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Management, Economics and Industrial Engineering (DIG)

Methodology for Development of Serious Gaming Scenario

for Life Cycle Analysis

Using TARGET platform

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1 Introduction

The global competition for highly skilled people has led to increasing acceptance by organizations, as a key business strategy, of the need to retain and re-train their existing staff through some kind of tailored competence development that reduces the lead-time for a learner to achieve target productivity: the "time-to-competence" (TTC). Today, the main route to shorten TTC is a bespoke face-to-face or blended course.

In other hand, sustainability is getting more and more attention and importance for customers and consequently firms nowadays. Sustainability is a long term approach to environmental protection and process improvements. Sustainable design prevents pollution from the start and calls for systems thinking, which acknowledges the connections between the economy, the environment and social responsibility. Sustainable manufacturing is developing technologies to transform materials without emission of greenhouse gases, use of non-renewable or toxic materials or generation of waste. One of popular techniques to help companies in this field is Life Cycle Analysis (LCA) which is a technique to assess each and every impact associated with all the stages of a process from cradle-to-grave.

Therefore having a deeper look on these concepts and creating an innovative tool to integrate them can be a great source of competitive advantages for firms. This tool can provide firms a way to support rapid competence development in the domain of global sustainable manufacturing and in the field of LCA.

The aim of this research is to integrate the concept of serious gaming and the LCA to provide an educational tool for organizations in the format of serious gaming scenario needed to develop that tool.

The case study of this research is TARGET-EEU project. The TARGET project is a collaborative project partially funded by the European Community under the Seventh Framework Programme. The main aim of TARGET is to research, analyze, and develop a new genre of Technology Enhanced Learning (TEL) environment that supports rapid competence development of individuals, namely knowledge workers within the domains of living labs (innovation), project management and sustainable global manufacturing. TARGET addresses the ever increasing need to reduce the time-to-competence of human resources within organizations. TARGET takes a strong approach of "learning by doing" or "active learning", such as Problem Based Learning (PBL). Therefore, an individual is confronted with stories where they are confronted with a complex situation that requires the use of particular set of competences. These stories are the core of what is considered a knowledge asset, which may be carefully crafted with specific learning objectives, dynamically created by the system or may result from the capture of a running TARGET session. A story is experienced by the individual when engaged with the serious game component.

Having a broad literature review on serious Gaming, sustainability and its powerful technique LCA helps us to understand them better and come out with a scenario to conduct LCA in a serious game platform which is TARGET here. As we can see in the literature review, there is a lack of developed serious games on the domain of sustainable manufacturing.

In this research after the literature review, first a methodology for developing the scenario in the field of sustainable manufacturing is been proposed and later by being part of scenario development team, team of designers, the applicability of it is been tested in the TARGET project on the subject of LCA through developing the LCA conducting serious game scenario.

2 Litreture review

2.1 Sustainability

The concept of sustainability has been introduced by the World Commission on Environment and Development in the so-called Brundtland Report 'Our Common Future' in 1987 stating that the goal of sustainability is to "meet the needs of the present generation without compromising the ability of future generation to meet their own needs". Later in academic debates and business arenas, other definitions have been proposed. A definition of sustainability according to the US National Research Council is the level of human consumption and activity, which can continue into the foreseeable future, so that the systems those provide goods and services to the humans, persists indefinitely.

Based on the definition of sustainability introduced by World Commission on Environment and Development, sustainable development is defined as "a holistic approach harmonizing ecological, economical and socio-political needs with respect to the superior objective of enhancing human living standards". The availability of natural resources and the task of conserving the ecosystems have to be considered so that future generations have the possibility to meet their own needs. However, this goal cannot be achieved with current resource productivity and current trifling with the ecosystem without bursting the limits of the globe (Figure 2-1) (Seliger, 2004).

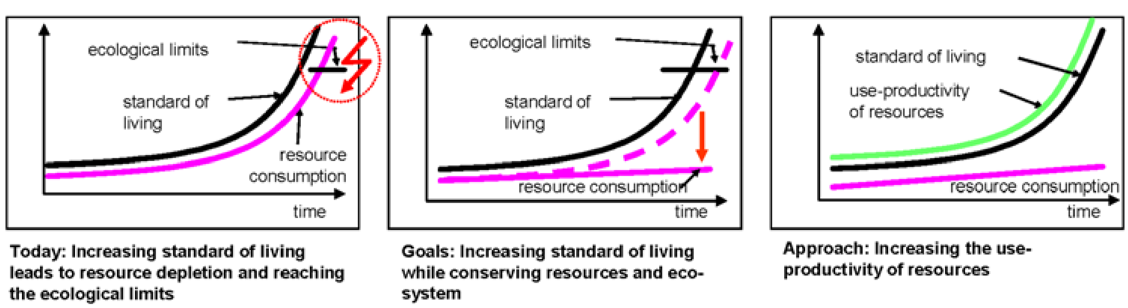

Figure 2-1 Approach to increase the global standard of living without bursting the limits of the globe
Source: Seliger 2004

Definition of Sustainability in engineering can be defined as "the application of scientific and technical knowledge to satisfy human needs in different societal frames without compromising the ability of future generations to meet their own needs." (World

Commission on Environment and Development (WCED), 1987). To achieve this goal, scientists and engineers cooperate in international and multidisciplinary groups and organizations utilize imagination, judgment and take initiative to apply science, technologies and practical experience to shape competitive processes and products. Management guides the creation, application and evaluation of science, technology, processes, and products, as well as the dissemination of knowledge. (Seliger, 2008)

2.1.1 Dimensions of sustainability:

(Source: Glavic, P. Lukman, R. (2007))

Sustainable outcomes for modern enterprises are those that make sense on the triple bottom line, taking into account economic (Profit), social (People) and environmental (planet) performance.

Figure 2-2 three pillars of sustainability

- **<u>Environmental Dimension:</u>**

Environmental dimension of sustainability denominate those terms that describe environmental performance, in order to minimize the use of hazardous or toxic substances, resources and energy. These terms are: renewable resources, resource minimization, source reduction (dematerialization), recycling, reuse, repair, regeneration, recovery, remanufacturing, purification, end-of pipe, degradation, and are arranged from preventive to control principles.

1. Renewable Resources*:*

Renewable resources are available in a continually renewing manner, supplying materials and energy in more or less continuous ways. In other words, renewable resources do not rely on fossil fuels of which there are finite stocks. The term emerged as a response to increased carbon dioxide emissions. It is fostered by the rise of the sustainability paradigm and includes energy resources such as solar, wind, tidal, wood, biomass, and hydroelectric. Of course food and feed are renewable resources as well.

2. Resource usage Minimization:

Minimization of resource usage is understood as conservation of natural resources. It is an activity that can be applied to any reduction of usage of resources. Therefore, the term encompasses not only raw materials, water, and energy, but also applies to natural resources such as forestry, watersheds, other habitats, hunting, fishing, etc. All these resources and processes which enable ecosystems to survive and are essential for helping societies to make progress toward sustainability must be addressed. Thus, resources can be conserved, their availability improved and maintained. Reduction in the usage of materials and energy can result in dramatic cost savings.

3. Source reduction:

Source reduction is the practice that reduces the quantity of materials entering a waste stream from a specific source by redesigning products or patterns of production and consumption (US Environmental Protection Agency (EPA)). Besides materials, this definition also encompasses energy. According to the EPA dematerialization refers to quantitative reduction in the volume of material and energy used to meet user‘s demand, while maintaining a uniform quality of services and as introduced by Wernick et al. (1998), it refers to the absolute or relative reduction in the quantity of materials required to serve economic functions and matters for the environment. Source reduction contributes to a lowering of disposal and handling costs, because it avoids the costs of recycling, municipal composting, land filling, and combustion. Source reduction also conserves resources and reduces pollution, including greenhouse gases that contribute to global warming.

4. *Recycle, Reuse, Repair:*

The recycling is defined as a resource recovery method involving the collection and treatment of waste products for use as raw material in the manufacture of the same or a similar product. The EU waste strategy distinguishes between reuse and recycling. The reuse means using waste as a raw material in a different process without any structural changes and recycling refers to structural changes in materials within the same process. Repair means an improvement or complement of a product, in order to increase quality and usefulness before reuse; it decreases consumption, because the product's life is extended.

5. Regeneration, Recovery, Remanufacturing:

Regeneration is an activity of material renewal to return it in its primary form for usage in the same or a different process. This activity enables an internal restoration and, therefore, decreases the environmental impacts. Recovery is an activity applicable to materials, energy and waste. It is a process of restoring materials found in the waste stream to a beneficial use which may be for purposes other than the original use, e.g. resource recovery in which the organic part of the waste is converted into some form of usable energy. Recovery may be achieved by combustion of a waste material in order to produce steam and electricity, or by a pyrolysis of refuse to produce oil or gas, or by anaerobic digestion of organic wastes to produce methane gas and a fermentate that can be used as a soil-conditioner. Remanufacturing is defined as substantial rebuilding or refurbishment of machines, mechanical devices, or other objects to bring them to a reusable or almost new state. This prevents many reusable objects from becoming waste. The remanufacturing process usually involves disassembly, and frequently involves cleaning and rebuilding or replacing components. Remanufactured objects are sometimes referred to as rebuilt objects.

6. Purification and end-of-pipe:

Purification is the removal of unwanted mechanical particles, organic compounds and other impurities. The process of removal could be mechanical, chemical or biological in order to improve the environment and quality of life. End-of-pipe is defined as a practice of treating polluting substances at the end of the production process when all products and waste products have been made and the waste products are being released (through a pipe, smokestack or other release point). This approach is designed to reduce the direct release of pollutants so as to achieve compliance with environmental regulations; sometimes it results in transmitting pollutants from one medium to another. Therefore, it can result in only a temporary delay of causing environmental problems.

7. Degradation:

Term degradation could be understood as a biological, chemical or physical process, which results in the loss of productive potential. From the biological point of view, degradation can lead to the elimination and extinction of living organisms. It can also refer to biological degradation of plant and animal residues, thereby making their elemental components available for future generations of plants and animals.

- **Economic Dimension:**

According to Glavic et al. (2006) economic dimension of sustainability includes terms like Environmental Accounting, Eco-efficiency, and Ethical Investments.

1. ***Environmental Accounting:***

Environmental accounting is designed to bring environmental costs to the attention of the corporate stakeholders who may be able and motivated to identify ways of reducing or avoiding those costs while at the same time improving environmental quality and profitability of the organization. Environmental accounting can be applied at the national, regional and corporate levels. National accounting refers to physical and monetary accounts for environmental assets and the costs of their depletion and degradation. Corporate environmental accounting refers to environmental auditing, but may also include the costing of environmental impacts caused by the corporation.

2. Eco-efficiency:

The term Eco-efficiency was perceived within numerous definitions of cleaner production. Eco-efficiency is the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth‘s estimated carrying capacity. It is based on the concept of doing more with less 'representing the ratio between economy and environment, with the environment in the denominator. It is about more efficient use of materials and energy in order to provide profitability and the creation of added value.

3. ***Ethical Investments:***

Ethical investments or socially responsible investments are financial instruments (mortgages, bank accounts, investments, utilities, and pensions), favoring environmentally responsible corporate practices and those, supporting workforce diversity as well as increasing product safety and quality.

- **Social Dimension**

Social dimension of sustainability is composed of terms such as Social Responsibility, Health and Safety, "Polluter pays" principle (Taxation), and Reporting to the stakeholders. Social responsibility refers to safe, respectful, liberal, equitable and equal human development, contributing to humanity and the environment. Furthermore, the term health and safety usually refers to the working environment and includes responsibilities and standards.

The Polluter pays principle was defined by the EEA (European Environmental Agency) as a principle that those causing pollution should pay the costs it causes. Thus, the polluter pays for environmental damage in the form of a clean-up or taxation but usually, in practice, this principle is overlooked. Reporting to the stakeholders is about sharing the progress, results and planning with the general public. The leading role has been taken by Global Reporting Initiative, presenting global effort to create a framework for reporting on economic, environmental and social performance by all organizations.

2.1.2 Initiatives for sustainability

According to Nourbakhsh (2008) many factors can initiate the adoption of sustainability by companies. Sustainability initiatives can be divided into four main groups as follows:

- **Customer Requirement**:

  Customer requirements play an important role in product and supply chain design and specifications, and suppliers usually comply with these requirements. Sustainable thinking lets the customers, especially major customers, use their influence on suppliers to adopt sustainable practices. This demand has cascade effect and goes through the entire supply chain. Also, major customers should help suppliers achieve this goal by partnering in product and process design.

- **Governmental and International Laws and Regulations:**

  Governments, national standard institutes, industrial development bureaus, and local authorities have a great impact on industries by passing laws and regulations and controlling the industries to implement these regulations. International unions, such as UN and EU, also pass laws and regulations which make countries conform to sustainability practices.

- **Organizational Sustainability Awareness:**

  The economical impacts of using old and worn products for purposes such as repairing, reusing, reassembly, refurbishing and recycling on organizational productivity and cost reduction is another important initiative for companies to develop sustainability practices.

- **Environmental Activists and Non-Governmental Organizations (NGOs):**

  These groups can create sustainability awareness within both societies and industries as well. First, they can encourage people to buy sustainable products instead of their non-sustainable counterparts. Despite the lack of expertise in technical fields, environmental activists, and NGOs can still have impact on industries by promoting sustainability awareness among people and requiring industries to adopt sustainable practices. (Kong 2002) examined how NGOs could create sustainability awareness in industries as their partners. They debated that consumers need to feel empowered to make a difference through their behavior; and they should also be able to improve their quality of life.

(The source: Nikbakhsh, E; Farahani, R; Asgari, N; Davarzani, H. (2009))

2.1.3 Sustainable Design

Design may be thought of as the glue that binds together many of the key themes underlining sustainability. Achieving sustainability will require that we redesign our society and many, if not all, of its sub-components: products, production processes, and the material and energy connections between these processes and products and the natural

environment. These redesigned products and processes will both change consumption patterns, and be influenced by consumption patterns. (Armstrong, T. (1997)
(The main source for this section is Clark, G; Kosoris, J; Hong, L-N; Crul, M. (2009))

2.1.3.1 Design for Sustainability

Design for Sustainability (D4S) is the process of designing goods and services that takes into account all the dimensions of sustainable development, and particularly environment, economics, and social factors. As such, it is a superset of the more commonly discussed "Design for Environment".
D4S is an eco-design concept that has evolved to include both the social and economic elements of production. It integrates the three pillars of sustainability - people, profit, and planet, but goes beyond simply greening products to embrace how to meet consumer needs in a more holistic, sustainable way. It also is unique in that it can focus specifically on the needs of industry in developing countries. Companies incorporating D4S into long-term product innovation strategies strive to alleviate the negative environmental, social, and economic impacts along a product 's supply chain and through its life cycle; t he "cradle-to-cradle" mentality.
While these drastic changes can present formidable challenges, there are encouraging developments that contribute to the expanding knowledge base of sustainable product development. These newly designed products and services offer increased functionality and ease of use, longer life spans, easy disassembly or recyclability, lower environmental impacts which can save the company money and improved materials sourcing and production which can positively affect communities. In other words, sustainability offers added value through better quality and lower price; the two motivators for most consumer decisions.

