciplines and facilitate reuse across different domains.
3.2.2 Topic: Serious Games Shared Services

To address the increasing demand for advanced, more complex SGs while maintaining a low Total Cost of Ownership, it has become necessary to enhance the quality, the flexibility and the agility of the existing services and reallocate personnel to more added-value activities, while enabling cost savings. Here the gap analysis shows that so far initiatives in the SG community have focused on resource development, and less on bridging together services and skills to create a mass of capability that is shared across the SG community. Thus within this topics we have identified three different key areas that need further research and deployment activities. The diagram below shows the timeline for Serious Games Shared Services. Since SG design and development imply complex processes, due to low budgets, most SG companies entities cannot employ extensive resources, especially human resources that specialise in narrow-expertise fields, even if this expertise can substantially increase the added value of the final product. Current practices find one person assuming more than one role in the SG design or development team. Shared services bring solutions to these issues, opening up a pool of expertise that can substantially increase the quality of future SGs. Still, such initiatives need to occur at community level in order to be effective and translate into substantial cost reductions. Singular actions are no longer the norm in cost-effective communities.
Strategies, models, tools, best practices, etc. need to be put forward to enable the transition to a shared service-based SG community that facilitate access to resources in a timely manner.

Figure 7: Timeline for Serious Games Shared Services

The seven identified challenges connected to reusability, interoperability and total cost of ownership will in most cases require that in-depth research is first carried out before large scale testing can start. However in this field we also see that there is a need for regulatory measures that consolidate the SG reuse approach, supporting its consistency and uptake. Here it is also important to mention that these initiatives have to be dealt with at international level to maximize benefits and exploration of the multiplication effects, and enable sustainable cost reduction.
### 3.2.3 SG Development from Art to Science

This topic is very important for reducing development costs, reducing development time and hence reducing adoption barriers. Currently SGs are one-off products that are developed from scratch for each specific application. This means they are costly to develop. There is a need to reduce this cost and speed development time. This topic is also related to the TCO topics on reusability and large scale SG reuse and sharing. Thus tools for SG design and development are desperately needed.

These tools should not only be for developers to use, but should also be able to be used by SG stakeholders (commissioners, end-users, training managers, instructional designers, etc). These tools can range from visualisation tools (eg. rapid storyboarding tools that can be used to talk stakeholders through a game’s flow) to authoring tools (eg. a tool that could convert a storyboard in to code segments with flow control). Critically tools should be developed for use by SG commissioners and users which enable them to express their game design ideas easily. The output of these tools can then be used directly to make the SG code. In this way the process of getting game ideas and specifications from users can be speeded up. Having visual tools will enable the stakeholders to visualise what the game will look like (something non-game designers/developers find very hard to do – they can only image a blank page...). This visual tool(s) will thus help users to be more precise and detailed in the descriptions of how they want the game to work. Tools which are able to produce software code as output will greatly speed the development. For this to work there is a need to develop standard semantic models and interoperability approaches. While these can been
seen as programming related issues, in companies SGs need to operate within strict security environments; and be able to talk to existing corporate systems (eg. systems that allow employees to register for training courses, HR record systems, etc).

3.3 Personalization and AI

Within the field 14 different challenges were identified and described in the sub roadmap. However, five of these were identified to have high priority. These are described below.

3.3.1 Map user models’ distinctive features and their impact on learning goals

The acceptance of serious games as an established reliable tool for learning and training depends on many factors. One of those is the utilization of mechanisms that enable serious games to identify distinctive features of the user in order to properly adapt the game according to the design goals. In this context, in 2020, models of key features will be mature and will guide serious games adaptation mechanisms by taking into account the player’s characteristics according to the model’s characterization. Even though there are several user/player models available the research in the serious game field specifically is very limited. Therefore, there is a gap in terms of understanding which user models are more useful to an interactive learning process, such as serious games, and in what conditions. Furthermore, there is still a gap in the identification of the dependencies between the different learning goals and the distinctive characteristics that support each model.

3.3.2 Make real-time emotion state sensing data a reality for the diverse existing methods

A fundamental step towards modelling and adapting to players is to understand their current state. Emotions are in fact individual characteristics associated with expressions that are signals exposing very important information regarding the player’s state and experience. An existing challenge is precise real-time measurements of emotions from players. Many existing systems are very intrusive which has significant detrimental effects for the learning experience and consequently to the quality of the data obtained regarding the player’s state and the practicality of such systems. As such, and given each system’s different
stage of research, much focus has been placed on the most promising approaches in an effort to improve them. A current trend is therefore to follow a single emotion detection system, however a single best approach is elusive and the best results often result from combining different channels of affective information. This constitutes a trade-off currently experienced between non-intrusive mechanisms and emotion detection accuracy which must be addressed before emotion detection systems can be readily used for adapting the learning experience to the player.

3.3.3 Framework or services mechanism creation facilitating access to content adaptation techniques

Reusability is a key procedure for efficient utilization of resources and efficiency in the development process. It is already successfully applied to assets. However, content adaptation techniques and their implementations are still not reused frequently, especially outside in-house developments. This problem is especially relevant for serious games since they typically do not have as many development resources as other applications. As a result, many of these techniques are regularly simply disregarded due to their significant development cost the current low reused practice which leads to a low accessibility and adoption. However, in this area we have seen progress, and within GaLA we have provided the tool SGREF as a starting point. However, this will not overcome the challenge, which is from the TCO point of view the difficulty of at one hand handle IPR and on the other hand making produced content available and easily adaptable to different context. Thus, in order to achieve this, especially if it should also be possible to automate this process, there is a need for a standardised structure of how to describe the content and a better way of examining an object in order to identify the relevance for reuse. This requires more research and a clear support for reuse. There are some taxonomies, also form GaLA that can be used as a basis. Concepts that could be considered are hardware and software as a service, as well as repositories etc.

3.3.4 Establish mature models for creating believable NPC systems that can be readily adopted in serious games

Even though there is a very significant amount of socio-cultural agent models that can be employed to support the development of intelligent NPCs in serious games, the reality is that there is still little transfer to the domain of serious games. This lack of adoption leads to a diminished understanding of the real impact that these models can have in achieving both educational and entertainment goals.

Many serious games frequently do not employ AI and Personalization techniques that could input valuable information to the game and better support the adaptation of the game content to the players. Subsequently, this would provide a more meaningful and complete learning experience. The acceptance of serious games an established reliable tool for learning and training depends on many factors. One of those to create an engaging learning experience, and towards that end the creation of believable and adaptable NPC is and will continue to be fundamental.

Figure 10 shows the expected timeline for research and demonstration activities. Since the market introduction is depending on the advances in the research questions, as well as of the maturity of the market, and the developed technology, these timelines have a high uncertainty.
Personalisation and AI

Map user models’ distinctive features and their impact on learning goals.

Make real time emotion state sensing

Creation of a framework or services mechanism

Establish mature models for creating believable NPC

Figure 10: Timeline for challenges Personalisation and Artificial Intelligence
3.4 Human-Computer-Interaction

New devices and platforms have emerged during the duration of the GALA network – and they will probably continue to emerge. There is a need to research how these new devices and platforms can be effectively used in the user’s context. Within the HCI area there has been an excellent progress and several new devices and technologies have been provided. Within this area, 14 different challenges have been identified. Some of these are in common with topics on GM-LM as well as related to TCO and reusability, or they are more related to design concepts like human centered design and early inclusion of MR in the design process. These are challenges, but not only related to serious games, but more to good design as such. Thus, specifically for HCI we have identified the following high priority challenges:

3.4.1 Understanding which MR devices can be adapted to SG

SGs, aka MRLG (Mixed Reality Learning Game) when using Mixed Reality, will take advantage of all the new technologies, with new interaction paradigms - using tangible objects to learn technical gestures or abstract concepts, improving collaboration between learners on multi-touch tablets, etc., enabling to learn everywhere with light and mobile devices. MRLG designers will be able to merge efficiently pedagogy with game mechanics and at the same time use correctly the appropriate MR device. Difficulties to design MRLG can be explained by the innovative, unusual and non-mature aspect of mixed reality technologies. Moreover, creating a MRLG is a long and difficult process. MRLG designers cannot be expert in every domain related to MRLG, and working in teams between experts from different fields is not so easy. If some method or tools exist for learning games or mixed reality design, there is none of them for MRLG design, thus suitable tools or methods to assist MRLG design are needed.

3.4.2 Interacting being immersed in mixed reality

Immersion in the virtual world hosting the SG is needed to enhance the presence feeling. Realistic rendering and immersive interaction tools are not efficient or realistic enough to be provided simultaneously to users. Attempts of using real objects as tangible interactive interfaces with the virtual environment remain limited. Improvement can be reached using the mixed reality paradigm, where reality is provided by elements from the real world. Indeed, a growing number of Serious Games use Mixed Reality (MR) technologies; we call them Mixed Reality Learning Games (MRLG). MR includes a wide range of devices such as see-through Head Mounted Displays (HMD), mobile devices like PDA, Tablet PC or smart phones, multi-touch tablets, or even tangible interfaces that control or represent virtual information.
3.4.3 **Multimodal and multisensory interfaces**

Enhanced links are needed between virtual and real worlds to make interactions more multi-modal and natural and to enhance the flow of information and interactions between virtual and real worlds. The health domain for instance is comprised of many complex multilayered systems that include biological, social, technological and economic subunits. Virtual worlds offer the possibility of representing the complex nature of these systems and permitting users to explore, interact and learn through them. However, existing human-computer interfaces for games have yet to fully exploit human sensory capabilities. The relevance lies in the fact that SGs utilize the same environment, digital tools and functionality. The development of more multi-modal and natural ways to interact with such virtual worlds will offer greater potential for learning and also the possibility of rehearsing real world medical procedures and also enable various forms of scenario planning. By enhancing the flow of information and interactions between real and virtual worlds, the virtual worlds can be made to represent a specific case or instance e.g. rehearsing an operation based on information obtained from medical imaging.