2.1.3.2 Design for Environment (DFE)

Design for Environment is based on life-cycle thinking and involves design procedures that minimize material and energy consumption while maximizing the possibility for reuse and recycling. It is possible to focus on a specific stage of the product's life such that the environmental impact is minimized in that stage as well as emphasizing the entire life of the product (Gungor and Gupta 1999). DFE is the systematic consideration of design performance with respect to environmental, health, and safety objectives over the full product and process life-cycle (Fiksel 1996). DFE improves the design of the product from an environmental perspective. It is a combination of several design-related topics, including disassembly, recovery, recycling, regulatory compliance, disposition, health and safety impact, and hazardous material minimization. Its key principles include use recyclable materials, use compatible materials, avoid contaminants, use simple fastening methods to join materials together, use clear material identification and marking, and ensure easy removal of component of product (Stuart and Sommerville, 1998). It takes place early in a product's design or upgrade phase to ensure that the environmental consequences of a product's life cycle are understood before manufacturing decisions are committed. The successful implementation of DFE calls for commitment from cross-functional interaction between design, manufacturing, marketing, sales, and accounting. DFE requires the coordination of several design- and data-based activities, such as environmental impact metrics; data and data management; design optimization, including cost assessments; and others. Metrics for measuring environmental performance and/or impact must be determined, information flow between departments needs to be supported, and an infrastructure to carry out DFE based decisions must be established. Failure to address any of these aspects will likely limit the effectiveness and usefulness of DFE efforts (Mizuki, Sandborn et al. 1996; Rose, Beiter et al. 1999).

2.1.3.3 Benefits of Sustainble Design

Sustainable design offers a variety of opportunities to prosper. Companies can gain access to markets, increase market share, reduce or avoid compliance costs, and more easily attract investor capital. There are also positive ripple effects related to product performance, cleaner production, customer satisfaction and brand loyalty, employee morale, and community relations. (The reference for the major part of this section is Business for social responsibility website)

- ***Better product performance through improved resource efficiency:***

Learning how to do more with less has the potential to spill over into better product performance and greater customer value. Consider the case of semiconductors and electronics. Designs that improve energy efficiency decrease direct energy use. They also decrease the thermal cycling that degrades microchips over time, reduce the active ventilation demands in downstream electronic products like computers, and lessen the energy needed for space conditioning where the equipment is used. The cascade multiplies improvements in product value.

- ***Strengthened market position:***

Consumer appetite for sustainability shows signs of increasing. Sustainability is now more readily associated with higher product quality, products less likely to cause consumer harm, and products that consumers can feel better about using. These associations make sustainable design a way to align with emerging consumer interests and to improve customer satisfaction and retention, provided that sustainability improvements are credible and clearly communicated. Sustainable design may also protect corporate value and reputation by reducing risk of operating crises (e.g., recalls, consumer campaigns, supply chain resilience, labor concerns). The combination has potential to broaden market access as well as to strengthen the brand and existing customer relationships.

- ***Improved compliance and preparedness:***

It has become an important matter that companies will strive to comply with environmental laws, but the legal landscape continues to change. An active program in sustainable design not only helps a company meet the obligations of current environmental laws; it may also avoid the need to operate emission controls or to pay for hazardous waste treatment, as well as create resources that help the company stay aware of and prepare for future legal requirements.

- ***Greater acumen and agility:***

In addition to streamlining regulatory review and costs, a sustainable design program may improve communication flows and enable a company to plan and manage complexity more effectively. For example, product leasing or product take back as part of a sales contract can alert a company to a customer's interest in another purchase. These strategies may increase operating efficiency, reduce business costs and improve technological agility.

- ***Serendipitous innovation:***

Many companies that undertake sustainability audits of their product lines identify opportunities for innovation. Some of these innovations emerge because investigations discover unnecessary complexity that adds costs, such as an unnecessarily diverse variety of materials going into products. Others come from dialogues with suppliers, customers and stakeholders that identify better-performing, cost-improving options and overlooked customer needs.

- ***Improved morale and productivity:***

Closely related to innovation potential, sustainability initiatives may bolster employees' satisfaction at work and encourage them to communicate insights and suggestions for improvement. Employee-driven design can be highly effective because their intimate knowledge of processes and products is a source of detailed, practical insights.

2.1.4 Sustainable manufacturing

In terms of sustainable development, manufacturing industry is often cited as a source for environmental degradation and social problems, but it is the major source of wealth generation. According to the Lowell Centre for Sustainable Production, sustainable production is defined as the creation of goods and services using processes and systems that are non-polluting, conserving of energy and natural resources, economically viable, safe and healthful for employees, communities, consumers and socially and creatively rewarding for all working people. This definition is consistent with current understanding of sustainable development, since it emphasizes environmental, social and economic aspects of firms' activities.

At the same time it is more operational, since it highlights *six main aspects of sustainable production*:

- Energy and material use (resources)
- natural environment
- social justice and community development
- economic performance
- workers

- products

Companies that wish to become more sustainable in their everyday practices should aim to address each of these six aspects and Risk should not be transferred between different aspects of sustainable production (e.g., between environmental protection and worker health and safety. (Veleva 2001)

The concept of sustainable production emerged at the United Nations conference on environment and development in 1992; the conference concluded that the major source for environmental degradation is unsustainable production and consumption patterns. (Veleva 2001) Although the concept of sustainable development was developed in the last decade, most manufacturing companies are still looking for improving environmental performance in their activities. The last two decades of environmental consciousness focused on end of pipe solutions i.e. reducing the amount of hazardous emissions and substances after manufacturing. The focus has shifted from controlling emissions to elimination or prevention at source, which is a proactive approach. Firms adopting a proactive approach consider the environmental challenge as a competitive business opportunity rather than as an obstacle. They integrate environmental aspects in all functions of the business and the goal is zero waste. (Thomas, A-J; Weichhardt, G. (2006))

At beginning activities in sustainable manufacturing started to focus on waste reduction in production, so-called cleaner production. The activities were extended to the reduction of resources and energy use in production. After this, the paradigm for sustainable manufacturing has been changed from production-oriented to product–oriented one. The changed paradigm is realized by the Integrated Product Policy (IPP). The product-oriented approaches are, on the one hand, activities for reduction of resources and energy in a product. On the other hand, there are activities for reduction of toxic materials, and development and use of renewable materials. In addition, the term 'cycle economy' was introduced (NN, 2003a). Until now, the cycle economy approach has focused on material recycling, which has had some successes in the cycle economy market. However, pure economic success is still difficult to achieve. Even the consolidated environmental regulations such as ELV (NN, 2000) and WEEE (NN, 2003b) make demands on pretreatment of toxic materials, including components, reuse and remanufacturing of components or products for the profitability of their activities. (Seliger 2008)

Until now, the scientific approaches have neglected to enhance sustainability in the use phase and have also focused on the design for environmental and material level recycling. However, sustainable manufacturing for the next generation should focus on enhancing use-productivity in the total product life cycle. For enhancing use-productivity, there are the three strategies illustrated in Figure 2-3: (Seliger 2008)

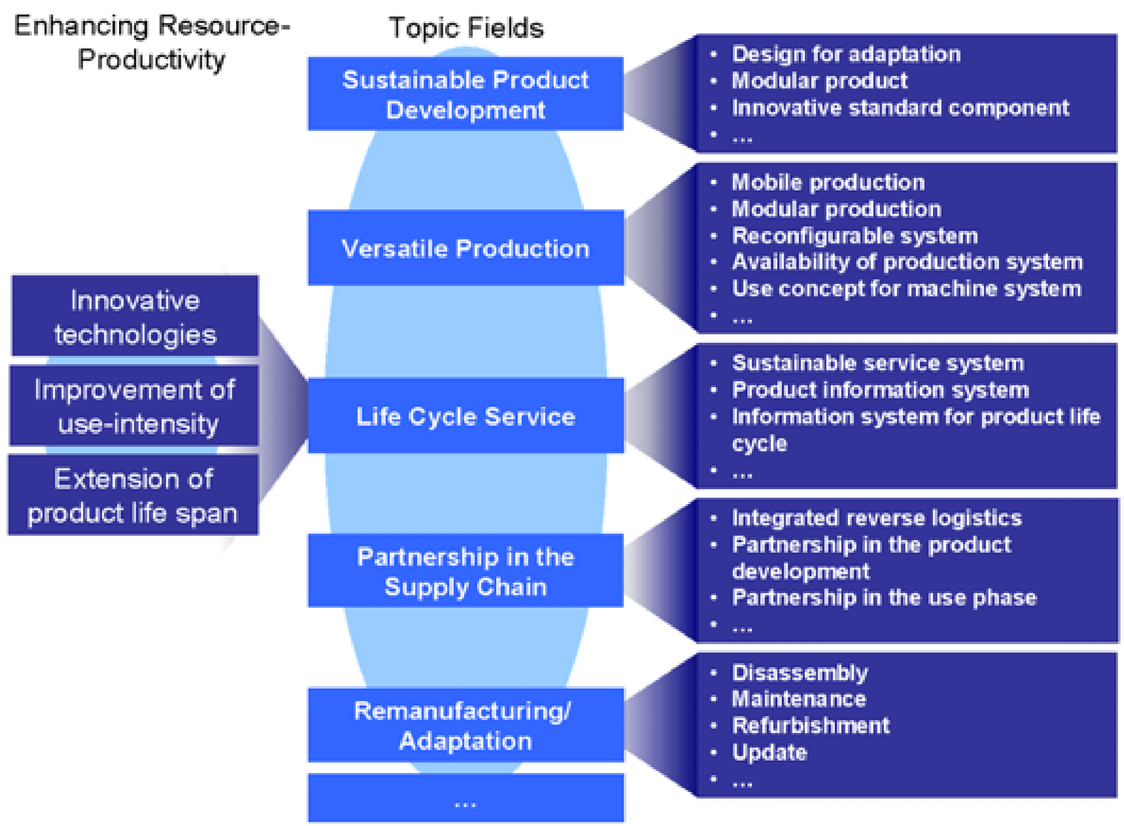

Figure 2-3 Framework for sustainable manufacturing based on Kim et al. (2006)

Implementation of Innovative Technologies

It is a strategy focusing on the evaluation and implementation of feasible and innovative technologies for resource-saving applications. Hereby implementation means both, application and implementation. Innovative technologies can be applied to improve product and process design, e.g., modularity and lightweight construction.

Moreover, innovative technologies can be implemented in products for resource-saving applications. Innovative technologies are, e.g., fuel cell, photovoltaic and laser technology.

Vital element of this strategy is the evaluation of technology according to sustainable manufacturing. (Seliger 2008)

Improving the Use-Intensity

It is a strategy to improve use-productivity by increasing the utilization ratio of a product. This strategy intends to maximize productivity per resource input. Improving the Use-Intensity of products is regarded as the use phase in the product life cycle. The objective of this strategy is to increase the utilization ratio of a product or of its components. Two approaches have been identified to achieve this goal; First by applying a business model where the use of a product and not the product itself is the object of the companies' business. This "*service-oriented approach"* is also called selling use instead of selling the product (Seliger et al., 2004). The second approach is related to a more sustainable use of a product by the user, named "*Distributed use of products and components"(Seliger 2008)*

1- ***Service-oriented approach***

In a service-oriented business model, the service provider offers the functionality of the product to the customer without passing the product out of his possession. He is responsible for the accessibility of the required utilization and the treatment of the equipment over the whole lifetime. The service provider manages the costs of investment, transport, operation, maintenance and disposal. Consequently, the customers only pay for the use that they obtain by the product and not the product itself (Seliger, 2000).

The service provider is responsible for the availability of the use at the right place and time in adequate quality. Therefore, he/she needs system-accompanying quality management, information and communication systems to guarantee product pursuit and product access. Leasing, rent and service-contracts regulate the responsibilities between customer and service provider.

Requirements on products for the service-oriented business model are modularity, integrability, customization, convertibility as well as diagnosability to support customer-driven adaptability (Seliger et al., 1997). The implementation of these properties in a high level increases the applicability and the availability of a product.

Requirements of the service process are higher idle capacity costs of a product when compared with the extra costs to be paid for logistics and information management

(Seliger et al.,1999). Logistics include all necessary processes to provide the demanded use at the right place and time in adequate quality (Fleig, 2000).

2- Distributed use of products and components

This approach is aiming at increasing the utilization ratio of products and components by its distributed use in different applications. To the same time functionalities and thus functional carriers of products are substituted. The utilization ratio is related to a product or component and can be calculated by comparing the standing time with the operation time. For example, if an automobile is used in average for 2.4 h a day, then the utilization ratio is 10%. Two possibilities of increasing the utilization ratio have been identified: Multiple use of products' functionality in applications not necessarily offering but providing the respective functionality. Hereby, the whole product and also components or modules can be used in different applications, e.g., a stand-alone MP3 player used in combination with a car radio and a home entertainment system. (Seliger 2008)

A reconfigurable product can be adapted to different applications by adding, removing, and changing functionality modules, respectively, e.g., modular disassembly toolkit (Seliger et al., 1999).

<u>Extension of Product Life Span</u>

It is a strategy focusing on extending the time between cradle and grave of a product by expanding the use phase and realizing multiple use phases. The resource consumption for production and disposal of products shall be reduced with this strategy.

Extension of the product life span can be achieved, on the one hand, by expanding the use phase and, on the other hand, by the realization of multiple use phases. Maintenance and modification are means of expanding the use phase of a product. A balanced strategy of preventive maintenance preserves or increases the residual value of a product (Seliger, 2000). Modification is the adaptation of a product during the use phase due to changed functional requirements. Kinds of adaptation are up- and downgrading, enlargement and reduction as well as rearrangement and modernization. Modification and adaptation require disassembly and reassembly processes (Müller, 2001). Additional processes are cleaning, testing, component supply and removal. Multiple use phases are realized by remanufacturing and adaptation. Nasr defines remanufacturing as reviving a product to a like-new condition in terms of performance and durability by disassembling, cleaning, inspecting, repairing, replacing, and reassembling the components of a product (Nasr, 2004). Adaptation processes are applied to react on changed functional requirements of the next use phase in the respective market. Requirements to products for this strategy are modularity, integrability, customization, convertibility, and diagnosability supporting efficient processes of preventive maintenance and modification as well as remanufacturing and adaptation. (Seliger 2008)

2.1.5 Sustainable Supply Chain

During the last two decades, the focus on optimizing operations has moved from a specific facility or organization to the entire supply chain. By optimizing along the entire sequence of steps that are involved in the production of a product whether it is a good or service, the greatest value can be produced at the lowest possible cost. (Handfield and Nichols, 1999). In many cases, this approach requires organizations to operate sub-optimally from a cost perspective to create the greatest possible value along the entire supply chain (Leenders and Blenkhorn, 1988). A focus on supply chains is a step towards the broader adoption and development of sustainability, since the supply chain considers the product from initial processing of raw materials to delivery to the customer. However, sustainability also must integrate issues and flows that extend beyond the core of supply chain management: product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life. (Linton, J; Klassen, R; Jayaraman, V. (2007))

Manufacturing by-products:

Consideration of the extended supply chain includes the reduction and elimination of by-products through cleaner process technologies (Kemp, 1994; Johansson, 1992) and quality and lean production techniques (Zink, 2005; Zhu and Sarkis, 2004; King and Lennox, 2001). From the industrial ecology literature and increasingly considered by Manufacturers is the use of by-products of manufacturing such as the use of waste heat for conditioning space or the use of food waste for producing new food products (Frosch and Gallopoulos, 1989). This is a function of both process design and continuous improvement activities. (Linton, J; Klassen, R; Jayaraman, V. (2007))

By-products produced during product use:

The management of product sustainability is not only a function of design, but also product management. The potential for great opportunities and profit have been recognized by many who have called for extended producer involvement and responsibility. This involvement has appeared in calls for the provision of a product as a service (Michaelis and Coates, 1994) or for manufacturers to provide a series of services to support and supplement sale of the original product (Wise and Baumgartner, 1999 and Linton, J; Klassen, R; Jayaraman, V. (2007))

Product life extension:

There are a variety of techniques that are used to extend the life of products (Linton and Jayaraman, 2005). Through the extension of product life, the depletion of resources through the production of new product is avoided. This approach works against the design for obsolescence typical in a consumption-oriented society. However, it increases the value created by an individual product. The challenge for the provider of the product is to develop offerings that allow for them to capture more of the product value. Such approaches are discussed by the authors of work relating to by-products produced during product use above. While some manufacturers have capitalized on opportunities created by product life extension (examples include: Woellert, 2006; Guide et al., 2003; Linton and Johnston, 2000), the failure of Original Equipment Manufacturers to capitalize on opportunities has led to vibrant highly profitable businesses in such areas as remanufacturing (Arndt, 2005; Lund, 1982, 1984).

Product end-of-life:

The disposition of the product at the end of its life relies to a great extent on actions taken at earlier stages. The initial product design has great influence on the degree to which a product can be reused, remanufactured, recycled, incinerated or disposed of. For example, the high lead content in cathode ray tube and electronics products results in complications for disposal due to the toxicity of lead. In the case of electronics, phase-out of lead use in solders in process (Liew et al., 2006) complicated disposal decisions. Policies that have been developed with the intent of producing more environmentally favorable modes of product end-of-life disposal have to-date resulted in more storage of product and less redeployment of parts and materials into new products than intended (Shih, 2001; Micklitz, 1992). Desired outcomes not only require changes in the process associated with the development of environmental policies, regulations, incentives and disincentives; but also the related operational aspects: forecasting, logistics, processing and other operations related functions. To date substantial research has focused on the capture of value remaining in products at the end of a products life through remanufacturing (Guide and van Wassenhove, 2003; Guide et al., 2000; Guide, 2000; Gungor and Gupta, 1999; Fleischmann et al., 1997).

Recovery processes at the end-of-life:

The recovery of used products has become a field of rapidly growing importance. A number of papers have been published on design considerations for product recovery networks (Thierry et al., 1995; Bloemhof-Ruwaard et al., 1999; Fleischmann et al., 2000; Jayaraman et al, 2003; Dekker et al, 2004; Flapper et al, 2005). A number of studies have found that an increased emphasis on sustainability in the supply chain is related to lower costs and a neutral or positive effect on value (e.g., Rao and Holt, 2005; Florida, 1996). However, others have identified trade-offs between what is economically rational for supply chain members and what is of greatest value to the entire system or population (Walley and Whitehead, 1994). Extending the supply chain to include issues such as remanufacturing, recycling and refurbishing adds an additional level of complexity to existing supply chain design in addition to a new set of potential strategic and operational issues, which in turn can increase costs, at least in the short term. Two basic problems gives rise to these issues: (a) the uncertainty associated with the recovery process with regards to quality, quantity, and timing of returned products, containers, pallets and packaging and (b) the collection and transportation of these products, containers, pallets and packaging. Increased costs can reflect the transfer of external costs from society to supply chain partners. If viewed broadly, sustainability opens a larger set of opportunities for improvement that may require short-term investment (Corbett and Klassen, 2006).

2.1.6 Methods and Tools for sustainability

(The main source for this part is Choi, J-K; Stuart, J-A; Ramani, K. (2003))

2.1.6.1 Life Cycle Thinking:

If the environmental concerns are broadened to include solid waste, materials and energy consumption, then traditional waste minimization approaches are too limited in scope. Additional conceptual frameworks and paradigms are needed. Life cycle thinking is a circular process that begins and ends with the use of raw materials in the most efficient way. Its approach is aimed at reducing the adverse environmental impact of a product throughout its existence from raw material to end of life (Fava 1993). Life cycle thinking forms the basis of a company's environmental activities. The goal is to reduce adverse environmental effects during the product life cycles by managing their own operations and supplier network and by incorporating Design for Environment principles into every stage. Design for Environment may embrace design, the environmental performance of their suppliers, decision-making within the company itself and responsible end-of-life practices. (Calcott, Walls 2000)(Ishii 1998) (Rose, Beiter et.al 1998)

2.1.6.2 Life Cycle Management (LCM):

Life Cycle Management (LCM) is a business toolbox involving product- and firm-based decision-making (Rowledge et al. 1999). It is complementary to existing management structures at the finance-technology environment interface. LCM aims at integrating environmental concerns into industrial and business operations by considering off-site, or supply chain, impacts and costs by quantifiable indicators. LCM seeks to increase the competitiveness between new and existing products by examining advantages and reduce business risks associated with the environmental and social aspects of a product throughout its life cycle (Kimura 1999). Therefore, LCM can be seen as a means of putting sustainable development to work within a firm, given its temporal and financial constraints (Hunkeler and Rebitzer 2001). LCM has been defined many different ways. In general, it is seen to consist of the integration of life cycle concepts "life cycle thinking" with other information systems and metrics for management decision-making in firms (Norris and Segal 2002). Life Cycle Management (LCM) is the application of life cycle thinking to modern business practice, with the aim to manage the total life cycle of an organization's product and services toward more sustainable consumption and production (Jensen and Remmen 2004). It is an integrated framework of concepts and techniques to address environmental, economic, technological, and social aspects of products, services, and organizations. LCM, as any other management pattern, is applied on a voluntary basis and can be adapted to the specific needs and characteristics of individual or organizations (SETAC 2004).

2.1.6.3 Eco-Efficiency:

In recent years a number of efforts to systematically address environmental effects of industrial processes and products have emerged under headings such as industrial ecology, cyclic economy, and sustainable production. These activities aim to improve materials use efficiency, close materials cycles, rely on inherently more benign substances and production methods, and reduce pollution over the entire life-cycle of a product or unit of service. Their goals are to avoid the shift of pollution from one environmental compartment to another, from one pollutant to another, from one place to another, or from this generation to the next.

Eco-efficiency promises to achieve a less polluted environment at lower costs than pollution control and ensure human well-being with less detrimental effects than adaptation and remediation (Hertwich 1997). **Pollution Prevention (P2)** and **cleaner technology (CT)** are examples of Eco-Efficiency. P2 focuses on process optimization, input substitution and better housekeeping measures. However, CT aims to develop new technologies that replace existing polluting technologies. Technological solutions have been prominent throughout environmental protection. The attempt to develop inherently clean technologies, in contrast to "end of pipe" technologies, has been called no-waste, cleaner, or environmentally responsive technologies, cleaner production, and zero-waste management (Hertwich 1997).

- **Pollution Prevention (P2)**: P2 focuses on reducing pollution from existing plants and processes. "Design for Environment" and "Cleaner Technology" are sometimes subsumed under pollution prevention; The US Federal Pollution Prevention Act of 1990 specifically lists seven source reduction practices which are provided in Table 5. Governments, consultants and the new ISO 14000 environmental management standards promote environmental auditing as a means of identifying pollution prevention opportunities. In addition, pollution prevention offices often promote the adoption of cleaner technologies that have moved into the commercialization stage or inform clients about technologies and practices that have been successfully implemented somewhere else. Seven source reduction practices in P2 are as follow:
  - Equipment modernization & modification
  - Improved maintenance
  - Improved operation practices
  - Inventory control
  - Process and product modification
  - Substitution of inputs
  - In-process recycling
- **Cleaner Technology (CT)**:

  Cleaner technology for product development ranges from manufacturing technology of near-net shape manufacturing of parts to the technologies for the utilization of renewable resources. Cleaner Technology is a manufacturing process which by its nature or intrinsically reduces effluent and other waste production, maximizes product quality, maximizes raw materials and energy. Thus one technology is usually compared to some other technology or process. Cleaner Technology may be thought of as a subset of Cleaner Production activities with a focus on the actual manufacturing process itself and considers the integration of better production systems to minimize environmental harm and maximize production efficiency from many or all inputs (Denmark Ministry of the Environment 1992). Production managers and other industry decision makers are often concerned with decisions regarding conflicting technology choices. In principle, choices should be made while considering the environment among the many other competing issues so as to select the cleanest technology, all other options being equivalent. Unfortunately in reality, choices are not so simple and a range of conflicting parameters may make selection of the most environmentally preferable option difficult (Ryding, Steen et al. 1993).

2.1.6.4 Design for Environment (DFE):

DFE improves the design of the product from an environmental perspective. You can see more information about it in the section 2.1.2 "Sustainable Design".

2.1.6.5 Extended Product Responsibility (EPR):

EPR is an emerging principle for a new generation of pollution prevention policies that focus on product systems instead of production facilities. The principle of Extended Product Responsibility relies for its implementation upon the life-cycle concept to identify opportunities to prevent pollution and reduce resource and energy use in each stage of the product life cycle (or product chain) through changes in product design and process technology (Stoughton, Shapiro et al. 1999). EPR is the principle that the actors along the product chain share responsibility for the life-cycle environmental impacts of the whole product system, including upstream impacts inherent in the selection of materials for the products, impacts from the manufacturer's production process itself, and downstream impacts from the use and disposal of the products. The greater the ability of the actor to influence the life-cycle impacts of the product system, the greater the degree of responsibility for addressing those impacts. Producers, for instance, accept their responsibility when they design their products to minimize the life-cycle environmental impacts and when they accept their share of the physical or economic responsibility for the environmental impacts that cannot be eliminated by design (Tojo 2001). The term EPR has gained greater acceptance in the United States because it implies shared responsibilities in the product chain, although often the producer is in the best position, both technically and economically, to influence the rest of the product chain in reducing life-cycle environmental impacts. There are three key attributes of EPR (Davis, Wilt et al. 1997):

- The extension or shifting of responsibility to a life-cycle stage or stages where responsibility currently does not exist or is not well-defined
- A product systems approach with a focus on creating feedback to product designers to design cleaner products

- Sharing of responsibility for the life-cycle environmental impacts of the product system among links in the product chain in such a way that there is a well-defined locus of responsibility, which may include more than one link.

2.1.6.6 End of Life (Eol) Management :

It describes the approach or method associated with dealing with the product at the end-of-life. End-of-Life treatment includes the activities associated with recovering value from the product, through manual labor and/or machinery. The EoL system includes the activities associated with strategic planning and implementation ranging from the collection of products, treatment of those products and the associated impacts to society and environment (Rose, Beiter et al. 1999)(Ishii, K 1999). The following defines end-of-life strategies based on the work of (Ishii 1995; Nilsson and Bjorkman 1999):

- **Reuse**: is the second hand trading of product for use as originally designed.
- **Service**: Servicing the product is another way of extending the life of a durable product or component parts by repairing or rebuilding the product using service parts at the location where the product is being used.
- **Remanufacture**: Remanufacturing is a process in which reasonably large quantities of similar products are brought into a central facility and disassembled. Parts from a specific product are not kept with the product but instead they are collected by part type, cleaned, inspected for possible repair and reuse. Remanufactured products are then reassembled on an assembly line using those recovered parts and new parts where necessary.
- **Recycling with disassembly**: Recycling reclaims material streams useful for application in products. Disassembly into material fractions increases the value of the materials recycled by removing material contaminants, hazardous materials, or high value components. The components are separated mostly by manual disassembly methods.
- **Recycling w/o disassembly**: The purpose of shredding is to reduce material size to facilitate sorting. The shredded material is separated using methods based on magnetic, density or other properties of the materials.
- **Disposal:** This end-of-life strategy is to landfill or incinerate the product with or without energy recovery

2.1.6.7 Life cycle assessment (LCA)

(The reference is Scientific applications international Corporation (SAIC), (2006) Life Cycle Assessment: Principals and Practices. EPA/600/R-06/060)

Life cycle assessment is a "cradle-to-grave" approach for assessing industrial systems. "Cradle-to-grave" begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. LCA evaluates all stages of a product's life from the perspective that they are interdependent, meaning that one operation leads to the next. LCA enables the estimation of the cumulative environmental impacts resulting from all stages in the product life cycle, often including impacts not considered in more traditional analyses (e.g., raw material extraction, material transportation, ultimate product disposal, etc.). By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection.

The term "life cycle" refers to the major activities in the course of the product's life-span from its manufacture, use, and maintenance, to its final disposal, including the raw material acquisition required to manufacture the product. Figure 2-4 illustrates the possible life cycle stages that can be considered in an LCA and the typical inputs/outputs measured.

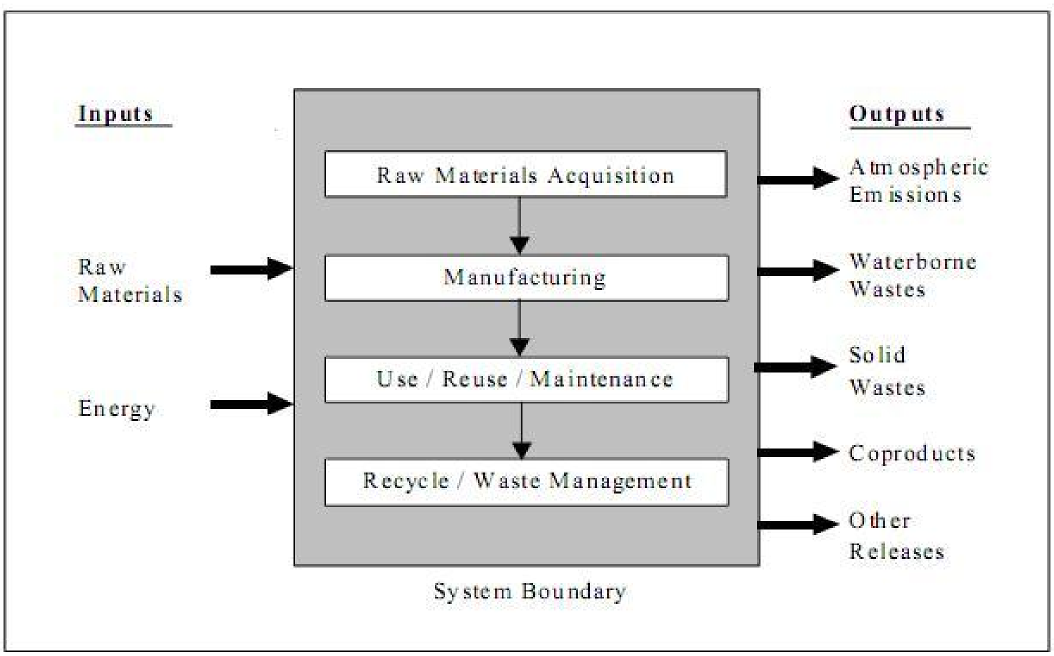

Figure 2-4 Life Cycle Stage (Source: EPA,1993)

Specifically, LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service.