3.4.4 **SG in mobility use context**

The appearance of smartphones and tablets recently has posed a challenge for SG developers and users. Do they move their games onto these devices or not? There could be an issue with the growth of casual games on these platforms that serious games running on them may not be taken seriously. In order to be used, it is also necessary to work at homogeneous access in nomad activity. The issue of centralised control was identified for requiring further work.
3.5 Learning analytics

Learning analytics has been one of the key areas where GaLA has made progress beyond the state of the art. With the GLEANER framework GALA has contributed a possible unified channel to submit data to cross-compatible repositories. After the GALA project there is an important there is a breadth of knowledge on how to capture data, and there are many advanced techniques to process data. Even though progress has been made (compare D2.4 LA/Flow), there are significant gaps in identifying which data to collect and how to detect significant patterns. These are the most outstanding gaps and challenges identified in the area of Learning Analytics applied to Serious Games. More details can be found in the sub roadmap on LA8 as well as in D2.4.

Figure 13: Mindmaps Challenges related to learning analytics

3.5.1 Streamlining game-specific trace aggregation and visualization

A single game can generate vast amounts of tracking data. The construct of higher-order data points through the combination of smaller data is possible (and even simple) using GLEANER. However, how to visualize these aggregated traces (e.g. time to complete a specific stage or score after completing a level) remains an open challenge, since these aggregated traces, their meaning and relative relevance may vary significantly across games and genres.

Tackling this problem in a cost-effective manner requires tools to work at a meta-modeling level, enabling authors to create aggregated traces and visualization widgets for their specific games, without requiring a development effort for each specific game.

3.5.2 Identifying flow / engagement / trouble

Ongoing research has assumed that from these rich data it should be possible to measure flow and engagement. However, we are still missing adequate techniques and data analysis tools to reliably identify flow states.

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8 Add link
The visualizations provided by GLEANER and Year 3 case studies allowed instructors to identify potential problems by studying the traces and on-the-fly visualizations. However, this always required a human to detect salient cases and then inquiry with the student about whether an actual issue existed. According to ongoing research, it should be theoretically possible to spot these cases automatically, although the specific models and data analysis techniques are not currently available.

Controlled research needs to be conducted to achieve a better understanding of flow in serious games and to be able to operationalize flow so that it more adequately addresses flow in serious games. To achieve this goal, good serious games have to be used as test beds in which users can really achieve flow state. In such a context it is possible to validly study the flow phenomenon and test possible extensions of flow. However, we have to ensure that all participants whose data is used in analysis have achieved flow. Thus, a mixed methods approach has to be used in which questionnaire data is enriched with, for example, interviews or neurological measures.

More valid methods to measure flow during playing have to be studied and developed. Because achieving flow state does not require all flow dimensions to be present simultaneously we should also consider new ways to analyze dimensional based flow data collected with quantitative measures. Furthermore, the usefulness of neurophysiological methods to assess flow in games should be more exhaustively studied.

- Further research in different serious game contexts is required that can clearly establish the impact of flow in learning and other cognitive domains.
- Research needs to be conducted to explore how different game mechanics influence on flow experience.
- Further research is needed to study the influence of individual and cultural differences, subject matter interest, game genre and social aspects of flow.

In order to support the design of good serious games, factors that prevent flow should be identified. Such knowledge could be very useful for game designers.

3.5.3 Automatic assessment and reliability of the results

Ongoing research, as well as the case studies from years 3 and 4 suggested that it is indeed feasible to compute grades through analysis of the collected data. Going further, ongoing research has identified high correlations when comparing automatically computed grades with the results of external quizzes. However, instructors still perceive such evaluations as not necessarily reliable.

While a relatively strong correlation may be sufficient for small experiments, the deployment of games in high-stakes scenarios needs a greater solidity and demonstrability of the accuracy of the evaluations.

3.5.4 Application beyond a single game

Learning Analytics’ results can be applied at different levels and with diverse purposes: at course-level, where teachers and students obtain a better perspective of the educational process and its results; at course-aggregated level, where predictive models and success/failure patterns can be found in the analyzed data; at administration-level, where more detailed statistics can be obtained for groups of students or schools in order to, for example, improve resource allocation; and at regional/state level, where all results obtained in all schools or faculties can be compared.
However, and in spite of the potential unification provided by the GLEANER framework, it is still challenging to obtain data sets combining information from different game sources. This is partially a consequence of a previous gap (the lack of a streamlined approach to analyze and visualize data from heterogeneous games), but also a challenge on its own, as it requires a significant buy-in of the game-based learning approach by the affected institutions: as of today, most applications of serious games are still isolated experiments, and it is difficult to deploy a collection of games across a school or a full region, let alone making them all transmit their tracking data to a unified repository.

3.5.5 Privacy concerns
The collection and analysis of massive data sets brings significant challenges in terms of privacy and data protection. Making all data anonymous limits these concerns, but also hinders the potential of LA techniques in singling-out students that may require further support.

In GALA we have explored different technical approaches to either anonymize or maintain identifiable data, but the exploration of how these technical solutions comply with different regulations was beyond the scope of the project. Further work is required in this area.

Figure 14 indicates the expected time lines for different LA challenges. The more research needed in order to solve the challenge, the more uncertainty is related to the time lines both of demonstration and market introduction activities.
3.6 Challenges related to psychology

Psychology is a very broad discipline covering diverse aspects of human behaviour and psychologists have developed a wealth of well-established constructs, validated ways of measuring these and expertise in both quantitative and qualitative research. Even though there is a lot of existing literature on existing research, theory and constructs developed in psychology that can help to understand the mechanisms in SGs; there is a need to develop a more integrated and coherent approach to understanding serious games and to establish a common language for discussion.

3.6.1 Lack of common language

The lack of a common language for discussion of such a multi-disciplinary research area is a challenge, and thus there is a need for establishing a framework that addresses some of the relevant elements such as providing: “a dynamic body of knowledge identifying the state of the art and knowledge gaps leading to research questions, operationalised models, hypotheses for testing”, “validated research instruments and tools, questionnaires, surveys and instruments”, “research designs and data-gathering procedures” as well as an understanding of ethical issues in research. (Mayer et al. 2013).
3.6.2 Cognitive learning in general and the concept of flow in games.
Also in terms of learning outcome, there are some psychological challenges to be addressed in order to understand how effective learning and behavioural changes take place. Independent of individual differences or preferences of users it is necessary to establish a common understanding of how learning in games occurs. In this context flow is an important factor one has to consider, since the state of flow ensures the optimal balance between challenge and skill.

3.6.3 Personalised learning.
In addition, we know that the learning outcome is related to how well a game fits the skill and competence level of the player, but still it is difficult to adapt games on the fly for fitting the personal needs. Also interindividual differences between players and how this might help to explain diverse player preferences and the use of different kinds of games has to be addressed.

3.6.4 How psychological theories should be used in the design of realistic and convincing NPCs.
A challenging issue in order to realise is to use NPCs in games. This does not only require the use of AI (see section 3.3), but it also has to be investigated the behavioural aspects related to the use of NPC. While psychology has the potential to advance research on serious games, it must also be acknowledged that human behaviour is complex and in some areas knowledge is contested. The effectiveness of games and the credibility of NPCs will be constrained by limitations on our understanding of human psychology.

3.6.5 Gathering and analysis of social and behavioural data.
Further research on how to apply learning analytics techniques will be carried out to analyse the behavioural data. Developing cohesive theories on how to interpret the data, based on solid psychological principles is a major issue. Determining what data about (social) behaviour is commonly gathered in a SG, based on common taxonomies of SG genres is necessary. The developed frameworks need to be specific enough for direct use in the SG, but they also need to be tied in to existing theories, i.e., social/psychological theories and (if developed) their common operationalisation.
3.7 **Neuroscience**

The new possibilities for integrating neuroscientific measures in serious games open up opportunities for improving stealth assessment and to give individual feedback. However, in order to take advantages of this,
it is necessary to consider these opportunities and the requirements it puts on a system in the early design phase.

3.7.1 Examining the neurophysiological correlated to learning in a serious game

In serious games one of the essential goals is effective learning. Games that are able to adapt the way their content is presented to the user’s characteristics have a higher chance of success. Therefore, neuroscientific methods will be used during game playing to assess brain correlates of learning. For applying good LA, not only the interaction of a user with the learning application can be used for learning analytics. Physiological signals as a basic metric to examine whether learning is happening during playing a (serious) game or not is a further possibility to get feedback about the player. Using neurophysiological data for monitoring brain activity in serious games is a promising approach.

However, the research on the use of physiological traces in learning analytics is sparse. Existing easy-to-use devices do not provide sufficient data quality. Devices are very susceptible to different sorts of artefacts (movements, etc.). Examining the neurophysiological correlates of learning in a serious game will be especially relevant for the clinical population or person with learning problems to support an optimal learning experience and increase training/learning outcome. Thus, identifying reliable neurophysiological correlates of learning that can be identified with portable neuroimaging devices, which deliver excellent data quality is a key challenge. The challenges identified in Figure 16 in the field of assessment and evaluation partly belongs to this main challenge, but also some of the design related like those dealing with frameworks and pervasive design.