LCA Components:

The LCA process is a systematic, phased approach and consists of four components: goal definition and scoping, inventory analysis, impact assessment, and interpretation.

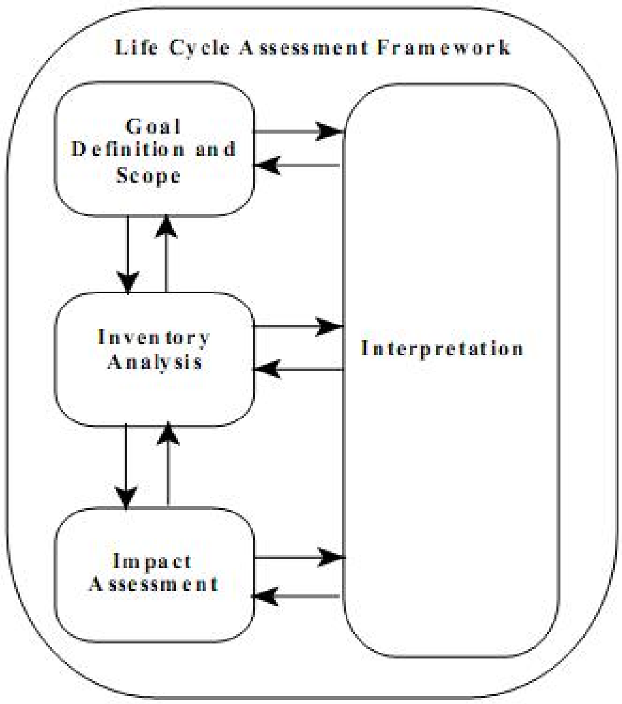

Figure 2-5 Components of an LCA

1. **Goal Definition and Scoping:**

   Define and describe the product, process or activity. Establish the context in which the assessment is to be made and identify the boundaries and environmental effects to be reviewed for the assessment. The following 6 basic decisions should be made at the beginning of the LCA process to make effective use of time and resources:

   1.1. Define the Goal(s) of the Project

   LCA is a versatile tool for quantifying the overall (cradle-to-grave) environmental impacts from a product, process, or service. The primary goal is to choose the best product, process, or service with the least effect on human health and the environment. Conducting an LCA also can help guide the development of new products, processes, or activities toward a net reduction of resource requirements and emissions. There may also be secondary goals for performing an LCA, which would vary depending on the type of project. (e.g., stablish bseline information or a process, Rank the relative contribution of individual steps or processes & Identify data gaps)

1.2. Determine What Type of Information Is Needed to Inform the Decision-Makers

Identifying the questions that the decision makers care about will help define the study parameters. Some examples include:

- What is the impact to particular interested parties and stakeholders?
- Which product or process causes the least environmental impact (quantifiably) overall or in each stage of its life cycle?
- How will changes to the current product/process affect the environmental impacts across all life cycle stages?
- Which technology or process causes the least amount of acid rain, smog formation, or damage to local trees (or any other impact category of concern)?
- How can the process be changed to reduce a specific environmental impact of concern (e.g., global warming)?

Once the appropriate questions are identified, it is important to determine the types of information needed to answer the questions.

1.3. Determine the Required Specificity

At the outset of every study, the level of specificity must be decided. In some cases, this level will be obvious from the application or intended use of the information. In other instances, there may be several options to choose from, ranging from a completely generic study to one that is product-specific in every detail. Most studies fall somewhere in between.

1.4. Determine How the Data Should Be Organized and the Results Displayed

LCA practitioners define how data should be organized in terms of a *functional unit* that appropriately describes the function of the product or process being studied. Careful selection of the functional unit to measure and display the LCA results will improve the accuracy of the study and the usefulness of the results.

1.5. Define the Scope of the Study

LCA includes all four stages of a product or process life cycle: raw material acquisition, manufacturing, use/reuse/maintenance, and recycle/waste management. To determine whether one or all of the stages should be included in the scope of the LCA, the following must be assessed: the goal of the study, the required accuracy of the results, and the available time and resources

1.6. Determine the Ground Rules for Performing the Work

Prior to moving on to the inventory analysis phase it is important to define some of the logistical procedures for the project which includes:

- Documenting Assumptions
- Quality Assurance Procedures
- Reporting Requirements

2. Inventory Analysis:

A life cycle inventory (LCI) is a process of quantifying energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases for the entire life cycle of a product, process, or activity.

In the life cycle inventory phase of an LCA, all relevant data is collected and organized. Without an LCI, no basis exists to evaluate comparative environmental impacts or potential improvements. The level of accuracy and detail of the data collected is reflected throughout the remainder of the LCA process. Key Steps of a Life Cycle Inventory are as follow:

2.1. Develop a flow diagram of the processes being evaluated.

A flow diagram is a tool to map the inputs and outputs to a process or system. The "system" or "system boundary" varies for every LCA project. The goal definition and scoping phase establishes initial boundaries that define what are to be included in a particular LCA; these are used as the system boundary for the flow diagram.

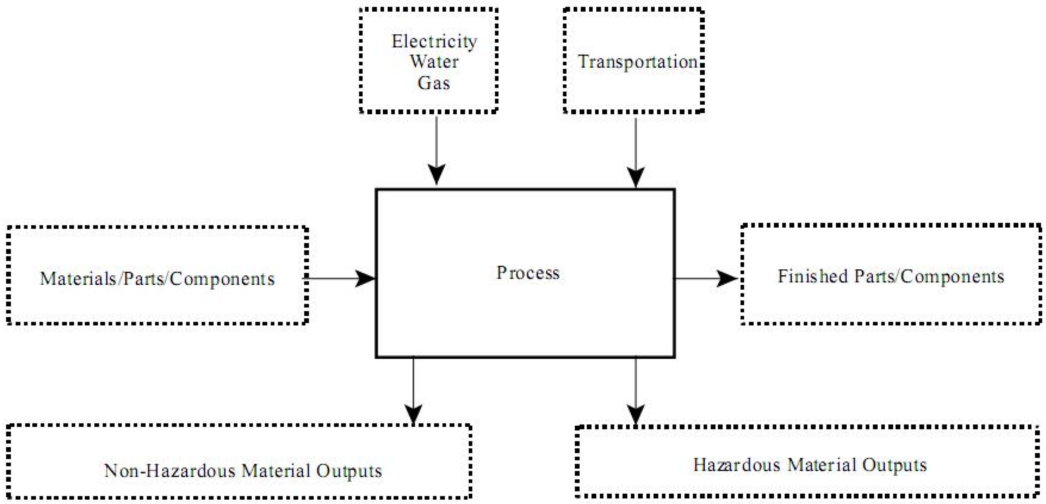

Figure 2-6 flow diagram of process with input/output

The more complex the flow diagram, the greater the accuracy and utility of the results. Unfortunately, increased complexity also means more time and resources must be devoted to this step, as well as the data collecting and analyzing steps.

2.2. Develop a data collection plan.

As part of the goal definition and scoping phase, the required accuracy of data was determined. When selecting sources for data to complete the life cycle inventory, an LCI data collection plan ensures that the quality and accuracy of data meet the expectations of the decision-makers. Key elements of a data collection plan include the following:

- Defining data quality goals
- Identifying data sources and types
- Identifying data quality indicators
- Developing a data collection worksheet and checklist.

2.3. Collect data.

Data collection efforts involve a combination of research, site-visits and direct contact with experts, which generates large quantities of data. As an alternative, it may be more cost effective to buy a commercially available LCA software package Prior to purchasing an LCA software package the decision-makers or LCA practitioner should insure that it will provide the level of data analysis required. A second method to reduce data collection time and resources is to obtain non-site specific inventory data. Several organizations have developed databases specifically for LCA that contain some of the basic data commonly needed in constructing a life cycle inventory. Some of the databases are sold in conjunction with LCI data collection software; others are stand-alone resources

2.4. Evaluate and report results.

When writing a report to present the final results of the life-cycle inventory, it is important to thoroughly describe the methodology used in the analysis. The report should explicitly define the systems analyzed and the boundaries that were set. All assumptions made in performing the inventory should be clearly explained. The basis for comparison among systems should be given, and any equivalent usage ratios that were used should be explained. Life-cycle inventory studies generate a great deal of information, often of a disparate nature. The analyst needs to select a presentation format and content that are consistent with the purpose of the study and that do not arbitrarily simplify the information solely for the sake of presenting it. In thinking about presentation of the results, it is useful to identify the various perspectives embodied in life-cycle inventory information. These dimensions include, but may not be limited to, the following:

- Overall product system
- Relative contribution of stages to the overall system
- Relative contribution of product components to the overall system
- Data categories within and across stages, e.g., resource use, energy consumption, and environmental releases
- Data parameter groups within a category, e.g., air emissions, waterborne wastes, and solid waste types
- Data parameters within a group, e.g., sulfur oxides, carbon dioxide, chlorine, etc.
- Geographic regionalization if relevant to the study, e.g., national versus global
- Temporal changes.

The life-cycle analyst must select among these dimensions and develop a presentation format that increases comprehension of the findings without oversimplifying them

3. Impact Assessment:

The Life Cycle Impact Assessment (LCIA) phase of an LCA is the evaluation of potential human health and environmental impacts of the environmental resources and releases identified during the LCI. Impact assessment should address ecological and human health effects; it should also address resource depletion. A life cycle impact assessment attempts to establish a linkage between the product or process and its potential environmental impacts. The following steps comprise a life cycle impact assessment:

3.1. Selection and Definition of Impact Categories - identifying relevant environmental impact categories (e.g., global warming, acidification, terrestrial toxicity).

3.2. ***Classification*** - assigning LCI results to the impact categories (e.g., classifying carbon dioxide emissions to global warming).

3.3. ***Characterization*** - modeling LCI impacts within impact categories using science-based conversion factors (e.g., modeling the potential impact of carbon dioxide and methane on global warming).

3.4. ***Normalization*** - expressing potential impacts in ways that can be compared (e.g. comparing the global warming impact of carbon dioxide and methane for the two options).

3.5. ***Grouping*** - sorting or ranking the indicators (e.g. sorting the indicators by location: local, regional, and global).

3.6. ***Weighting*** - emphasizing the most important potential impacts.

3.7. ***Evaluating and Reporting LCIA Results*** - gaining a better understanding of the reliability of the LCIA results.

4. Interpretation

Life cycle interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the LCI and the LCIA, and communicate them effectively. Life cycle interpretation is the last phase of the LCA process. ISO has defined the following two objectives of life cycle interpretation:

4.1. *Analyze* results, reach conclusions, explain limitations, and provide recommendations based on the findings of the preceding phases of the LCA, and to report the results of the life cycle interpretation in a transparent manner.

4.2. Provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study. (ISO 1998b)

Benefits of Conducting LCA

An LCA can help decision-makers select the product or process that result in the least impact to the environment. This information can be used with other factors, such as cost and performance data to select a product or process. LCA data identifies the transfer of environmental impacts from one media to another (e.g., eliminating air emissions by creating a wastewater effluent instead) and/or from one life cycle stage to another (e.g., from use and reuse of the product to the raw material acquisition phase). If an LCA were not performed, the transfer might not be recognized and properly included in the analysis because it is outside of the typical scope or focus of product selection processes.

This ability to track and document shifts in environmental impacts can help decision makers and managers fully characterize the environmental trade-offs associated with product or process alternatives.

Limitations of conducting LCA

Performing an LCA can be resource and time intensive. Depending upon how thorough an LCA the user wishes to conduct, gathering the data can be problematic, and the availability of data can greatly impact the accuracy of the final results. Therefore, it is important to weigh the availability of data, the time necessary to conduct the study, and the financial resources required against the projected benefits of the LCA. LCA will not determine which product or process is the most cost effective or works the best. Therefore, the information developed in an LCA study should be used as one component of a more comprehensive decision process assessing the trade-offs with cost and performance, e.g., Life Cycle Management.

2.1.6.8 Material Input per Service unit (MIPS):

The MIPS concept is a life cycle tool for analyzing material inputs per service unit and it is the measurement for material and energy intensity from processes, products, infrastructure and services in our economical system. This concept uses a resource indicator to measure the environmental performance of a cradle-to-grave business activity. Calculations are made per unit of delivered “service” or function in the product during its entire life cycle -- manufacturing, transport, package, use, reuse, recycling, new manufacturing from recycled material, and final disposal as waste. By calculating material and energy flows and the number of products produced, it is possible to calculate the material intensity related to the function of a particular product (Ryan 2000). The whole material and energy input are indicated in kilogram or ton, measured from raw material extraction process from the environment until disposal of waste material to the environment. Thereby a picture of the environmental performance related to that product is achieved. The concept is based on the philosophy that a better utilization of materials and resources is needed to achieve sustainable development. Using this concept, one may analyze the entire working process including all inserted natural resources, material and energy in the process to produce a desired product or service (Spangenberg, Hinterberger et al. 1999).Thus, MIPS is a benchmark in the best tradition of economical principles to achieve a certain result with a minimum input (dematerialization) and to reach a maximum result with a certain input (resource productivity)(Cahyandito 2001). M.J. Welfens from the Wuppertal Institute for Climate, Environment and Energy in Germany has developed strategies to practice dematerialization. Strategies for dematerialization mean that resources are used in a more efficient way (Welfens 2000). From the technical perspective, the use of the MIPS concept has the following advantages and disadvantages. (Choi, J-K; Stuart, J-A; Ramani, K. (2003))

Advantages of MIPS:

- Material and energy expenditures are measured in the same units. In doing so, contradictions in the ecological evaluations are avoided, and the evaluation becomes directionally stable.
- The MIPS Concept helps in the design of industrial products, in the planning of environmentally-friendly processes, facilities and infrastructures, as well as in the ecological assessment of services.
- The MIPS Concept can serve as the basis for a comprehensive ecological labeling strategy, and can be an aid in purchasing decisions and customer counseling.

Disadvantages of MIPS:

- The MIPS Concept does not take into account the specific “surface-use” for industrial as well as for agricultural and forestry activities. This is of considerable importance as the amount of the earth’s surface available for our purposes is limited.
- The MIPS Concept does not take into account the specific environmental toxicity of material flows. The approach is not intended to supplant the quantification of Eco-toxicological dangers of materials in environmental policy, but rather to supplement it by stressing the material and energy intensity of economic services.
- The MIPS Concept makes no direct reference to questions of biodiversity. It seems fair to speculate that the chances for species survival are related to the intensity of soil and resource use. Therefore we cannot exclude the notion that the material intensity of a society’s economy has something to do with its contribution to species extinction.

Using this assessment methodology a comparison between alternatives is possible for products and services providing the same benefit, because the material input is related with the service gained. Therefore, MIPS is a useful tool either for enterprises resource management, policies evaluation, or product certification and eco-efficiency signaling. Five or six different categories of material input are considered: abiotic (or nonrenewable resources like mineral row materials, fossil energy carriers, soil excavations), biotic (or renewable resources from agriculture and silviculture) earth movement in agriculture and silviculture (mechanical earth movement or erosion), water (surface, ground and deep ground water) and air (the quantity of oxygen combusted that reflect the amount of carbon dioxide formed); also erosion can be calculated separately.