3.7.2 Measuring the user’s subjective experiences with physiological measures

One of the areas with the hugest potential of really making a difference in future (serious) game development, validation and evaluation is the use of physiological measures to quantitatively measure the user’s subjective experiences (e.g. measuring the user’s subjective experiences during interacting in virtual worlds to measure presence, engagement, etc.).

However, it is very difficult to do that adequately. This is why almost all of the existing studies are using self-report questionnaires to assess subjective experiences, such as flow, enjoyment, engagement or the “sense of being there” otherwise known as “presence”. This is not optimal, thus we need more research to be done to understand complex subjective feelings such as flow, engagement or presence. After identifying and operationalizing those subjective feelings offline new methods can be developed to identify them reliably online during gaming. This approach leads to an optimal user-oriented and user-guided design process of serious games and will significantly improve the quality of the learning experience.
Figure 17: Challenges related to neuro science
4 Challenges related to deployment of Serious Games in application fields

In chapter 3, the main concern was to identify challenges where more research and development are needed across domains, i.e. a research oriented view. Even though those analyses clearly identify the need for more research in the SG field, it can also be stated that the deployment of already existing SG applications has been hindered by several barriers. These barriers cause a low market penetration (see chapter 5). Consequently, in some cases more research is needed, and therefore the same challenges appear both under research as well as under deployment. This chapter is based on an analysis of the input descriptions delivered by the expert groups in the six Special Interest Groups as well as the area of corporate training. The analysis of the challenges in section 4.1 has been done based on the application domain. For most of the application domains we find that SGs have been developed for primary, secondary and higher education, as well as for training. Within corporate training, there are not many legal and regulatory barriers and less dependencies on national legislation, thus we have in addition to the field analysis also carried out a sector specific analysis on corporate training. This is described in section 4.2 and these barriers are in addition to those related to the application field.

4.1 Challenges related to specific application areas

The large scale deployment of SGs in different sectors has so far not reached its full potential. As a part of the work within the GALA Special Interest Groups, we have been working on identifying the barriers and challenges that prevent SGs being deployed. In a first step, as presented in the second roadmap (D1.6), we identified application domain specific barriers. Within each SIG there are good examples and best practice SG deployments. In some cases the games can show clear evidence of effectiveness, whereas other domains have examples where the fidelity to reality and the use of 3D graphics is very good, creating an excellent user experience. However, these examples are only known within the domain, and thus there is hardly any transfer of knowledge. It is our assumption that one domain can learn from other domains which are further in the deployment of SGs. We therefore revisited the SIG specific challenges identified in year 3 (see D1.6) in a focus group involving the SIG leaders. The aim was to identify similarities and dependencies and produce a synthesis. The outcome is the identification of six grand challenges comprising sub-challenges (see Figure 18). With the “utility of learning experience” we address topics such as how can I teach what I want with an SG, how to use the game or how to facilitate collaboration among players, how to deal with the complexity of the topic. The challenge is often to reduce the complexity so much that the player understands, but on the same time to make sure that the game is sufficiently realistic in order to achieve the learning goals. “Integration into learning process” comprises topics specifically related to accreditation, evaluation, effectiveness, proof of concept, i.e., pre-requisites that would allow the acceptance of SGs as a qualified learning tool, worth being adopted into established learning practices. Moreover, the challenge includes aspects regarding the quality of the learning experience as such, e.g. issues about fidelity and realism.

“Business models” are of great concern and comprise also topics on IPR and dissemination channels. The topic on “Quasi standards” derives out of the need in most SIGs to comply with specific industry standards, but also to meet standards supporting accreditation, and provide something similar to SCORM, but for games. As described previously, the TCO for SG are far too high, and some domains do not have access to
large markets or have high financial resources. Therefore, the low degree of “Reusability” has also been identified as a main challenge for deployment. It also comprises the issues of reusing assets from other domains (i.e. 3D scanned artefacts from museums in a game, etc.). Finally, our last Grand Challenge is the “Connection between real and virtual worlds”. The major topics here are related to emotional engagement and HCI. For SG deployment in the application fields covered by GaLA we have identified the following grand challenges:

![Image: Identified Grand challenges for the SG deployment]

These Grand Challenges represent the main barrier for higher deployment. As can be seen these are highly related to many of the research challenges regarding learning analytics & educational assessment needed for the better integration of SG in the learning process. Furthermore, the complexity as well as learning experience topics like mechanics and flow are of high relevance. For many of the application areas the visualisation and also the link between reality and virtual world are of great importance. Here topics like HCI and modelling of reality come into play. However, one key for all application areas is related to topics like TCO, standards and reusability (see section 3.2).

Each of the SIGs has prepared their own sub roadmap which describes the challenges in more detail and also with more examples. This part summarises the key challenges and proposes timelines for how the challenges can be met with relevant support.

4.1.1 Utility of Learning Experience

4.1.1.1 Building collaboration

Within Business & Management, Manufacturing & Engineering as well as within Security and Crisis Management topics on team and collaboration are a main issue. Thus the question is how to leverage collaboration dynamics: This challenge involves building collaboration into business and manufacturing games for stimulating a better team working; or for safety and security games and how to get multiple player games for collective training, since collaboration is seen now as crucial to success, where teams seek win-win situations rather than pure competition. This specific challenge involves not only building collaborative and consensus seeking scenarios to elicit such behavior during game play but also in the deployment of the games, for example, by having teams of players.
4.1.1.2 No standard practice of game design for SG manufacturing for demonstrating effectiveness

The creation of serious games, as with entertainment games, remains very much a craft and this will continue to be the case. Trying to standardize the process to create serious games in the domain is unrealistic, but to have guiding principles with patterns of what works and in what circumstances is a feasible goal to achieve. The mention of measuring a serious game effectiveness is unrealistic since it depends on too many factors: the quality of the facilitator, the context of how the serious games is being used, the complexity of the content, the background of the learner, the amount of time to engage, etc., etc. Advances have been made with the newly developed SG Evaluation Framework (See GaLA D3.6), that has been one of the main achievements of WP 3 of year 4. So bottom line challenge would be to study and make recommendations on guidelines to facilitate the development of new games - however, these guidelines/recommendations should go beyond the high-level abstractions of existing frameworks that are devoid of any context.

4.1.1.3 Representation of Complexity (3.1, 3.2, 3.6)

The challenge in this domain is the difficulty in modelling and representing different content domains in a way that is realistic, meaningful and relevant for players. This requires content experts who are invested in the process as well as designers who can translate content into game dynamics. Moreover, any game environment represents only a number of complexities in a system of complexities - it requires a delicate balance in order not to overwhelm the player with too much complexity while preserving the realism of the game.

Complexity also exists in the role of facilitation, in particular, how to accompany the game play with facilitated debriefing. Looking at the available games for this content it can be stated that there are several games mediating managerial skills to engineering students - these games are typically played in teams or in collaboration, and most of them are facilitated. Several of the business and management games can be used for teaching managerial skills to engineers. Also most of the supply chain games used in the education of engineers belong to this category, often focusing on decision making and transparency. This challenge is also closely related to the grand challenges on full integration.

4.1.1.3.1 Elude- a good example

http://studies.seriousgamessociety.org/
Innovative representation of a complex concept

A good example of a game that in a positive way has managed to represent the complexity in a good way is the game “Elude”

Elude was designed to make people aware of depression as an illness. The representation and awareness creation mechanisms for such problems are very difficult. The game designers of Elude were able to overcome this by creating a vibrant game environment that contrasts metaphorical representations of different emotional states, in order to empathize with depressed people.

4.1.1.4 High realism and high fidelity

Within the security, safety and crisis management realism and fidelity are still a challenge. It is often low which might have a negative impact on the learning outcome. Thus, it will become more and more demanding for SGs to respect the actual requirements due to the more intense use on training and education; this will require to introduce also in SG, as in simulation, effective Verification and Validation (V&V) issues and to improve physical engines and model fidelity as well as a need to include realistic behavioural models.

Within the health domain there is a need to develop more realistic and adaptable Patient/Client/Non-Player Character artificial intelligence to reflect the complexity, since there are many different forms of human interaction within the health domain (e.g. doctor/patient, nurse/patient, etc.) and are important both to professional practice and social functioning.

4.1.1.1 High quality and faithful reproduction of culturally significant artefacts in games

This challenge is in line with the previous one, but whereas the above mentioned challenge needs better modelling, the challenge is within heritage and humanities more than new technological solutions for
rendering high resolution 3D models in real time is important for a better utilisation. This is needed because we expect more and more technological solutions to cope with high resolution models in games as well as we envision large-scale access and fruition of digital cultural artefacts from online shared repositories and serious games to engage people with the vast amount of digitized resources available. The technical feasibility of managing high resolution models, possibly enriched with further complex and heterogeneous data in real-time, is therefore a pre-requisite for a better user experience within the SG.

<table>
<thead>
<tr>
<th>Utility of Learning Experience</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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<tr>
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<td>Representation of Complexity</td>
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Figure 20: Utility of learning experience Data Timeline

4.1.2 Sustainable Business Models

This section is related to a part of the research topics on total cost of ownership, such as reusability and interoperability.
4.1.2.1 **Incorporating games for connectivity and creativity into COPs**

This challenge is related to incorporating *connectivity* (linking players with common interests and needs together) and *creativity* (facilitating creation and new thinking) into business games. There are already some examples of social/collaborative games that tap into the collective intelligence and voluntary participation of a group of interested/invested individuals (e.g. World Without Oil and Foldit). The models behind these games can greatly contribute to harnessing the ideas of a community of players.