The core of MIPS calculation lays on MI factors. They are the ratio between the quantity (in mass units) of resources used and the quantity (mass) of product obtained. Many MI factors of materials and “modules” (electricity, transport, etc.) have been calculated and are published by Wuppertal Institute. It makes MIPS calculation easier, because not every pre-process-chain needs to be recalculated by each user. In the interpretation of MIPS results water and air categories have to be examined separately, taking into account the different uses (processing or cooling water, combusted or transformed air, i.e.). The “earth movement in agriculture and silviculture” category is often counted out from the interpretation as the available documentation is still inadequate and just “erosion”, which is encompassed in this category, is considered.

2.1.6.9 Material Flow Accounting/ Substance Flow Analysis (MFA/SFA):

Under the notion of sustainability, the focus moved from the output side of the production system to a complete understanding of the physical dimension of the economy. From this point, the economy was conceptualized as an activity, extracting materials from nature, transforming them, keeping them as society’s stock for a certain amount of time and, in the end of the production consumption chain, disposing of them again in nature. It has been recognized that environmental problems can arise at every step in this process. Under the heading of Material Flow Accounting (MFA), empirical research has been stimulated by this new conceptualization of society’s environmental problem (Fischer-kowalski and Haberl 1993; Fischer-kowalski, W.Bruckner et al. 1999) (Ayres and Simonis 1997). The aim of MFA is to draw a complete picture of the physical dimension of the social system by capturing all material flows driven by these system activities. The total amount and the progress through the economy of these materials are ideally reported within an accounting framework provided by MFA methodology. Most influential empirical work has been done on economy-wide MFA concentrating on bulk material flow analysis. Within Material Flow Analysis, there are two approaches, material flow accounting (MFA) concentrating on material and Substance flow accounting (SFA) concentrating on chemical substances like carbon, nitrogen, lead, chlorine and so on. Despite these differences, both approaches result in rather similar methodological assumptions. Moreover, due to methodological correspondence, MFA can be linked to SFA rather easily. One basic idea of MFA should be the attempt to reach a full balance integrating the input and the output sides. This idea of a mass balance is one of the most powerful features of the MFA approach. In terms of policy, this approach allows for the development of integrated resource and waste/emission strategies. Balancing is also a methodological tool, as it provides a framework for consistency checks and estimation of data gap. For material balances the first law of thermodynamics, the “law of conservation of mass” applies, which is also a leading theoretical criteria for material accounting. The law of conservation of mass attributed to MFA results in the following equation:

The sum of material inputs into a system = the sum of outputs corrected by changes in stocks

This equation applies not only to the system as a whole but also to all its sub-systems to which we refer as components of the system (Schandl and Schulze 1997).

2.1.6.10 Check Lists (CL):

Check-lists are qualitative tools that give guidance to design, environmental management, and setting eco-labeling criteria. CL used for a particular purpose, such as check lists for design, may be general or customized for a specific sector or company. CL considers various different aspects such as recyclability or minimizing harmful substances (Behrendt, Jasch et al. 1997).

2.1.6.11 Life Cycle Costing (LCC):

A company cannot afford to make product design decisions on strictly an LCA basis, without regard to economics and product performance. For an economic assessment, a decision maker has to address all the costs and benefits for which actors and participants in a product's life-cycle are accountable. This investigation of economic impact is called Life-Cycle Costing. Basically, LCC is an assessment of the costs in each stage of the life-cycle of a product. The different cost factors (such as capital, labor, material, energy, and disposal) are investigated on the basis of current and/or future costs. LCC and LCA have major methodological differences despite the similarity of their names. LCA evaluates the relative environmental performance of alternative product systems for meeting the same end-use function from a broad, societal perspective. However, LCC evaluates the relative cost-effectiveness of alternative investments and business decisions, which is related to the usage phase in LCA, from the perspective of an economic decision maker such as a manufacturing firm or a consumer (Choi and Ramani 2003). Even if LCA and LCC are extensive methods in accessing environmental and economic respectively, each method has some limitations and absences of important concepts for the application in real business situation.

2.1.6.12 Total Cost Accounting (TCA):

Total Cost Accounting (TCA) was introduced in the late 1980s with the introduction of clean production. The method typically focuses on in-company assessments of cleaner production investments. TCA can be described as a normal, long-term oriented cost accounting method, which pays special attention to hidden, less tangible, and liability costs. Liability costs are fines due to liability for items such as future clean-up, health care and property damage. Less tangible costs are consumer acceptance, corporate image and external relations. The TCA method also focuses on the risks and hidden costs associated with a product or activity.

In this method, also the economic benefits of pollution control measures are included, whereas in conventional accounting only the costs of pollution prevention would be taken into account. This inclusion of positive trade-offs clearly indicates life cycle thinking. The term "life cycle", however, is often defined in another way in the economic sciences, namely as the sequence product development - production - marketing/sale - end of economic product live (Norris and Segal 2002), this economic "life cycle" may be even shorter in some products than the physical life cycle ("cradle-to-grave") used in LCA. In a further step, even the external costs due to environmental damages connected with the products may be included. These costs are not incurred to the company, but rather to society or even to future generations. Since damages connected to the interventions caused by a product system is not clear, the quantification of these costs is difficult.

2.1.6.13 Cost Benefit Analysis (CBA):

Cost-benefit analysis is an economic tool for supporting decisions on larger investments from a social point of view. Its domain of application includes regulatory and technology choices. It has been developed as a tool to remediate a number of shortcomings of a purely market oriented analysis of costs and benefits. CBA repairs some of the deficiencies cause by the market imperfections such as external effects and collective goods which are not expressed in market prices. For example, costs of emissions collection versus costs of emission damages (Boardman 2001). The main focus in the development of cost-benefit analysis is on how to evaluate unpriced effects. As in market choices, individual's preferences can be expressed in monetary terms. The overall evaluation then is in one single category: money, providing a comparable yardstick for the decision maker (Hanley and Spash 1993).

2.1.6.14 Economic Input/output (EIO) Analysis:

Production of most typical products and materials requires a large number of diverse inputs, which in turn use many other inputs in their production. Often there are interdependencies in inputs, which have to be modeled. Attempting to trace all the direct and indirect inputs and associated environmental burdens all the way to ultimate raw material extraction becomes unpractical. In order to keep the analysis tractable, most LCAs limit the scope of analysis only to the major inputs at each stage, leading to problems of subjective boundary definition and comparability across studies. Moreover, data on input requirements and emissions for even such truncated LCAs have to be collected from a large number of different suppliers leading to high cost, time, and issues of data confidentiality and verifiability. To address the problem of subjective boundary definition in conventional LCA, Economic input-output life-cycle assessment (EIO-LCA) has been introduced by Lave (Lave, L et al. 1995). EIO-LCA takes a top-down approach and treats the whole economy as the boundary of analysis. Other Strength of EIO-LCA approach is that economy-wide interdependencies in inputs are modeled as a set of linear simultaneous equations. EIO-LCA leads to a consistent boundary definition. However, it is still subject to several well-recognized limitations (Joshi 2000).

2.1.6.15 Eco-Labeling (EL):

Eco-labeling is a voluntary method of environmental performance certification and labeling that is practiced around the world. An "Eco-label" is a label which identifies overall environmental preference of a product or service within a specific product/service category based on life cycle considerations. An Eco-label is awarded by an impartial third-party in relation to certain products or services that are independently determined to meet environmental leadership criteria. Eco-labels are used to provide information about the environmental impact of a product. In environmental claims, it is important that verification is properly conducted (EU 1997).

2.1.7 Barriers to sustainibility

The major barriers to sustainability included organizational, labor force, and financial factor. Organizational and structural barriers reflect the inability or resistance of organization to change their systems.

Sustainability cost:

Min and Galle (2001) debated that sustainability requirement costs and investments is the main obstacle to sustainable purchasing programs. Customers/suppliers partnership in sustainable project and governmental loans can initiate many projects which in turn will be profitable. (Nikbakhsh, E; Farahani, R; Asgari, N; Davarzani, H. (2009))

Lack of sustainability awareness:

Although mentioned sustainability awareness as one of the initiatives of sustainability but there is still a huge lack of sustainability awareness (specially in non-developed and developing countries) which leads to other barriers such as lack of government involvement and participation, and lack of top-level management support to name a few. Therefore, it is every body's responsibility to promote sustainability, especially governments and final customers.

Technological barriers:

Lack of proper technologies which can lead companies to a sustainable strategy is one of the main barriers to sustainability. Breaking technological barriers can only be achieved via inter-organizational cooperation and investment from both governments and large influential companies.

Lack of sustainability information, knowledge and training:

By talking about lack of sustainability information we mostly mean environmental and social dimensions of sustainability in which there is a huge difference between knowledge and training in different parts of the world. This barrier can be resolved through environmental and social information databases, knowledge transfer networks and providing more training classes for government and organizations personnel.

2.2 E-Learning & Serious gaming

2.2.1 An introduction to E-Learning

E-Learning is the employment of technology to aid and enhance learning. It can be as simple as High School students watching a video documentary during a class or as complex as an entire university course provided online. e-Learning began decades ago with the introduction of televisions and over-head projectors in classrooms and has advanced to include interactive computer programmes, 3D simulations, video and telephone conferencing and real-time online discussion groups comprised of students from all over the world. As technology advances, so does e-learning making the possibilities endless (Dewath 2004).

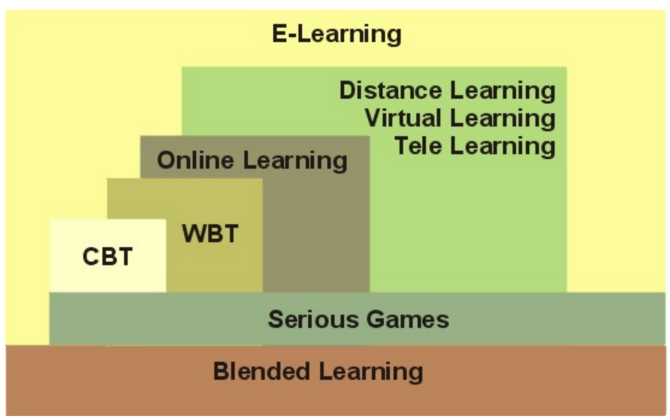

Figure 2-7: Methods of E-Learning

The methods of e-Learning can be further be classified into (Back et al 2001)

- Serious Games, which corresponds to digital games to support learning in a particular domain
- Distance Learning, Virtual Learning, Tele Learning, which includes e.g. correspondence courses and Sat-TV courses.
- Online Learning, which employs network based online resources (e.g. video communications) resulting in Tele Teaching, Tele Tutoring and Virtual Collaboration.
- Web-based Training (WBT)
- Computer-based Training (CBT)
- Blended Learning is the combination of traditional learning methods with e-Learning. Face to face and group tuition is still considered extremely important.

Educational Games can roughly be divided into computer based and traditional educational games. The computer based educational games can be seen as part of CBT and/or WBT depending on whether they make use of the web or not. This kind of view puts the view of using ICT to deliver the game, but there are also non computer based educational games on the market, which – per definition – do not belong to the e-Learning sector. Sometimes educational games are also called edutainment (this artificial word combines the terms education and entertainment). The main principle behind edutainment is the mediation of knowledge combining it with entertainment.

The economic, social and technological dynamics associated with the transition to the knowledge-driven economy continue to change the global economy, and established practices in organizations and the world. The knowledge within an organization is clearly evident in the products or/and services that are offered to the market. As depicted in Figure -8, knowledge drives innovation, but human capital is an essential resource that requires lifelong learning.

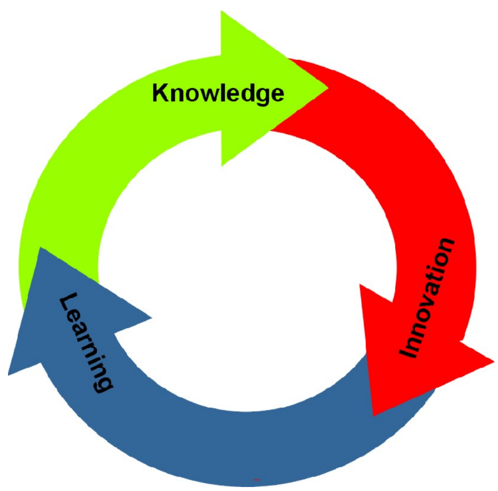

Figure 1-8 – Innovation cycle

The essence of the “core competence” argument is that an organization needs to invest in their knowledge resources. As a result, there is a growing need for continuous education and training. The movement to lifelong learning and the changing demographic balances in most advanced economies mean that the demand for higher education, especially professionally related course and non-traditional delivery modes, is increasing. However, while demand is growing, the capacity of the public sector to satisfy the demand is being challenged. This is due to budget limitations, the changing role of government, and increased emphasis on market economy and privatization.

At the same time, innovations in ICT are providing alternative and virtual ways to facilitate learning. New types of providers such as corporate universities, for profit educational specialist institutions, consultancy firms, and media companies are emerging. This scenario is changing further by providers – public and private, new and traditional – delivering education services across national borders to meet training and education needs in other countries. Alternative types of cross border program delivery such as branch campuses, franchise and twinning arrangements are being developed. As a consequence, the emerging picture of higher education and training provision is becoming increasingly complex, making decisions on the part of public authorities and organizations more complicated.(Knight, 2002) (the main reference in this section is State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.2 The strategic importance of e-learning

The transformations associated with the transition to the knowledge-driven economy have increased the strategic importance of the intangible assets of organizations, especially their organizational learning capabilities. In this context e-learning has emerged as a strategic issue for organizations because of its potential to enhance their learning abilities. The concept of the learning organization (Marsick and Watkins, 1993, Nonaka and Takeuchi, 1995) has grown exponentially in the context of the transition to the new knowledge-driven economy. Today, corporate learning and the learning organization have ascended to a position of strategic prominence in the context of managing and growing an enterprise (Mcrea, Gay and Bacon, 2000). Urdan and Weggen (2000) have identified the knowledge-based economy, the paradigm shift in the way education is viewed and delivered, and the huge knowledge gaps in the operation of organizations as key conditions that act as the main drivers of e-learning among organizations.

The increase in complexity and velocity of the work environment brought about by technological and economic changes are also major forces that have fuelled the demand for e-learning. The shift from the industrial to the knowledge-driven era, rapid technological change, the ever shortening product developmental cycles, lack of skilled personnel, enterprise resource planning, the migration towards value chain integration and the extended enterprise are also prominent drivers of e-learning (Mcrea, Gay and Bacon, 2000). The emerging economic and business competitive environment requires companies to work together to create online networks of customers, suppliers, and value-added processes – that is, an e-business community (EBC) (Ticoll, Lowy and Kalakota, 1998, Castells, 2000).

The trends discussed above have given rise to several business issues that need to be addressed if companies are to retain their competitive edge. Research indicates that ICT-enhanced and supported business strategies must be anchored on the following forces: First, the redefinition of value must be addressed because wealth creation, communication, commerce and distribution converge on common digital, networked platforms. Industry boundaries blur, causing providers to rethink the composition of value creation processes. Second, digital knowledge economics must be understood well because hoarding knowledge is proving to be counterproductive. In the digital economy knowledge must be shared. Third, information technology is driving change everywhere. Thus, every executive, in every industry, must embrace the pace and dynamics ICT. Fourth, jobs, business processes, companies, and even entire industries face elimination or digital transformation. This means that customers will be gaining both tangible (quality and cost) and intangible benefits (information, control, relationships) while they contribute ever more value to the system. Lastly, the digital implosion drives disaggregation and specialization, undermining the economic rationality of the vertically or horizontally integrated firm. Digital knowledge reduces the time and financial costs of information and coordination. It is now economically feasible for large and diverse sets of people to have the information they need to make decisions in near real time. Thus, companies can increase wealth by adding knowledge value to a product through innovation, enhancement, cost reduction, or customization at each step in its life cycle (Ticoll, Lowy and Kalakota, 1998, Castells, 2001, Drucker, 2001).

The business forces discussed above have set the stage for the ascendance of e-learning to an issue of strategic importance for organizations. As companies digitally transform their businesses, knowledge and training become rapidly obsolete. As a result, “just-in-time” training becomes a basic survival need, and identification of cost-effective ways of reaching a diverse global workforce becomes critical (Urdan and Weggen, 2000). In addition, new learning models are needed given the skills gap and demographic changes. Flexible access to lifelong learning is highly desired. Managing organizational competency, providing employees with competency roadmaps, distributing latent knowledge within the organization, aligning business objectives and learning outcomes, and extending learning to value chain partners are key business issues. Validating outcomes directly with increased

ROI, providing on-demand task related resources, rationalizing duplicative training, and reducing delivery costs and increasing organizational efficiency are also e-business related issues that write out the strategic importance of e-learning (Mcrea, Gay and Bacon, 2000).
Parallel to these business forces there are several additional factors that account for the strategic importance of e-learning. Internet access, for example, is becoming a given at home and work. Second, advances in digital technologies continue to enrich the interactivity and media content of the web. Third, increasing bandwidth and better delivery platforms make e-learning feasible and attractive. Fourth, a growing selection of high-quality e-learning products and services is now available. Lastly, technology standards, which facilitate compatibility, and usability of e-learning products are emerging (Urdan and Weggen, 2000). The Internet and its distributive architecture will, for the first time, give organizations the power to combine a series of discrete, unlinked and unmeasured activities into an enterprise-wide process of continuous and globally distributed learning that directly links business goals and individual learning outcomes (Mcrea, Gay and Bacon, 2000). The projected benefits are highly attractive. They include: accessibility of courses via Intranets and Internet, training can be self paced, availability of training at any time and place, training being less expensive and reduced or eliminated travel time (Hall and Karon, 2000)
On the other hand, a higher retention of content through personalized learning is possible because ICT-based solutions allow more room for individual differences in learning styles. Such solutions also improve collaboration and productivity among students as the online environment offers case studies, storytelling, demonstrations, role-playing, and simulations among other tools. Online learning is a risk free environment that encourages experimentation and reduces the social pressure associated with making mistakes. Nevertheless, if the benefits of e-learning are obvious organizations are far from achieving the strategic importance of the digital economy and digital learning. The current organization of training is based to a large extent on off-site classroom based on "just in case" learning, misalignment with business objectives and outcomes, unknown competency gaps, 'one size fits all' philosophy and the training department is in the back office, mean that corporate entities are far from achieving the benefits promised by e-learning (Urdan and Weggen, 2000). Their organizational culture is in desperate need of change. (Source: State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.3 Organizational culture: a key to successful and sustainable e-learning

Organizational culture is critical to the inception, growth and success of e-learning in any organization. Organizational culture can be thought of as having several levels that differ in terms of their visibility and their resistance to change. At the deeper less visible level, culture refers to values that are shared by people in a group and tend to persist over time even when group membership changes. At the more visible level, culture represents the behavior patterns or style of an organization that employees are automatically encouraged to follow by their fellow employees. Notions, of what is important in companies vary considerably. Kotter and Heskett (1992) have identified money, technological innovation and employee well being as values that may underlie organizations. Nahavandi and Malekzadeh (1993) have identified assumptions as being additional level of culture. This level is composed of basic assumptions resulting from an organization's success and failures in dealing with the environment. These assumptions encompass an organization's basic philosophy and worldview, and they shape the way the environment and all other events are perceived and interpreted. Values, behavior and assumptions combined with organizational leadership nurture the bond and identity that unites the members of organizations.

Leaders influence culture by being role models; by controlling reward systems and hiring decisions; and by deciding on structure, strategy, and the physical setting of an organization (Nahavandi and Malekzadeh, 1993). Understanding of the different levels of culture and their functional influence in an organization is an important prerequisite to the development of an e-learning strategic plan. An e-learning strategic plan that hasn't addressed culture of the organization in which it is to be implements has little viability. For instance, Harreld (1998), has drawn attention to the 1997 Meta Group report which shows that that 32 of 41 organizations surveyed had measured substantial returns on their investment in Intranets and two companies were close to breaking even. Among the seven corporations where Intranets were not delivering value, the survey revealed that the work environment was a major inhibiting factor. The report shows that the organizational culture placed high value on information possession and control and that these organizations found the basic nature of the Intranet is in direct conflict with their basic business.

Research shows that becoming a knowledge organization is not easy. It requires new types of investments, new systems of reward and the adoption of new philosophies of management, especially regarding employees and customers. Risks are proportionate to rewards in such cases. The most serious risk for corporate leaders is not to make decisions that will move their organizations to become knowledge generating (Huseman and Goodman, 1999). Harreld (1998), for instance, has argued that imposing new technologies and management processes on a culture that is not prepared to embrace them is futile. Knowledge management and e-learning processes require people to behave in some fairly counter-cultural ways such as, sharing their know-how with everyone else, making mistakes public and spending a lot of time exchanging information in collaborative processes.

Knowledge-intensive firms do not work properly as structured and hierarchical organizations (Nurmi, 1999, Castells, 2000). Knowledge-intensive firms work best as 'network organizations' which generate process, network, culture, and marketplace for mutual learning and knowledge. Additionally, Nurmi has argued that strategy cannot be imposed from above. Strategy emerges by way of strategic learning and grows into a core competence, where the know-how of the company and the needs of its customers meet. McCrea, Gay and Bacon (2000) in discussing the business-to-business e-learning industry recognize that employee value is not simply measured by the ability to execute strategy and manage teams, but also their residual pool of on-the-job knowledge they have amassed during their tenure. They also stress that until recently corporate managers were still failing to harness the value of tacit learning. In other words, the technological capability of the organization is only one part of the e-learning equation. Having an organizational culture that supports and rewards the self-directedness, motivation and autonomy of employees to continually use and apply learning resources to improve performance is the other.

For this to happen, research identifies the following as major issues when reviewing the organizational fabric's conduciveness to e-learning and knowledge management. First, leadership must encourage knowledge sharing through behavior. Second is the need for process. The organization must find a way to integrate technology with day-to-day work activity. Third is the need for operating standards. Standard terminology is particularly critical when communicating across functional lines. Project teams are not fruitful when the marketing experts, and 'techies', for example, speak their own jargon. This becomes even more critical with global e-learning. Fourth is the need for quality control. If an organization expects employees to dedicate time to knowledge sharing and learning, the organization must ensure that their time is well spent. Technologies must be easy to navigate and be resources that deliver value. Fifth is the need for measures. Measuring the effectiveness of a knowledge management program serves two purposes: to motivate individuals to keep using the program and second, to persuade managers to keep funding it. Lastly is the need for incentives. Integrating knowledge management and e-learning to compensation and reward systems is desirable and has more persuasive power. However, while knowledge learning and sharing require a revisit of organizational culture, care must be taken not to take the alternate road of structure, strategy and process extinction (Harreld 1998). (Source: State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.4 The trainers' roles in an e-learning era

The majority of the discussion on e-learning tends to focus on the learner and the notion of learner-centricity. However, as in traditional types of education the role of the trainer – the one that develops the content of e-learning – remains critical in e-learning. The traditional questions 'who educates the teacher' and 'what makes a good teacher' apply with equal force in e-learning as they have always applied in traditional learning environments. Many researchers agree that technology will never replace the trainer or instructional designers. However, technology brings with it more demands for teamwork and collaboration among a diverse group of workers (Wagner, and Reddy, 1999). Trainers, in particular, will need to take on new roles as their work design and environment changes.

The traditional trainer roles include instructional designer, instructional developer, trainer, and materials supporter. As an instructional designer, the trainer performs the initial analysis and instructional design tasks. He or she also advises on course exercises and revision. As an instructional developer, the trainer writes course materials, exercises, and auxiliary materials and develops overheads. A trainer also does course development, becomes familiar with course flow, and learns how to use the technology. As a materials supporter the trainer produces the training materials, manuals, overheads, graphics, exercises, and so forth (Abernathy, 1998). Lastly, a trainer also facilitates.

In addition to their existing roles, trainers are now involved in technology support, facility support, and distant-site facilitating (Chute, Sayers, Gardner, 1999). In performing technology support, the trainer may choose the technology and help install the equipment. Trainers may also learn how to use the technology. As technology supporter, the trainer may also coordinate technology issues with the facility supporter and distant site facilitators. As facility supporter, the trainer may ensure that distant sites are set up and operable. The trainer, as distant-site facilitator, coordinates all distant-site set-ups and ensures that the technology works, welcomes students to class, and is available to students in case there are problems.

It has also become essential for trainers to use new technologies in working with participants. Instructors become orchestrators of multimedia technologies. Much like a conductor of a symphonic orchestra, the instructor calls up inputs from various media sources to enhance the presentation effectively (Davie and Wells, 1998)

In addition, ICT-enabled learning fundamentally changes the locus of control of the learning from being trainer-centered to being learner-centered. Trainers are no longer seen as the providers and creators of knowledge. This is more than a major philosophical change. It has serious practical implications which affect the power structure of an organization. For instance, Human Resource (HR) and Human Resource Development (HRD) departments are often unwilling to give up control of the learning process. Yet, in the absence of organizational change that allows the learner to actively shape and participate in the learning process, the introduction of ICT – the part that often is understood as 'e'-learning – is just a way to distribute the same old training practices through new technological channels (Galagan, 2000). Giving learners more control of the learning process does not mean losing value of corporate education. Instead, it indicates that when a trainer can sit at a computer and publish a course with the help of an authoring tool and a public portal, the role of the trainer is changing. With the advent of content providers, training management systems, portals, delivery systems, authoring tools and integrated solutions, the trainer is also becoming the coordinator between internal and external training resources. As companies outsource their training (Bassi, Cheney and Buren, 1997) trainers are expected to coordinate and create structures to support networks of internal and external providers. Leonard (1996) describes the new trainer's roles as someone who facilitates, mentors and guides employers and employees to use the best and most timely training available. The goal of the corporate trainer is to find, interpret and assess a wide range of information and technologically sophisticated products. Even though trainers are expected to play multiple roles, they cannot do e-learning alone. E-learning is labor-intensive and is dependent on an array of skills. Thus, a team approach is a requirement for the institutionalization of an e-learning program. Team members could include graphic designers, network managers, server installers, end-user support personnel, programmers, instructional designers, and content experts (Driscoll, 1998). (State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.5 The learners' roles in an e-learning era

There are no universally accepted learning theories. However, Kolb's experimental theory of learning integrates many of the competing perspectives (Bostrom, Olfman, and Sein, 1990) and has become one of the best-known learning style theories. Kolb's Learning Style Inventory (LSI) (Kolb, 1985) contains 12 sentence stems, each having four sentence completers to be rank ordered. This inventory is psychometrically rated as strong in regard to reliability and fair in terms of validity and is widely used in computer-mediated learning studies. It draws ideas from Dewey's (1938) experience-learning theories that stress the need for learning to be grounded in experience; Lewin's perspective that emphasizes the importance of being active in learning; and Piaget's (1985) emphasis on intelligence as the result of the interaction of person and environment.

Kolb's (1984) experiential learning theory conceives of learning as a four-state cycle starting with concrete experience, which forms the basis for observation and reflection upon experiences. These observations are assimilated into concepts and generalizations about experiences, which, in turn, guide new experiences and interactions with the world. This model reflects two independent dimensions: Concrete Experience (CE) – Abstract Conceptualization (AC); and Active Experimentation (AE) – Reflective Observation (RO). These two dimensions form four quadrants reflecting four learning styles depicted in Figure : Accommodator, Diverger, Assimilator, and Converger.

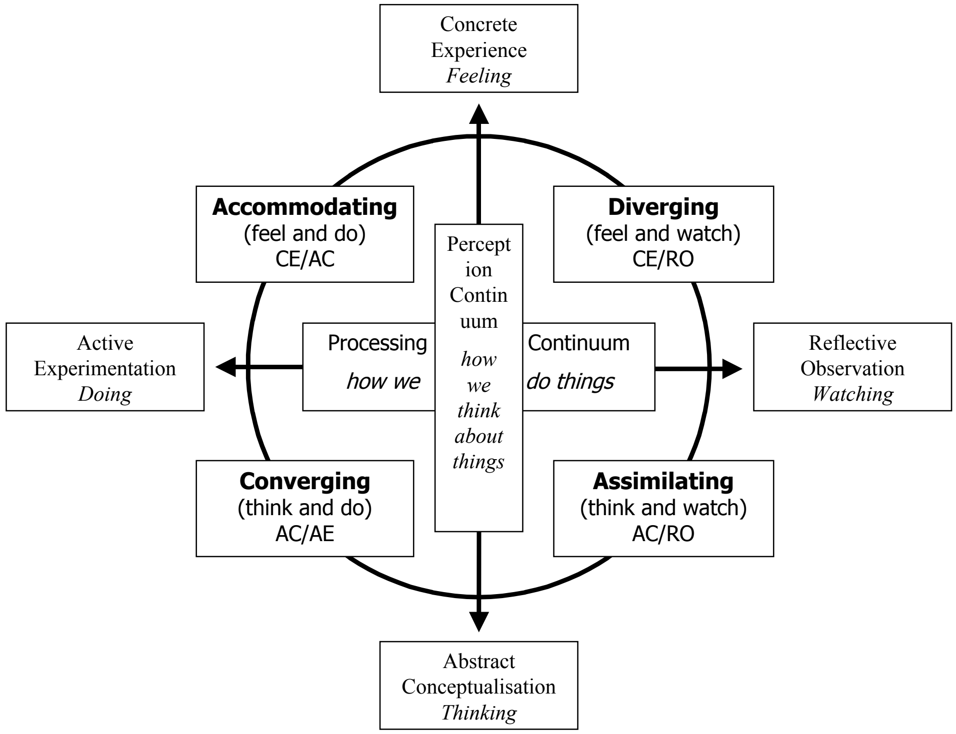

Figure 2-9: Kolbs Learning Cycle and Learning Styles (Kolb and Chapman 2005)

Each of the four Kolb learning styles (Kolb and Chapman 2005) can be briefly described as:

- Diverging (feeling and watching - CE/RO) - These people are able to look at things from different perspectives. They are sensitive. They prefer to watch rather than do, tending to gather information and use imagination to solve problems. They are best at viewing concrete situations several different viewpoints. Kolb called this style 'Diverging' because these people perform better in situations that require ideas-generation, for example, brainstorming. People with a Diverging learning style have broad cultural interests and like to gather information. They are interested in people, tend to be imaginative and emotional, and tend to be strong in the arts. People with the Diverging style prefer to work in groups, to listen with an open mind and to receive personal feedback.
- Assimilating (watching and thinking - AC/RO) - The Assimilating learning preference is for a concise, logical approach. Ideas and concepts are more important than people. These types of learners require good clear explanation rather than practical opportunity. They excel at understanding wide-ranging information and organizing it a clear logical format. People with an Assimilating learning style are less focused on people and more interested in ideas and abstract concepts. People with this style are

more attracted to logically sound theories than approaches based on practical value. These learning style people are important for effectiveness in information and science careers. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.