4.1.2.2 **Leverage cloud computing and web technologies**

Another challenge is to *leverage cloud computing and web technologies* in order to increase access to and deployability of business SGs. Leveraging this technology can greatly contribute to providing anywhere, anytime access to the game. It can also facilitate simultaneous online playing among different players in different locations.

4.1.2.3 **Personal learning serious games lifecycle development and dissemination**

Games in this category could be developed in an integrated approach so that there should be a global catalogue for indexing the relation between games and topics of personal learning. In this way, when in need for a given game to train a given type of skill, there would be an easily accessible catalogue that could offer a basic characterization of the game and its access conditions. Even though not specific to games in this domain the serious game repository of the serious game society is already a first step in this direction.

4.1.2.4 **Formalization of serious game lifecycle knowledge**

Serious games for social awareness will be a fundamental tool in mobilizing people in diverse areas and fostering real world interactions based on the information that people become aware of. Furthermore, such games will permeate people’s everyday life with a variety of important topics not only through institutional means, such as education, but also outside typical learning contexts, i.e. in leisure time, given the appeal that the topics addressed in social awareness serious games have. However so far, there is no formalisation. In order to fully utilise the potential in a learning context, there is a need to develop validated and standardised measures for both these issues. If these standardised measures are used then the performance of different games can be compared and lessons learnt for developing better games derived.

4.1.2.5 **Integration of serious game studies as part of a PSLE serious game development lifecycle**

Studying serious games is fundamental to verify their value proposition of achieving learning or knowledge transfer in a very interactive and engaging way. Research in serious games has received a tremendous amount of effort towards the creation of mechanisms to address the scaffolding (Panzoli et al. 2010) of the learning and to ensure the proper integration of the pedagogical goals (de Freitas and Ott 2013) in the game design (Suttie et al. 2012). However, with regard to studying the games created the field does not seem to be well developed.

4.1.2.6 **Creation of channels to reach the general public (3.6)**

Serious games for social awareness will be regarded as a very strong media to transmit messages about community and especially global issues that affect people. As such, it will be a fundamental tool in mobilizing people in diverse areas and foster real world interactions based on the information that people become aware of. Furthermore, such games will permeate people’s everyday life with a variety of important topics not only through institutional means, such as education, but also outside typical learning contexts, i.e. in
leisure time, given the appeal that the topics addressed in social awareness serious games have. The gap between the current SoA and the vision is not very significant. Serious games in this domain already have well-structured approach and several dissemination channels and venues where such games are discussed and promoted. One gap that exists is the transfer of the discussion that already exists in creating games to a more formal medium that can be more easily shared between stakeholders. Additionally, even though there are already several channels to reach a broad audience, this area could also benefit from having channels of dissemination that would directly link such games to the general public, which sometimes is lacking. There are very few examples of serious games that have selected the right channels to reach the general public, but the game “Darfur Dying” did manage.

4.1.2.7  Darfur is Dying
GaLA.studies.seriousgamessociety.org

⇒ High reach

Darfur is Dying was developed with the goal to make people aware of the Sudan Humanitarian crisis. However, contrary to many other social awareness games it was able to have a high reach to its audience. This was possible due to a combination of opportunities and design decisions:

- A partnership between mtvU, Reebok Human Rights Foundation and the International Crisis Group held a contest for a game about the Sudan Humanitarian crisis that created the opportunity to create awareness about this topic;
- The partnership provided from the start a very high reach through diverse audiences and with several types of media;
- The partnership and the contest generated added interest through the contest and its winner award;
- The game facilitated players to take action on the subject by easily sending messages to friends or directing them to contact their political representatives among other types of action.

4.1.2.8  Lack of feasibility to apply in the short time

Within the engineering and manufacturing, games the challenge is the applicability of a serious game in the slot of a classroom session of 1-3 hours. Although the use of a serious game counters the decline of attention and motivation associated to theoretical classes, it is difficult to keep students playing for more than 4 hours. However, for serious games in this domain, it may not be sufficient to have a play session that fits into a classroom slot (or workshop setting). In addition, when considering a facilitator setup, it is highly recommended to have a debriefing session to support socialization and externalization (SECI learning model). This challenge is intertwined with the complexity of the domain. Thus new concepts of games tailored for 1-2 hours gameplay are required. This would lead to a larger potential market for deployment.

4.1.2.9  Sustainable Business model for cultural and health serious games

In Humanities and Heritage we face a mismatch between supply and demand. New dissemination channels, like offering some games as Apps are often not realised. This is often due to the lack of relevant business models for cultural SG, having the citizen as target customer, not only the museum in which the game might be played. Furthermore, looking at a different application area with high governmental involvement, we see that also the health sector faces challenges in providing sustainable BM. SGs have a minimum necessary complexity in order to function as a game and therefore are a significant undertaking to develop and produce. At the same time, health systems are complex eco-systems of interlinked organisations. In order to
be adopted for use, SGs face the challenges of demonstrating effectiveness, value for money and also need to be able to become part of the eco-system. Service-based business models therefore need to be developed, perhaps based on pay-per-use or even outcome-based payment models.

**Sustainable Business Models**

- Incorporating games for connectivity and creativity into COPs
- Leverage cloud computing and web technologies
- Personal learning serious games lifecycle development and dissemination
- Formalization of serious game lifecycle knowledge
- Integration of serious game studies as part of a PSLE serious game development lifecycle.
- Creation of channels to reach the general public
- Lack of feasibility to apply in the short time
- Sustainable Business model for cultural and health serious games

**Figure 21: Business Models for culture and health SGs timeline**
4.1.3 Integration into Learning Processes
A major barrier for the deployment of games lies in the challenge to integrate SGs into formal and informal education. There are several reasons for that, but the main challenges have been identified and several of these are the same across the application domains.

4.1.3.1 Provide a one-stop learning experience
Within the business and management domain, one of the challenges to cater to busy executives is to provide a one-stop learning experience, where facilitation and debriefing are part of the experience. This involves going beyond the face-to-face workshop structure, and to mixing the three phases of Briefing, Play and Debriefing into one on-line learning experience.

4.1.3.2 Evaluation of game effectiveness and “actionability’
Another challenge is the evaluation of game effectiveness and “actionability’. There is currently a lack of effective measurement of impact (going beyond post-game first impressions). Given the resources invested in the development of games, there needs to be a more systematic way to measure and capture the impact of the game in terms of transfer of learning into the workplace- i.e. actual change in behaviour.

4.1.3.3 Serious Games for Personal Learning
Even though there are several efforts to defragment the diverse domains of serious games, including PSLE, these different approaches are also creating meta-fragmentation in terms of the coherence between the different approaches. This creates a gap of completeness between the different approaches and hinders the efforts to provide a defragmented catalogue for educators and trainers.

Serious games for Ethics are those that provide the user with elements of thought helpful to address and rationalize ethical issues. One should note that this is substantially different from exposing the user to a moral message where the moral thought is already formulated. Challenges within this category are related with questions of morality and vary according to the context where the ethical problem emerges. SGs in ethics can facilitate the exposition to morality scenarios and promote moral behaviour (Pereira et al. 2012).

4.1.3.4 Balance between fidelity of reality and the game design (3.2)
The balance between fidelity of reality and the game design is a difficult challenge to achieve. In the domains of engineering and manufacturing, both dimensions (fidelity and game design) are at odds with one another. The evidence of existing serious games demonstrates that if the game is simple, then the didactical benefit of the game is very much reduced to the point of undermining the motivation of learners who perceive it as boring and limited. However, on the other end of the spectrum, one has serious games that lead to frustration due to the fact that learners deem the context too complex to handle. In the latter case, one may argue that the fallacy may not be in the game design, but in the user experience in improving the onboarding by providing an incremental engagement with step-wise tutorials

4.1.3.5 Adoption of SGs in formal education(3.5)
We envision SGs in formal disciplines as a real and interactive support to the teacher, able to personalise his/her lesson according to the interests and the levels of the different students. Social mechanisms will help students to cooperate and enhance their learning will be fully implemented.
Especially in games for formal education, the adaptation of the difficulty level to the specific student is crucial to support the teacher using learning games in the classroom; however, real in-game adaptation to the learner’s level is still a big issue. New pedagogical strategies need to be formalised to update the educational contents and their presentation to the students in such a way they are beneficial in a modern and digitalised learning environment. To reach such objectives, some steps are needed:

- Adaptation mechanisms to adapt the difficulty level to the learner capabilities;
- Evaluation of the learner performance both for tuning adaptation and for assessing student performance;
- Personalization of scenarios by the teacher;
- Policy to update national curricula with new technologies.

4.1.3.6 Feedback & Performance Assessment

This challenge is again a challenge with more aspects very highly related to the lack of useful LA in many of the games currently existing in the market. The lack of the ability of giving individual feedback and stealth assessment reduces the market of potential users to a large extent. LA is still an area where research has to be carried out in order to exactly know what to track for different application domains. For the different application domains, there are different needs and there is also a need for both defining collective and individual measures.

4.1.3.6.1 Good example of SG fully integrated- StopDisasters!

An example is the game “Stop Disasters” a game developed for the social and ethics domain.

- Integration into local communities and target populations
- Support curricular integration

StopDisasters! was developed to make players understand the risks underlying 5 types of natural disasters and how simple measures can be effective in preventing and mitigating the impact of those disasters. A strong barrier to the adoption of awareness games is the lack of links to the target community. However, the StopDisasters! game was developed in a context that helped overcome this barrier to some level:

- Developed as part of the World Disaster Reduction Campaign (2006-2007) “Disaster Risk Reduction Begins at School” by the United Nations International Strategy for Disaster Reduction which enabled the connection to the communities;
- Developed in several languages that eliminated language barriers from local communities;
- Designed to consolidate the Disaster Reduction campaign results by being a complementary medium to school education about disaster prevention.
### Integration into Learning Processes

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<tr>
<th><strong>Provide a one-stop learning experience</strong></th>
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<td><strong>Serious Games for Personal Learning</strong></td>
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<td><strong>Balance between fidelity of reality and the game design</strong></td>
<td><strong>Market Introduction</strong></td>
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<td><strong>Adoption of SG in formal education</strong></td>
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<td><strong>Feedback &amp; Performance Assessment</strong></td>
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Figure 22: Integration into learning Timeline

### 4.1.4 Quasi Operability Standards

#### 4.1.4.1 Adoption and validation of PSLE (Personal and Social Learning & Ethics) study methodologies

These studies will constitute the fundamental theoretical support for correctly balancing the game design of serious games for PSLE in terms of their mechanics to operationalize the educational and entertainment goals in an educative yet engaging experience. With this regard there is still a significant gap in supporting the complete serious game development, deployment and study lifecycle in a well-defined framework. The studies part, even though already existent, are still in an initial stage of consolidation of study methodologies to properly verify PSLE serious games value propositions and communicate these to the academic and educational communities.

#### 4.1.4.2 Lack of learning analytics frameworks for Manufacturing

Industry is very much performance driven and simulations provide numbers, but measuring the competences and knowledge being acquired through a serious game remains a hard problem. The first step
of the challenge is building the appropriate model and the second step is encouraging the adoption for recognizing the validity of a particular model. In order to achieve a higher deployment rate for corporate training, it is necessary to develop standardised competence frameworks and common measures to assess the competence of an individual.

4.1.4.3 Lack documentation of using game for the facilitator
Many of the serious games in manufacturing and engineering can be used by learners, but the true potential of learning is unlocked by a facilitator of the learning process, whether in a workshop or classroom setting. However, the quality of facilitation varies significantly from one individual to another, since much of the facilitation is tacit knowledge. The challenge is in externalizing the tacit knowledge and to carry out training of the facilitators to improve the quality. So the first step of the challenge is the externalization of the knowledge and framing it within a pedagogical framework that is easily understood by non-educational practitioners.

4.1.4.4 Physical interfaces
There is a need for health SGs to be able to run on a wide range of personal digital devices in order to promote uptake and use. Continuing professional development and the management of chronic conditions are two important scenarios where a health SG is likely to be used in an informal setting over a significant period of time. In order to maximise the opportunity for use, it will be vital that such a SG is able to be operated on a wide range of consumer personal digital devices.

4.1.4.5 Interoperability
Standardization enables the accomplishment of various goals, such as technical performance, learning effectiveness, better performance in development, broadness of distribution with on-line/remote access of games, and improved quality in educational environments. Interoperability was not usually addressed with few exceptions until few years ago; limited customer solutions were available just among the same games and/or some basic hardware; there is a slight evolution in this area from the point of view of hardware integration, while interoperability among different models and SGs is still a major gap.

4.1.4.6 Conceptual Modelling for Interoperability
Up to now, there is no standardized specification or standard to integrate desktop games with an LMS platform. Serious Games and LMSs require further attention, in order to explore and employ their full capacity within learning environments. Interoperability initiatives such as between SCORM compliant games and LMSs can have a significant impact on serious games development and it is expected that existing standards will be a subject of inspection.

4.1.4.7 Develop links/use of existing health knowledge bases
There is a need for health SGs to be able to interface with patient electronic health record systems. The management of chronic conditions has significant potential for application of SGs. However, given that a comprehensive record of a given patient’s status and interactions will be required over a prolonged period of time, and the need for medical professionals to be able to regularly review and monitor progress, such a SG will need to be able to interface and communicate with established patient health record systems. Furthermore, given that frequent remote monitoring is likely to generate significant additional data above and beyond that collected during current professional driven monitoring (e.g. out-patient clinics, home
visits, telephone consultations) there may also be a need to adapt and extend current electronic health record systems.
### Quasi Operability Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Research and Development</th>
<th>Demonstration</th>
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<td>Develop links/use of existing health knowledge bases</td>
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**Figure 23:** Quasi Operability Standards Data Timeline
4.1.5 Links between Virtual and Real Worlds

4.1.5.1 Emotional Engagement
Emotional Engagement will become more challenging due to the evolution of SGs and the use over new conditions due to the mobile solution. Game Generation will emerge to have decision making position; this will introduce people in the process with positive attitude versus SG and experience in this framework; this will provide opportunities as well as more challenging requirements for developers. New user modes and general evolution (i.e. users, computer games, devices) will require to reinforce emotional engagement connecting the real and virtual worlds’ experience in a meaningful way. It will guarantee the emotional involvement of the users, so that he get immersed- in term story, impact, story, engagement.

For instance in the cultural sector, we imagine it will be possible to continue virtual quests in the real world thanks to geo-referenced locations (in the game) and geo-localization of the player, and to the scalability of the content according to different devices. The majority of municipalities, museums and places of interest will be able to offer games to engage with the cultural content: it will be possible everywhere, anytime to join other players in a pervasive MMORPG experience, also through more natural user interfaces rather than the mobile (e.g. the Google glasses).

4.1.5.2 HCI for personalized experience
There is a need to enhance the links between virtual and real worlds by making interactions more multi-modal and natural and to enhance the flow of information and interactions between virtual and real worlds in order to personalise the experience.

Health as well as the security and crisis domain are comprised of many complex multilayered systems that comprised of biological, social, technological and economic subunits. Virtual worlds offer the possibility of representing the complex nature of these systems and permitting users to explore, interact and learn through them. The development of more multi-modal and natural ways to interact with such virtual worlds will offer greater potential for learning and also the possibility of rehearsing real world medical procedures and also enable various forms of scenario planning. By enhancing the flow of information and interactions between real and virtual worlds, the virtual worlds can be made to represent a specific case or instance e.g. rehearsing an operation based on information obtained from medical imaging. Within safety, security and crisis management, this challenge is related to Man Machine Interface for team working

Within humanities and heritage it has up to now been a trade-off between the level of interaction and personalization and the number of visitors which can be involved at the same time, varying from a massive experience which allows little interaction and no personalization (e.g. in a dome) to a single-user application. A challenge here is to move from a mass-oriented approach towards a personalized experience even within an application targeting a wide audience contemporarily.
4.1.6 Reusability of Digital assets

4.1.6.1 Reuse of components
This involves reusing processes, models and possibly digital assets for executive education games. They are often bespoke with respect to what is available for middle management that relies often to off-the-shelf games and are built by using Learning Objects and used in combination with Learning Management Systems and Learning Content Management Systems. It also comprises issues related to adaption of content supporting personalisation. Available authoring systems etc. are often complicated to use, but in this field we see progress with both contribution within (SGREF) as well as through the contribution from new projects supported by the European Commission.

4.1.6.2 Smart management of digital cultural content
This challenge is related to the documentation of different media, which suggests interdisciplinary issues in connection with the semantic web community. In fact, efficiently sharing, searching, and reusing in particular 3D data, also in networked environments, has been proven to be fundamental, together with the preservation of the annotation according to the specific application. There is a need to manage in a smart and automatic way the digital cultural content, for instance for using artefacts from a digital museum repository in a game, or for increasing the level of natural interactions between characters and objects inside a game, or for accessing related multimedia information while remaining inside the game environment, but also in order to increase the reusability of content and therefore contributing to a reduction of TCO.

Within health it is a need to create digital assets for use in SGs in ways that enable re-use in order to reduce the need to recreate such assets and therefore reduce the duration and cost of production of SGs. Many aspects of the health domain are highly detailed and involve complex interactions. While the degree of fidelity of any virtual worlds created for health SGs will vary with the particular application, there is often a need for highly detailed representations of both form and function. The time and cost to produce such high fidelity representations can be significant and even prohibitively expensive. By creating digital assets for use
in health SGs that enable future re-use, this will reduce the duration and cost of production of SGs over time and therefore help promote their uptake and use.

4.1.6.3 Exploiting existing health knowledge bases
There is a need to develop ways to exploit existing health knowledge bases for use in SGs in order to enhance realism and to help lower cost of production.

There is a wide range of knowledge bases currently available in the health domain (e.g. genetic, biochemical, anatomical, pharmacological, diagnostic, disease, treatment, etc). Such knowledge bases could potentially be exploited to enhance the realism of SGs and may also help lower the cost of production by negating the need to create specific knowledge bases from scratch. They also offer the possibility of SGs based on them being able to evolve as the knowledge base grows and develops.

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<td><strong>Reuse of components</strong></td>
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<td><strong>Smart management of digital cultural content</strong></td>
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<td><strong>Exploiting existing health knowledge bases</strong></td>
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**Figure 25:** Reusability of digital assets
4.1.7 Challenges priorities

The priorities of the different grand challenges differ depending on the application area. The figure below shows that variation.