- Converging (doing and thinking - AC/AE) - People with a Converging learning style can solve problems and will use their learning to find solutions to practical issues. They prefer technical tasks, and are less concerned with people and interpersonal aspects. People with a Converging learning style are best at finding practical uses for ideas and theories. They can solve problems and make decisions by finding solutions to questions and problems. People with a Converging learning style are more attracted to technical tasks and problems than social or interpersonal issues. A Converging learning style enables specialist and technology abilities. People with a Converging style like to experiment with new ideas, to simulate, and to work with practical applications.
- Accommodating (doing and feeling - CE/AE) - The Accommodating learning style is 'hands-on', and relies on intuition rather than logic. These people use other people's analysis, and prefer to take a practical, experiential approach. They are attracted to new challenges and experiences, and to carrying out plans. They commonly act on 'gut' instinct rather than logical analysis. People with an Accommodating learning style will tend to rely on others for information than carry out their own analysis. This learning style is prevalent and useful in roles requiring action and initiative. People with an Accommodating learning style prefer to work in teams to complete tasks. They set targets and actively work in the field trying different ways to achieve an objective.

By adapting Kolb’s experimental learning theory and LSI, Gunawardena and Boverie (1993) have studied the interaction between adult learning style and computer-mediated classes compared with non-equivalent traditional classes. Their study focuses on the interaction between learning styles and the media, methods of instruction and group functioning in a distance learning class using audio-graphics and computer-mediated communication. They find that learning styles do not impact how students interact with media and methods of instruction, but do affect satisfaction with other learners; Accommodators being the most satisfied and the Divergers the least satisfied with class discussions and group activities. In

1991, Sein and Robey also used Kolb's LSI to study the interaction between learning style and efficacy of computer training methods. They concluded that Converger subjects who combine active experimentation and abstract conceptualization perform better than subjects with other learning styles. This suggests that students' learning outcomes when using computer application software may be affected by the style of the learner, regardless of the training methods. However, in an endeavor to seek the relationships between learning style preference and the effectiveness and acceptance of Interactive Video Instruction, Larsen (1992) finds no significant differences between learning style groups and suggests that both effectiveness and satisfaction are independent of students learning style preference.

With the learner placed in the centre of learning through social interaction, dialogue becomes the main vehicle for knowledge construction. This makes discussion, debate and collective analysis critical to the learning process. For establishing a teaching setting, the best pedagogic approach favors hands-on, self-directed activities that lead to debate, design and discovery. The most important task of the teacher is to facilitate an environment where the learner is stimulated to act on the learning material and interact with each other. Learners that are active in formulating the problems will be motivated to search for solutions through interaction with other learners and resources relevant to solving the problems.

Learners' perceptions about the characteristics of instructional delivery media and their ability to learn using these media have been shown to be key determinants in predicting student motivation and success in traditional classrooms (Coggins, 1988, Gee, 1990). These perceptions may also be equally important when implementing computer technologies as the major source of information transfer to students in e-learning environments. Few empirical studies indicate an interaction between learning style and attitude toward computer technology. In a study conducted by Reiff and Powell (1992), the reflective observation subjects had a negative attitude toward computers. The findings of the study suggest that for students whose learning styles are concrete and experimentation-activity oriented, computer-assisted instruction would be an appropriate option, while when reflective learners are introduced to this method of instruction, they may feel uncomfortable and frustrated. Similarly, an earlier study by Enochs, Handley, and Wollengerg (1984) has found that "students with more interest in objects or things (concrete experience) and less interest in working with people learned better using computer-assisted instruction". (Source: State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.6 Traditional e-Learning Overall Assessment

The benefits of e-learning can be summarized as follows:

- **Anytime, anywhere**. The current communication technology, wired and wireless enable the Internet to be a network with global connectivity that allows a learner to access e-learning content from anywhere and at anytime.
- **Cost savings**. As with teleconference, access to e-learning anytime and from anywhere allows significant cost savings, as the results reported by concerning the deployment of online learning within the corporation. One success story is Rockwell Collins, which reduced the cost by 40% event with only a 25% conversion of the training courses to WBT. However, the savings are offset by the cost of content creation.
- **Deployment**. The deployment of new learning content is greatly reduced from the approaches based on educational classroom and/or training courses.
- **Personalization**. Each learner can personalize their own experience by customizing the learning process, affecting the delivery, pace and content.
- **Learning Management.** Most of the e-learning courses are delivered via a Learning Management Systems (LMS), which allows organizations to monitor learners, thus enabling some form of evaluation of effectiveness.

However, there is a tacit agreement that the potential of e-learning has not been achieved, partially due to the following problems and obstacles:

- **Cost.** The process of content creation entails a significant cost, with no guarantees for high quality and effective material for learning.
- **Content Quality.** The created content follows similar structure and mechanisms since the early stages of corporate e-learning. The engagement of the courses based on linear content compromises the effectiveness of the learning process. This usually leads to disappointment with a significant dropout rate, which ultimately has the potential of compromising the success of the e-learning market.

- **Unknown Effectiveness.** The effectiveness of e-learning is difficult to measure and continues to be an active area of research. Taking into account the difficulty of quantitative measurement, evaluation methodologies are based on qualitative measures that prove to be highly subjective.

2.2.7 An Introduction to serious gaming

In the knowledge society, lifelong learning is essential for knowledge workers in their work processes. All learning tools, methodologies and content that mainly consists on digital support is considered as e-learning, those Information Technology (IT) is the seed enabler. The advent of communication technology (ICT) permitted for the support of both distance and collaborative learning.

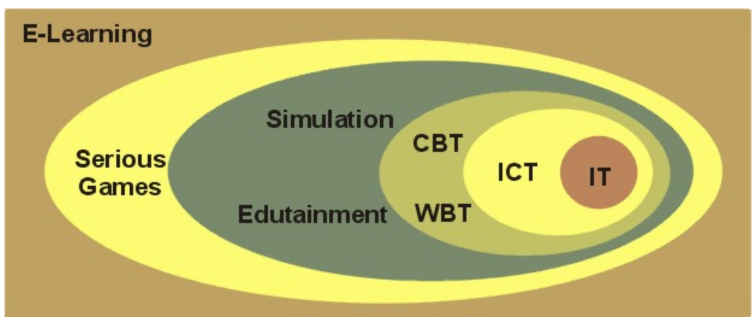

Figure 2-10

Serious games are considered as the next evolutionary generation of learning tools, which address some of the short-comings of its predecessors, namely the shortage of engagement and low motivation. Serious Games have significant key advantages over other e-learning tools, such as the ability to successfully engage and motivate the user so they are immersed into the flow. (Source: State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

2.2.8 Definition of Serious Gaming

Even a brief survey of the literature soon reveals that there seems to be as many definitions available as there are actors involved, but most agree on a core meaning that serious games are (digital) games used for purposes other than mere entertainment. With the U.S. Army's release of the video game *America's Army* in 2002 (www.americasarmy.com; Gudmundsen, 2006), the serious games movement got started. The same year the Woodrow Wilson Center for International Scholar in Washington, D.C. founded *the Serious Games Initiative*, and the term "serious games" became widespread (www.seriousgames.org/index2.html).

Original proponents, Ben Sawyer and David Rejeski, propose the following description:

Serious Games are Entertaining games with non-entertainment goals.

Such a broad definition does not properly capture the tacit understanding of what qualifies as a serious game. In fact, this is reflected by the contradictory perspectives between an observer and a user of a serious game:

- **Observer.** The user is playing a game.
- **User.** They are engaged in a serious learning activity that is fundamental to their productivity in the work environment.

Although a clear definition does not exist, it is important to state that a serious game is not a simulation. Probably the most distinguishing factor is the ability to successfully engage the user, such that they are completely immersed in the environment portrayed in the application. Another important factor is the artificial conflict generated to raise challenges to the user, but done with the correct balance to ensure satisfaction whilst avoiding frustration. An important characteristic of a simulation is the sophistication and realism of the supporting model, whereas in a serious game the focus is on the overall user experience, thus realism is many times is sacrificed. In fact, a serious game prefers a low fidelity simulation with only a few critical elements are modeled in detail. This is clearly evident in the case study given in the Corporate Economic Planning group at Sun Oil Company. In this case, the aim was to develop a highly sophisticated simulation such that a user mastering the simulation would be able to govern the real organization. After 13 man-years to develop and an additional 10 man-years to promote awareness with management, there were no users as the simulation proved to be too complex and daunting. As pointed out by Schrage, there is no use to have a map with a ration of 1:1.

Game-based learning (GBL) is described as "a branch of serious games that deals with applications that have defined learning outcomes" (en.wikipedia.org). Others consider game based learning and serious games more or less the same (e.g., Corti, 2006). According to Corti (ibid.), GBL has the potential of improving training activities and initiatives by virtue of, e.g., its engagement, motivation, role playing, and repeatability (failed strategies etc. can be modified and tried again). *Digital game-based learning* (DGBL) is closely related to GBL, with the additional restriction that it concerns digital games. In the words of Marc Prensky, DGBL is the "newest trend in e-learning" (twitchspeed.com/; see also, e.g., Kiili, 2005; Squire et al., 2005). DGBL is, Prensky argues, based on two key premises; firstly, the thinking patterns of learners today have changed, that is, today's students are 'native speakers' in the language of digital media. Secondly, this generation has experienced a radically new form of computer and video game play, and "this new form of entertainment has shaped their preferences and abilities and offers an enormous potential for their learning, both as children and as adults" (Susi, T; Johannesson, M; Backlund, P. (2007))

The differences between entertainment games and serious games are summarized in Table 2-1.

	Serious games	Entertainment games
Task vs. Rich experience	Problem solving in focus	Rich experiences preferred
Focus	Important elements of learning	To have fun
Simulations	Assumptions necessary for workable simulations	Simplified simulation processes
communication	Should reflect natural (i.e., non-perfect) Communication	Communication is often perfect

Table 2-1

According to Tarja Susi, Mikael Johannesson, Per Backlund suggests the following definition:

> "***Serious Games:*** *The application of gaming technology, process, and design to the solution of problems faced by businesses and other organizations. Serious games promote the transfer and cross fertilization of game development knowledge and techniques in traditionally non-game markets such as training, product design, sales, marketing, etc.*"

To summaries, there are many different terms that all point to what is here called serious games. Yet, the concept is defined in many ways; definitions agree on some matters, but also vary depending on different perspectives and interests. One issue most definitions agree upon, more or less, is that serious games are concerned with the use of games and gaming technology for purposes other than mere entertainment or "fun". Such purposes include education, training, health, etc. Although fun and entertainment are excluded in many authors' definitions.

The research community claims that most people learn most effectively through experience. This premise is reflected in the collective wisdom of humankind, as clearly captured by the Confucius saying:

I hear, I forget

I see, I remember

I do, I understand

However, some argue that learning by doing is not sufficient, it is necessary to engage the learner. Contrary the act of doing does not imply fun. This argument is the basis for the motivation of serious games.

2.2.9 Similarities and Differences of Serious Gaming with Traditional E-learning

The following table summarizes similarities and differences when comparing the traditional e-Learning approaches to the serious gaming approach. (Source: State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

Aspect	E-Learning	Serious Game
Technology	Is always based on ICT.	Can be based on ICT, but is not restricted to.
Motivation	Mostly extrinsic. Learners learn because others want it. Sometimes intrinsic (auto didactic)	Intrinsic, because gaming is fun.
Usage Mode	Mostly Single-User	Mostly Multi-User
Tutorial Support	Some forms are with tutorial support, others without	Most cases include tutorial support
Learning Environment	Can be anywhere with computer access	Can be anywhere in case of computer-based or computer-supported educational games. Non computer-based games are normally played in one room.
Virtual World Model	Mostly learning about the world as an abstract item	Learning within the (virtual) world with the need to act
Pedagogical Model	Mostly behaviouristic	Mostly constructivistic
Diverging Learning Style	Medium support of the needs of diverging style learners; most restrictive is the pre-programmed content of the learning medium	Good support of the needs of diverging style learners because games allow to develop and test new ideas
Assimilating Learning Style	Good support of the needs of assimilating learning style learners when	Good support of the needs of assimilating style learners because as long as the

	the content is logical and concise	game rules are logical and concise
Converging Learning Style	Problem solving in e-Learning is mostly abstract so that the converging learning style learner is not very well supported	Good support of the needs of converging style learners because games produces lots of problems to be solved
Accommodating Learning Style	Hands-on experience is badly supported by traditional e-Learning	Good support of the needs of the accommodating learning style learner; hands-on is a must for gaming (acting in a game following the game rules)
Ability to mediate "soft skills"	Mostly not	Mostly yes

Table 1-2: Comparison of classical e-Learning with Educational Games

2.2.10 The Effectiveness of Serious Games

As with traditional e-learning, there is little factual evidence if the learning effectiveness of serious gaming is greater than conventional teaching. However, as evidenced in the reported interview with a 10 year old child playing RuneScape, a serious game ensures that learning is fun and engaging which according to many researchers it is fundamental for learning. The interviewed child got together a group of friends to create wealth by mining and smelting ore to craft products for other players to buy. The result of the interview is summarized in Table 2-3, where the child's understanding of the virtual world supported by the game is mapped onto key business concepts. (State-of-the-art report in serious gaming. PRIME. *Alfamicro*. Version 8.0)

Child's Understanding	Key Concept
Not viable to do everything alone, so involved friends and delegated roles/responsibilities	Supply Chain and Division of Labor
The market value is increased once the ore is smelted	Added Value
The price of a product is determined by the needs of the other players	Supply and Demand
Everyone within the business specialized in their functions	Organizational Structure
Ensure that all within the group have a job	Vertical Integration
Resources from all members of the group were pooled together	Wealth Creation
Letting someone go who does not fulfill their obligations or is not integrated in the group	Management. Good Communication.

Evaluating decisions and deciding on improvements	Management Training
Not playing full-version because it would be too addictive and mother would not approve – would not get money's worth	Return on Investment

Table 2-3

As evidenced in the table, although the child may not be acquainted with the theory of economics and business, they have internalized the underlying concepts.