As described in the introduction, the maturity of games developed within these sectors, the acceptance to use SG as well as the degree of deployment varies for several reasons. Thus, the relevance of the different Grand Challenges for each sector also varies. Figure 26 shows these differences. The Grand Challenges on Sustainable business models is identified as the challenges which have the highest priority for all but one SIG. The reason for the less relevance of this challenge for the area of safety, security and crisis management may lie in the long tradition such games have within military education. The deployment and proof of concept of effectiveness within the sector has been evolving over time, and due to the nature of the training also evidence of effectiveness has been delivered. The long period has also led to the development of sustainable business models taking the specific needs and opportunities of training in a risk free environment by using games into account. Comparing the application domain with the research topics, there are, as expected, very many commonalities with the research area, but since we are there focussing on the deployment, we see that for example the topics related to business models (BM) are so important that we have reduced the TCO topics to only comprising BM. From a deployment perspective, the integration into learning is much related to topics like how easy it is to implement it, how it can support the purpose of the course, etc. A very important barrier is here the lack of accreditation and also the lack of suitable assessment systems. Improvements in stealth assessment will in the latter case help to increase the deployment, since it will give both teachers and pupils better instruments for personalised teaching and feedback. However, as long as there is a lack of accreditation and standards for integrating the games as a complete part of the class (i.e. to be used instead of exams, reports etc.), it will be challenging to increase the deployment rate. This is the topic where there is a need for regulatory changes, since this is an administrative issue and also in some cases requires a change in the curricula. The identified grand challenges comprise several sub challenges derived from the different deployment sectors.
As outlined in the timelines in chapter 4.1, we see that for some of the challenges we have very long timelines. This is because we are here looking at the aggregated activities across all the application areas. This includes areas like crisis, safety and security. As shown before, this is a sector with high maturity, lot of investment and several applications already being used. This also includes the military area. Therefore, looking at areas like GALA, we see that they do have a lot of assets, but due to the structure and the finance of the sector, the SG applications are less costly, and often lack a suitable business models. Health is an area where a lot of progress has been made, and where we also see some sustainable business models – for example servitisation models. However, these are still exceptions. Most of the games are still one of a kind production, with low reusability and high customisation rates. Unexpected is perhaps that there is a need for sustainable business models also for the business and management area. This is an area where we find a huge amount of available games. The main reason for this is likely to be, that not the game is sold as a product, but far more, due to the complexity as a package with a facilitator, and that many of the available games are a sort of advanced prototypes only used in the educational institution in which they were developed.

4.2 Industry demand-the use of serious games in companies

This section summarises the sub-roadmap on SG in companies, a more detailed description of each topic can be found in the sub-roadmap document. The main challenge is the adoption and use of SGs in companies. Companies are still not aware of the benefits of SGs. The surge of interest in digital serious games has helped to raise awareness; however, more needs to be done. Obviously the application domain of SGs within companies was the most important topic, but also topics already identified as research topics on a general
level, described in chapter 2, like evaluating the effectiveness of SGs, game analytics, data and privacy issues, and game mechanics and learning are of importance for the uptake. We also identified technical topics as being important: development of mobile SGs/learning, emerging interaction devices and interoperability, but here we consider specifically the aspects relevant for an improved deployment in companies.

The following main topics were identified for the sub-roadmap on SG in companies:-

1. Corporate SG Applications
2. Evidence of SG Outcomes in companies: learning & commercial outcomes
3. Game analytics & data and privacy issues
4. Game mechanics and learning
5. SG development from ‘art’ to science
6. Development of remote/mobile SG learning

4.2.1 Corporate SG Applications

The main gap we have identified here is that although much is claimed for SGs - that they develop team-working, decision-making and soft-skills there is no rigorous evidence to back this up. There is therefore a need to understand how team playing and group dynamics impact on SG results; and how SGs can mediate soft-skills effectively and how these can be transferred to participants’ everyday work.

![Timeline for Challenges for Corporate Application of SGs](image)

**Figure 27: Timeline for Challenges for Corporate Application of SGs**

There is also a need to develop serious games for service based organisations – there are many SGs for manufacturing companies and for supply chain management but not so many for mediating service processes. However, the development of SGs for new applications in companies should be strongly led by the market. This requires SG developers and researchers to understand the market needs of companies.
before embarking on the development of new games. For example, there are many business simulations/games on the market - new ones need to show added value.

The research on the impact of SGs on team dynamics, decision-making and soft-skills can be carried out without the development of new SGs – although this may be useful or needed, depending upon the specific research questions to be addressed and the SGs to be used in the experiments. There is also a need to develop effective measures for soft-skills and commercial outcomes. The experiments and the development of the measures need to proceed in parallel.

4.2.2 Evidence of SG Outcomes in Companies

This is one of the most important topics. There is a desperate need for evidence of the effectiveness of SGs in companies and in particular of the commercial outcomes. Virtually all the rigorous studies of SG effectiveness have been conducted in an educational context with either school pupils or higher education students. We simply do not know if the positive results for learning effectiveness in the educational context apply to SGs in companies. We also do not know if SGs can produce positive commercial outcomes (improved productivity, increased revenue) for companies and if they justify their cost, thus the main gaps we have identified in this area are: First there is a dearth of academic/research studies of the evaluation of SGs in companies. Second, the few studies that exist suffer from a lack of rigor, methodological weaknesses and poor measures/metrics. In the case of soft skills it is even more difficult to measure game effectiveness (for example: self-control under very stressful conditions is measured by sensors of sweat, eye movement, face expressions, etc., which are often invasive and may perturb the game conditions). Finally, there is a lack of research studies of commercial outcomes of SGs. This is probably due to commercial confidentiality reasons. Therefore, challenges were formulated to address these gaps, in studies, methods and measures. Also the role of learning analytics was identified.
Most of the research identified for Evidence of SG Outcomes in Companies is basic research, and thus in line with topics also identified in chapter 2, but here we explicitly look at the need from a corporate perspective. It consists of the development of methodologies and accompanying measures. This type of research can be completed in one to two years – it consists of the design of experiments and analysis techniques. The development of measures requires literature review, collation of existing constructs from the literature, refinement of constructs, experiments to collect data based on the constructs, statistical analysis (including reliability analysis) and it concludes in a set of validated constructs for measuring the concepts (learning, commercial outcomes, etc). This work is required for the research identified in the SG Applications topic on studying the impact of SGs on team dynamics, decision-making and soft-skills. All of this research is high priority and should be carried out as soon as possible.

4.2.3 Game Analytics and Data Issues

This topic has been of major concern from the beginning of GALA and as described in chapter 2, it is still a new field, and thus the gap identified is related to effective game analytics for assessing different types of
learning; for assessing different types of learning content; for assessing different types of learning style. This concerns the use of analytics in games to determine the progress of the participants and to use that to adapt the game to their rate of progress, but specifically used in a corporate setting. There are some issues related to the collection of sensitive personal information on the participants. This information needs to be treated with care, especially in a commercial environment, and processed according to the laws of data protection and privacy. For data and privacy challenges there is a need to know what information can be collected and what is permitted to be done with it. There is also a need to inform the user that information is being collected, for what purpose and what will happen to the data after the game.

![Figure 29: Game analytics and Data issues](image)

The first two topics, concerning game analytics, are research and development oriented. The emphasis of this R&D should be on developing game analytics for use in companies and of course it should be carried out in collaboration with the research on game analytics in general. The remaining challenges concern the legal and regulatory aspects of data privacy. These do not need research as such; rather guidance and demonstrators of best practice can be produced. Further, best practice in communicating the data collection and the use it will be put to can be produced. For example, if data gathered during a gaming session will be
stored after the game is over and used for league tables or benchmarking purposes then the user needs to be informed in an appropriate manner.

4.2.4 Game Mechanics and Learning Analytics

For the topic of game mechanics and learning there is a large amount of research to be done, and thus this is one of the three key areas identified in chapter two as an important topic for general SG research.

![Figure 30: Timeline for Game Mechanics and Learning Analytics in Companies](image)

Within corporate training, the time line with the identified challenges has a slightly different scope than the general topic which is more focussing on the GM-LM connection. For corporate games, often training team skills etc, it is of more relevant to look into individual and organisational learning. Furthermore, as mentioned in the beginning, the main challenge is to deploy the game. Currently, SG development is quite costly. Thus a second challenge that helps in this perspective is to find a standardised way of describing game mechanics. Once a standard way of describing game mechanics has been agreed upon it can be used to build a knowledge base of all the known game mechanics, GaLa has been contributing to this with its PPSM (purpose-processing-structure methodology (WP2 D2.4 Report 3), but only in a small area. The emphasis should be on developing game mechanics for use in companies and it should also be carried out in collaboration with the research on game mechanics in general. Longer term research is needed to study the effectiveness of individual game mechanics; and in the corporate context we need to know the impact on organisational learning. It may be that game mechanics could be a very effective method for promoting organisational learning – this is something very difficult for traditional training methods (lectures, exercise, workshops, etc.) to achieve. Therefore research which shows that SGs can uniquely deliver organisational learning would be helpful in promoting SG adoption in companies.
5 Risk analysis of Innovation uptake

The previous chapters have looked at the areas where there is a need for more research and development for reaching the vision, in order to reach a better deployment of pre-commercialised games. However, as described in the previous chapter, the adoption and deployment is a real barrier. Thus, the industrial partners and their communities have carried out a risk analysis regarding the innovation uptake.

We understand that this is not only a matter of access to financial resources for buying and implementing SG in an educational context, but also a matter of the market maturity and demand. Thus, within GALA the industrial partners as well as the industrial community have looked at the risk of failure of the vision from the industrial perspective. i.e. even though the research challenges might have been overcome, the product still might not find its way to the market.

From a business perspective, the Roadmap vision is very optimistic and in terms of research is quite fine, but in terms of innovation uptake, we are fair less optimistic. SG has been breaking out for 10 years and yet in some sense it remains just a promising technology and is certainly not mainstreaming except in the sense that many in education have at least heard of it by now. In many senses the reasons for the lack of penetration by 2020 are less technological than they are a result of current 2014-level market maturity and the slow pace of change which can be expected in this regard. Most likely the successful developers will exploit the niches which emerge from early adopters and which are the most mature in their use of Serious Gaming solutions. Most of these are reasonably well known and include health, military and manufacturing, as well as pre-school education. Each of these markets has its own conditions which make successful penetration difficult, however. In the military case the budgets exist but many developments are done internally, in the health and manufacturing spaces very specific sales expertise is required (which is often beyond the developer companies which we see at the forefront of the European community), the pre-school market is pretty saturated with products and so on. We do not foresee mainstream education as achieving high levels of serious game usage by 2020. This process will take longer and move slowly. By comparison, VR simulation training has been available in the manufacturing sector since the 1970s, yet market penetration is only poised to break 5% between now and 2020. Market maturity is a HUGE challenge, one which most likely does not have a ‘magic bullet’. Europe does not lack in competent developers, rather it lacks a market of sufficient size and which is growing at a sufficient rate to enable the hoped for penetration.

Regarding technology it can be stated that good progress have been made:

- User Interaction is developing really rapidly in a number of directions and novel UI will be an early strong feature for the coming SGs (natural user interaction is already very possible, including haptics, and there are many promising technologies in various stages of consumer market readiness such as Oculus, Leap, Kinect and so on)
- Graphics cards continue to increase power rapidly at low prices

However, looking at the some of the identified research challenges, the industrial stakeholders stress that they see large risks and expect that:

- Neuro- approaches will not be mature by 2020
• AI is still a very long way from what is required to really personalise learning services in a deep sense. It also does not appear to be a very attractive application area for researchers.

• Authoring tools are becoming more rather than less complex and creates a barrier for participation by non-technical specialists (i.e. most teachers...). Despite Unity’s stated mission to democratise game development a project making use of that tool still requires a multidisciplinary team with C# experience and access to appropriate graphical resources.

• Mesh services and heavy use of semantics are nice, but will take time to develop and are certainly no guarantee of uptake. In particular semantic technologies have extremely low penetration in the educational space at the current time, with many developers questioning whether the benefits outweigh the costs of deployment and maintenance.

• The place where semantic technologies might make an impact is the delivery of personalised learning services. Once again, personalisation and adaptivity have been on the ‘coming soon’ list for a long time without significant breakthroughs and I do not perceive this as likely to significantly change in the coming 5 years. AI has been very slow to evolve in this area, and seems to be unattractive to researchers who develop more actively in other domains. Semantics might help to speed things up somewhat, leveraging the rich relationships between objects to drive better and deeper engagement. Nonetheless, it does not seem to be much interesting work in this direction at the current time.

Summarizing utility, accessibility, ease of use and return on investment are some of main challenges. The vision is focused on education and learning and the opportunities for SGs and the technologies impacting it over the next 6 years. This entire area is undergoing changes continuously whilst little is changing in the way the individuals teach, new teachers seem more open to use new technologies, but the main challenge is whether the software is accessible and usable for students. And whether older teachers are willing to change the way they teach. Whilst entertainment games are pervasive, there is still a long journey to get to SGs being pervasive.

5.1.1.1 Mechanisms necessary in order to ensure the ROI

With the huge pressure that is on teachers to deliver students that have the highest attainment, the real ROI is helping the teacher teach more/better with less effort. In industry ROI can be measured in terms of how effectively or efficiently the training has occurred – if any solution is better than the status quo and costs the same or less then it will more than likely succeed.

Therefore, to answer to this issue depends on the case of study. For the education market a revolution in distribution needs to occur, and the solutions will need to be delivered on a large enough scale, so curriculum area will play a huge role. In the commercial and industrial space the situation is more fluid. The value derived from the solution will facilitate decisions around complexity, graphical fidelity and so on.
5.1.1.2 Relevant factors to reduce the time to market of SG products compliant in the vision

Each market is different, and as such each market may be in the different frame of reference and time with respect to what’s in, what’s expected and what and how people should be taught and trained. There really is no one size fits all – and commercial success is probably as likely in SGs as is in other types of game – but the difference is most people involved in SGs are blind to this. In the commercial space some 95 to 97% of games fail to make the type of return on investment that would have a publisher make another – this 3 to 5% success rate is similar to books and music – however for inexplicable reasons many involved in SGs expect the success rate to be 90%+. This disparity between reality and ideal will never be fixed. No report or vision will make a big impact on the rate of success.

If it becomes easier to make SGs, then a lot more will be made and a lot more will fail – it is rather naive to imagine that by writing a better dictionary we will have better writers. Or by creating a piano with keys that light up we'll have more people playing the piano really well. Yes there will be more people trying but that does not make best products, it just makes better products.

5.1.1.3 Relevance of the availability of standards and specifications that will ensure the interoperability and reusability of SG components, services?

Interoperability has traditionally meant stifling innovation. One of the reasons why so much e-learning is passed up as 'not worth the virtual characters in it' is because they have to adhere to an outmoded version of an LMS. Interoperability should be done at the most basic level. Due to our experience it is unlikely that such initiatives will reach the critical mass. Thus, from a developer of commercial SG’s perspective – open web, accessible ubiquitous technologies such as Javascript, open APIs and the very well documented examples that don’t force a structure but provide the framework for different technologies to work together. WebGL native support in browsers is important. From a developer’s perspective it is important to distinguish different priorities for standard adoption. Core standards that enable key functionalities of SGs (e.g. the runtime environment, hardware interfaces) should be addressed first, and at a later stage, after these are properly implemented and supported, the focus should move to more specialized areas (e.g. user tracking; interfacing with other systems).

The question is different if you are considering it from a content or technology point of view. Here we see that the defence industries have made enormous strides in creating a vast range of standards for simulations that incorporate everything from 3D to GEO to specific behaviour of entities within a virtual environment, there is even an entire section of ISO devoted to it – it even has its own organisation – the Simulation Interoperability Standards Organization.

In the educational space the lack of money to commission or buy solutions is much more relevant. In the commercial area common standards outside of general technology hold almost no value.

Conclusively we can say that the problem is not about the standard – the problem is that most of them are too prescriptive to become ubiquitous. We should be looking to open web instead like WebGL and XML3D.

5.1.1.4 Instruments ensuring the availability of some tangible evidences of learning outcomes when deploying SG based approaches which support the stated vision

What will really be effective evidence is the commercial success. Nothing else will do if there is no evidence in a market place of sales! In addition, it is important to consider that value decisions in industry tend not to be based on learning outcomes but other metrics – time saved, money saved, and so on.
In education it is about time and accessibility/ease of use, not learning outcomes. Teachers will use games if it saves them time and makes their jobs easier.

5.1.1.5 Challenges related to SG business models and market

The main challenge for most SG companies is to survive. The term SG does not sell and most UK SG companies have gone bankrupt. Thus, we emphasise that there is a need for a larger market, which might be reached by looking at the term Applied Games and Gamification. The problem is whilst in education and in games there are many publishers – there are no educational games publishers to rival and support the level of investment needed to make this domain a success. It’s possible that such an entity may come about not through private investment but through mindfull European focus on building open markets together with tools and method for delivery.

As mentioned before, the early successful companies will service niches and have business models highly specialised in this direction with regard to service scalability and content production. As-a-service models are not really present at the moment but surely this situation will not last much longer. Someone might figure out a distribution model or service.

5.1.1.6 Challenges related to company’s business model and its ability to cope with high pace of technology evolution?

There is no right answer to this, since nobody knows what will be successful in the long run. YouTube swallowed millions of dollars before it made a penny. Since most SGs don’t have anything like this type of scale, and probably more importantly most SGs are not bought by consumers directly, the opportunity to innovate on business plans is limited. The usual tricks of the trade in Freeware and games with premium content or subscription do not seem to have worked in SGs – again probably because nobody actually buys an SG for themselves at the point of usage, it’s usually for a class or learners or the company or paid for by an organisation in order to be given out freely at the point of consumption. This is unlikely to change, unless attitudes toward learning and training shift from an institutional one to a product one. So imagine an SG that will give you a degree certificate if you complete it – if such a thing could exist (and there are the outlines of it in Mozilla’s badges and similar ideas) then maybe a positive change in this situation will occur.

5.1.1.7 Relevance of R&D efforts and large scale testing needed for achieving an innovation uptake

We are aware of a variety of existing R&D efforts across Europe and in UK funded by the European Commission, EPSRC, NESTA, Technology Strategy Board and others that are looking at these areas. Priority depends on research and testing point of views but must strongly rely on Utility, ROI, and Ubiquity of the resulting products. There is a need for more innovation actions but it is crucial they will show tangible evidences of effectiveness - And the fact is that R&D funded by central agencies so rarely makes it into the hands of the real makers and doers and there are not available examples of commercial success. Unfortunately, R&D results can be slow to adjust to real market forces and sometimes it is viewed by the commercial world and the marketplace as ‘interesting’ approaches rather than ‘critical’ needs.

We still would like to emphasise the main driver for a market is to deliver commercial success stories. Summarising, the analysis of potential risks for not achieving the vision by 2020 in terms of a wide adoption is high.
There are three main risks concerning the likelihood of achieving the innovation uptake in such a degree that the vision can be fully reached by 2020 also from a commercial point of view

- The maturity of technology development advances faster than the pace of market needs, which leads to R&D without market.
- Today’s game designers and game developers are largely unaware of the potential for applied games and gamification – undoubtedly if we could create an environment that supports this in a more grounded and open way – think a marketplace with hundreds of products – then this would make a big impact.

Conclusively, we state that from a R&D and technological point of view, the vision might be reached, but is not likely to lead to large market adoption, since to some extent there is a hardly consolidated SG market with strong demand. Consequently, the vision will not have an impact on the market size. In addition, another important factor to take into consideration in order to increase the awareness of the potential need of SG is the way of creating and using dissemination and marketing tools, which need to be easy, fast and attractive – like the card game for WP3, or the Roadmap Infographic.
6 CONCLUSION
From a research perspective we have identified four grand challenges in which the research activities can be clustered

![Challenge clusters](image)

**Figure 31: Challenge clusters**

2020 milestone

By 2020 research and development on pervasive SGM will advance to include adaptive SGM, user-centred game design, and the translation of real life scenarios into SGs through SGM. Methodologies and frameworks that link learning paradigms with SGM will be identified, analysed, assessed and ready to be regulated. SGM will evolve to be integrated into interoperability and reusability best practices, building upon their autonomy and their capacity to automatically perform reusability analytics. Demonstrations of self-adaptable SGMs will be carried out.

SG reusability will cover not only technical components and source code, but models to facilitate access and maintenance of other SG reusable assets (e.g. SG design patterns, SGM) and associated knowledge supporting ease of integration and access to SG development for people without advanced IT skills. Research and demonstration will support the development of standards for SG reusable components until the next milestone is reached. Complementary to these goals, the lack of competencies will be covered by the development and demonstration of SG shared services that are crucial in order to boost the SG development and open up a new era for complex SGs that can compete with entertainment games as SG development teams will be able to easily integrate top, specific expertise required to build the next generation of SGs.

Since costs represent a significant challenge and a top priority, by 2020, SG development will be based on cost-effective mechanisms and design patterns, authoring tools, interoperability practices and semantic models will be ready for market introduction.

In terms of personalization and AI, the SG of the future will be able to recognize and adapt to specific features of the user and will perform real-time measurements and analytics in order to maximize the learning outcome. SG content will be reusable and easy to reintegrate in new SGs, supporting cost reductions. Research on how NPC models can reach maturity will support the beginning of demonstrations in the next 5 years.
HCI brings new opportunities for future SGs and in the next couple of years research and development will consider the adaptation of MR devices for SGs. Research will focus on how SGs can be enhanced by multimodal and multisensory interfaces.

Since assessment is a key element in SGs, research will focus on flow/engagement and on enabling automatic assessment to support market introduction by 2020. Regulation of privacy concerns is an immediate priority and, due to its complexity, will extend until the 2025 milestone.

Research in the psychology field will focus both on near future achievable goals such as gathering and analysing behavioural data, but also on in-depth analysis of cognitive and personal learning. In collaboration with personalization and AI, research will consider the design of NPC in SGs.

To enhance SG assessment, metrics on physiological signals and physiological measures of the user’s subjective experiences will be identified and demonstrated, in the perspective of regulation and market introduction.

2025 milestone

Building upon previous outcomes, research, development and demonstration activities will focus on understanding more complex challenges of game and learning mechanics. Developments on how pervasive measures are linked to various pedagogical paradigms for SG learning will be available. A reference framework of how learning paradigms link with SGM will be created and tested. Authoring systems that support SGM context and content will be introduced to the market, increasing the maturity of SG products.

SG reuse challenges will be addressed by 2025, with standards for SG reusable components, assets and knowledge being tested and available for adoption. The maturity of the SG market will be strengthen by global SG Shared-Services that have the ability to support complex match-making of demands and resources available.

SG development support will be consolidated by tools, interoperability practices and standard semantic models that enhance core processes enabling designer/developers to increase their performance and reduce development costs and timeframes.

SG will employ Personalization and AI techniques for a more complete, meaningful learning experience that considers user models, mapping specific features that enhance learning. SG adaptation will be based on real-time emotion tracking, and enhanced NPCs.

The growing number of SGs using MR technologies and devices will increase, and research and development of multimodal and multisensory interfaces will continue in order to enable the full exploration of human sensory capabilities.

In less than a decade, SG authors will be able to create in an easy and cost-efficient manner aggregated traces and visualization widgets for their games. Such tools will be tested and fully introduced on the market until 2025.
Research and testing of techniques and data analysis tools that measure flow and engagement will be able to support the better design of SGs. Learning analytics research will provide the tools to support automated and reliable assessment, easing the work of the teachers, providing meaningful insights, and contributing to the mass adoption of SGs. Automated assessment procedures will be subject to standardization. The possibility to analyse large sets of data collected from more than one SG will enable a better comprehension of the player’s performance and needs, and a better and more accurate evaluation.

Best practices and standards concerning privacy and data protection will be consolidated by 2025, making SG data anonymous under certain limits.

Cognitive learning and NPC design will be key challenges addressed in the next decade, providing insights on how psychological theory and constructs can support a better understanding of SGs and a more streamlined approach. Advances on personalised learning will enable customization of SGs to fit personal needs, boosting not only player performance within the game, but also the learning outcome.

The methods to analyse SG neurophysiological data will remain a challenge in the next decade, as data quality remains a significant issue. However, learning analytics tools will be improved by integrating data collected from monitoring brain activity.

**2030 milestone**

The next generation of SGMs, supported by interoperability and reusability standards and able to build upon and mirror real life experiences, are envisioned for the 2030 timeframe. Further exploration, testing and revision of the interconnections between learning paradigms and SGM/ LM-GM will be carried out to enable alignment and incorporation of new paradigms and of the advancement of research and technology. In-game systems will be able to self-adapt, enhancing human learning.

Advanced multimodal and multisensory interfaces will be market ready, contributing substantially to a more consistent uptake of SGs.

Techniques and data analysis tools that enable the measurement of flow and engagement will be introduced to the market accompanied by evidence of the impact of flow in learning, and of the impact of SGM on flow experiences, while considering preferences and differences at individual and community level, and game genre.

Due to the complexity of cognitive learning and NPC design, research will continue until the end of 2030, but will advance to support market introduction.

As devices will become more accurate, the quality of brain monitoring data will be enhanced, enabling a better assessment of the player state, including of people with learning problems.

As we see in the risk analysis of innovation uptake, SG development is still a business with high risks. As pointed out in chapter 5, the main challenge is the small market for SG applications, the lack of suitable business models, and the lack of enough success stories. The maturity of the market is low, and as explained in the case of the challenges in deployment area it will remain low as long as SGs cannot be fully integrated.
in the learning process, without requiring specific competences and a large amount of time for the teacher to use. For this research activities and also regulatory actions should initiated.

The Gala R&D roadmap has identified some key research areas (design, TCO, evaluation, etc) in which it is important to invest and to initiate research projects in order to make SG better and to reach their full potential in terms of personalised, immersive learning. It has also identified deployment barriers for which more market related activities (like the new instruments in H2020) with a high technology readiness level (for example TRL 7-8), or pre-commercial activities demonstrating the potential, which seem to be a better way forward. A specific attention has to be put on the topic of accreditation, since this is not only depending on EU policies but to a much higher degree on regional and national policies.
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7 Challenges emerged from collaborative research across GALA NoE

An example from the design and pedagogy relation shows that design and development of SGs will benefit from an evidence-based guideline that is specific in the lower level components of what makes a game-based approach effective in supporting learning. A complete SG design toolkit will require extensive studies of the various key game components and pedagogical practices supported by evidence of games developed as a result of the validated patterns of learning and mechanics, but is also expected to have a high impact.

Figure 32 summarises the different research challenges needed for providing such a toolkit.

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<tr>
<th>SGMs toolkit</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
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<td>Use of pervasive methods and game mechanisms</td>
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<td>SGMs to meet accreditation and educational policies</td>
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<td>SGMs to meet interoperability and reusability</td>
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Figure 32: SGM toolkit Overview Timeline

The long-term goals are related to providing a reference framework where SGs can be benchmarked. There will be a special emphasis on epistemic, semiotic and ergodic components for knowledge transfer – a key to deploying and applying SGs for research, across industry and use in academia. The activities here will focus on taking SGs to a new level of pervasiveness and emergent technology use where they can make a significant difference.

The long term risks are associated with the step change in the way SGs will be designed, developed and used. However, the trend towards highly user-centred environments not only for education but for the range and spectrum of different fields where use of SGs can play a key role warrants this approach.

Finally, application domains of SGMs out with SGs need to be taken into account. These will both be driven by the market. In similar manner as user demands for new devices to be used for SGs it is also the basis to develop new games by finding out what end users want. This can be done informally, through specific-commissions, or through market research. It is fruitless of developers to develop new SGs based on their own intuition about what a good SG would be, without establishing a market need for the product and assessing the existing competition (cf. the point about business games above). There is space to develop new
and innovative SGMs but we cannot predict what these will be or which areas of business/users they will target.

In terms of the overall priority of topics in corporate setting, we present the timeline in the diagram below.

<table>
<thead>
<tr>
<th>SGs in Companies</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
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</thead>
<tbody>
<tr>
<td>Corporate Applications SGM</td>
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<td>Evidence of Outcomes SGM</td>
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<td>Game analytics and data/privacy SGM</td>
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<td>Game mechanics and learning SGM</td>
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<td>SG development from ‘art’ to science SGM</td>
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<tr>
<td>remote/mobile learning SGM</td>
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</tbody>
</table>

**Research and Development**

**Demonstration**

**Regulatory & Standards**

**Market Introduction**

*Figure 33: SGs in Companies Overview Timeline*