2.2.11 Application areas of Serious Gaming

Serious games apply games and simulations technology to non-entertainment domains and can be applied to a broad spectrum of application areas. They define an interdisciplinary research area where concepts such as human-computer interaction, user-centred design, social networking, signal processing, computer graphics and subject experts, are interwoven. Samples for application areas are as follow: (Zyda, M. (2005))

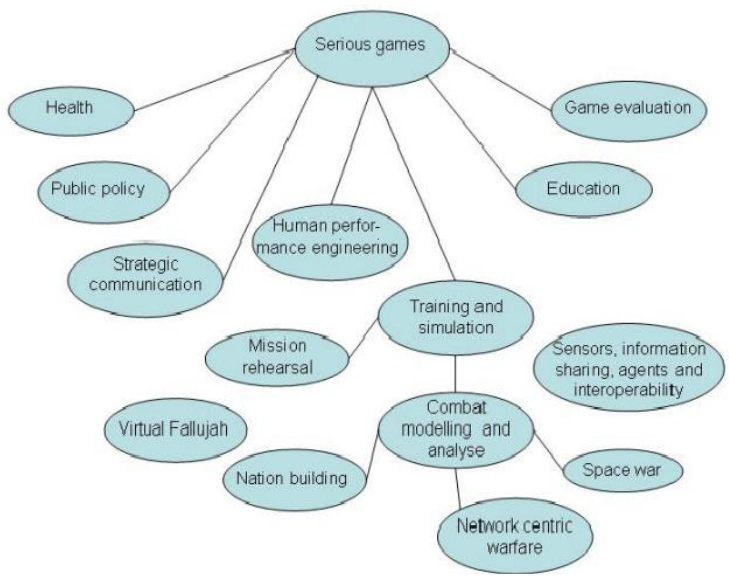

Figure 2-11 – Samples of application area

2.2.12 Advantages of serious gaming

- **Experiential learning**

According to Raybourn, Deagle, Mendini and Heneghan (2005) well designed 'serious games provide the opportunity for experiential learning and they provide an environment for active, critical learning'. Experiential learning opportunities enable game players to 'learn from contextual information embedded in the dynamics of the game, and through the risks, benefits, costs, outcomes and rewards of alternative strategies that result from decision making' (Raybourn et al, 2005 and (Caird-Daley, A (2009))). Experience in game will positively influence perceptions of subject matter areas and increase interest in portrayed areas because person is assuming a role within the game that they identify with and want to emulate. Yee and Bailenson (2007) have shown that an experience as an avatar can change a person's real life perceptions and behaviors. James Paul Gee, states that no deep learning takes place unless an extended commitment of self is made for the long haul. Good video games capture players through identify. Players either inherit a strongly formed and appealing character or they get to build a character from the ground up. Players become committed to the new virtual world in which they will learn and act. (Kaplan EduNeering. 2010)

- **Higher levels of declarative & procedural knowledge retention of material**

Sitzmann and Ely (2010) in a meta-analysis found that learners participating in simulation game learning experiences have 11% higher declarative knowledge, 14% higher procedural knowledge and 9% higher retention of training material than those trainees participating in more traditional learning experiences. Increase in learner knowledge, recall and retention of content of due to increased frequency of interacting within a game due to motivational factors and due to the fact that the learning takes place in a realistic environment. (Kaplan EduNeering. 2010)

- **Active Learning**

Unlike some classroom based 'chalk and talk' training sessions, serious games ensure that learning is an active rather than a passive process. According to Gee (2004) good learning requires that learners feel like active agents (producers) not just passive recipients (consumers) Training games (i.e. serious games) allow learners to actively engage in the content they are learning, which is likely to produce positive learning outcomes' (Belanich, Mullin and Dressel). Put very simply, serious games require players to participate in the action. Games do nothing until a player acts and then the game responds, presenting the player with feedback and new decision making events. (Gee, 2005).

- **High Motivation**

Learning happens when people are self-motivated to learn. Serious games can be highly motivating, and as such encourage players to commit time and effort to a game. According to Abt (1987, cited in Michael and Chen, 2006) *'Games are effective teaching and training devices for students of all ages and in many situations because they are highly motivating, and because they communicate very efficiently the concepts and facts of many subjects'*. Intrinsic motivation appears to be increased as games encourage curiosity and competition, or as Gee (2005) suggests, motivation comes from being challenged by a game.

- **Strategies Thinking & Ability to learn through repeated failure**

Serious games may encourage exploring and trying new things (Gee, 2005). According to the design of a game, serious games enable learners to explore the solution space, i.e. they enable players to actively explore alternative decision making strategies, and to learn from experiencing the outcome of their decisions. Design advantages encourage wider and repeated use, and amplify strategic thinking and learning opportunities among users.

- **Timely feedback**

Belanich et al (2004) identified that the ability to provide feedback to students about their performance was important and should be provided according to the learners' needs and the task at hand. An advantage of using serious games for training is the ability to provide this timely feedback.

In addition to being able to leverage the properties of games and digital games for learning, serious games also possess many of the properties of simulator based training devices. For example, serious games may provide the opportunity for after action review, either by being designed to collect objective data, such as the route taken in executing a task, which can then be benchmarked against an optimal course of action, or by means of a replay of action from either a first person or bird's eye view. (Caird-Daley, A (2009))

- **Increase in learner's self-efficacy, self-regulatory and self-observational**

confidence to perform the task for which they trained, increased ability to solve problems and to work with others . Bandura's (1986) social learning theory, Sitzmann and Ely (2010) found post-training self-efficacy was 20% higher with simulation games than comparison groups in meta-analysis. They state that confidence to perform the task for which they trained, increased ability to solve problems and to work with others are outcomes of serious gaming.

Sitzmann and Ely (2010 found that learners gained more knowledge when simulation games conveyed course material actively rather than passively and well designed simulation games are active. Means et. Al (2009) in a US DOE meta-analysis of studies comparing online and face-to-face instruction found that online learner activity and self reflection are key factors in increasing learning outcomes. (Kaplan EduNeering. 2010)

- **Elimination of risks and danger**

In military training, Serious games also provide students with a safe benign learning environment which enables students to explore decision making under a range of hazards and in dangerous activities and to learn from the outcomes of their actions without risk to life or equipment. (Caird-Daley, A (2009))

- **Anytime, anywhere access to learning content**

They enable training to take place 24 hours a day, seven days a week regardless of weather conditions; and without damage to the environment (Rolfe and Staples, 1986). They can be easily tailored to the skill levels of the training audience and are readily accessible.

In military training, it is acknowledged that serious games, just as with simulator training devices, have limitations, for example they cannot replicate morale, fear, fatigue or physical adaptations to extremes of climate which are best trained in the live environment. This does not undermine the use of serious games for military training, but acknowledges that serious games are not the media solution for all training needs. (Caird-Daley, A (2009))

The other advantages of serious gaming are as follow:

- **Reduction of the requirement for costly sites and equipment**
- **Lower environmental impact**
- **The ability to do things that are impossible in the real world**
- **Acceleration of experience**
- **Integration of knowledge and skills**
- **Improved transfer of learning to real-world**

2.2.13 Challenges of Serious Gaming

(The main source in this section is BinSubaih, A; Maddock, S; Romano, D. (2009))

The serious games field is still a relatively new one and is facing challenges which range from the selection of a suitable topic to the method of assessment used. Many of these challenges require interdisciplinary approaches to address them appropriately which correspondingly requires collaboration between professionals from different disciplines (e.g. subject matter, game design, game development, and instructional design) and this is in itself has been described as an awkward problem (Stokes, 2005). The challenges can be as follow:

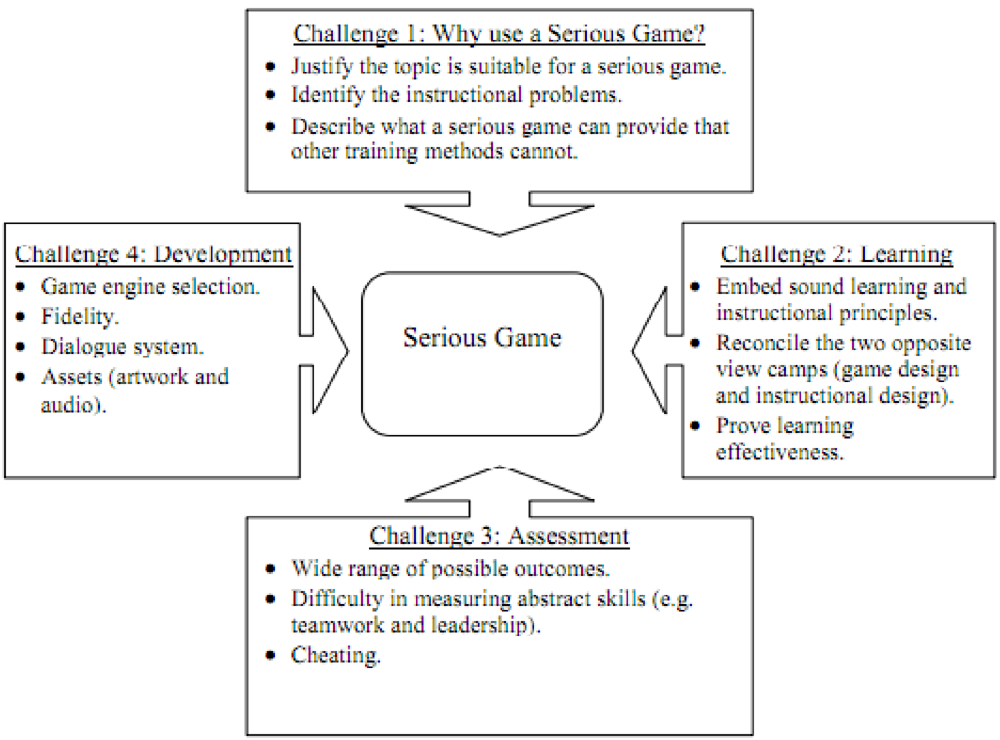

Figure2-12 - Challenges facing Serious Gaming

<u>**The first challenge: Why Use a Serious Game?**</u>

The first challenge in designing and developing any serious game is to justify its need by examining the suitability of the topic, by identifying the instructional problems, and by finding out why a serious game may be more effective than other training methods. With regards to the topic selection, Thaigi and Prensky agree on the possibility of using games to teach anything to anyone at any time (Nichani, 2001). However, Prensky raised some concerns of its worthiness considering the time and cost involved and suggests the power of games should be reserved for material the learners do not want and even resist to learn because it is boring (e.g. policies) or complicated (e.g. complex software)

The Second Challenge: Learning

Once the instructional problems and learning objectives are identified the next challenge is to integrate them into the serious game in a way that goes beyond making the game a sugar-coating for educational purposes, which was how edutainment was perceived (Kirriemuir & McFarlane, 2004). Egenfeldt-Nielsen (Egenfeldt-Nielsen, 2005) describes the problem as the lack of connection between the learning and the game play which very often limits the use of games as a reward for learning.

The Third Challenge: Assessment

The assessment of learning in serious games presents another challenge that has to be addressed. The future growth of the serious games industry depends on it according to Kevin Corti of PIXELearning (Chen & Michael, 2005). Researchers have identified a number of assessment issues facing serious games. One of these issues arose because serious games rely less on memorization of facts and therefore traditional methods may not appropriately reflect the learning gained (Chen & Michael, 2005). The other issue concerns the wide range of possible solutions due to the open-ended nature of serious games which entail different levels of knowledge transfer (Iuppa & Borst, 2007; Chen & Michael, 2005). Iuppa & Borst also described the issue of measuring the improvements of abstract skills such as teamwork and leadership. Chen & Michael added the problem of identifying what is cheating in the context of serious games. To meet these issues three main types of assessments have been used by serious games developers (Chen & Michael, 2005): completion assessment, in-process assessment, and teacher evaluation.

The Fourth Challenge: Development

After the serious game is designed the next challenge becomes the development. The two main development options are either to build from scratch or to reuse game engines. The advantage of the first option is that the team has full control over the source code. The disadvantage, and what has been argued as being a prohibiting factor, is cost (Gaudiosi, 2005). Cost can also be an issue with the second option. However, the wide range of game engines available means the cost range varies from free to six figures plus royalties. The other factors pushing towards the second option are: the graphics capability, the availability of scripting, the small learning curve, physics and networking.

Other Challenges

There are other challenges facing serious games in general which are not mainly design and development issues. During the Serious Games Summit 2006 a panel session was held to investigate what is wrong with serious games (Terdiman, 2006). Ben Sawyer raised the problem of the domain's perception which is looked at as a failure and a joke because it has failed to produce a large library of finished games. Henry Kelly, president of the Federation of American Scientists, pointed out that the problem is with the direction the serious games is focused on which often targets government-funded institutions (e.g. schools or military). Kelly argued that governments are often sceptical about projects with abstract goals. He added that the lack of easily measurable standards for success or growth makes it difficult for outsiders to judge if the projects work. Paul Gee, a professor of learning sciences at the University of Wisconsin-Madison, painted a more urgent case that needs a quick solution. Early evidence and managing expectations were attributed as problems that have hindered VR field (Jerz, 2005; Stone, 2005). Others have warned that the current early evidence seems to present only small-scale studies (Sandford & Williamson, 2005).

2.2.14 Examples of serious games in Manufacturing, sustainability and Management & Leadership

Examples of the serious games in the market in the domain of manufacturing, sustainability and management & leadership have been talk about below.

In the table bellow a summary of some of the specification of these games are illustrated.

Game Name	Manufacturing	Sustainability	Management	3D	Simulation	Competence development	Knowledge giver
Beer Game	***				**	*	**
Serious Leap 90	***			**		**	*
ERPsim	***				**	**	*

PRIME	***			--	--	**	*
Enercities		***		**	*	**	*
CityOne		***	*	*	**	**	*
INNOV8	*	*	***	**		*	**
Deloitte Business Simulation		*	***		**	**	*

Table 2-4 summery of examples of serious games

Serious Games on Manufacturing

✓ Beer game:

Functioning much as an aircraft simulator does, the software program gives students the opportunity to ‘fly’ a company solo. The user takes command of a virtual firm and pilots it from startup to success. More important, the simulator serves as a laboratory in which students can systematically explore the consequences of strategies without risking the fortunes of a real enterprise.

A key tool for teaching the system dynamics of supply chains and the core principles of effective management, The Beer Game puts teams of students in charge of managing the four areas of a distribution chain. The players at each level—retailer, wholesaler, distributor, and factory—receive shipments of beer, fill as much of their customers’ orders as possible, and place new orders for beer with suppliers. As in real business, the goal is to keep company costs low while meeting customer demand.

The Beer Game does not produce winners or losers. Students make operational decisions and receive feedback from past decisions. Often, they’re surprised by the side effects and delayed consequences of their actions, but realize how much better it is to be surprised at the keyboard than in the boardroom. By game’s end, management students have gained insight into the behavior of a distribution system—and the difficulties of developing a robust strategy for managing even a simple operation.

The Beer Game management simulator is actually based on a manual version called the Beer Distribution Game, created at MIT Sloan in the 1960s by system dynamics founder Jay Forrester and the MIT Sloan System Dynamics Group. It is one of many management

simulators that have been developed over the years by MIT Sloan faculty, including Sterman, who is also the creator of such popular programs as *Boom and Bust* and *People's Choice*.
http://web.mit.edu/jsterman/www/SDG/beergame.html

The MIT Beergame Version 2.0

Release Date: 7/1/2002

Figure 2-13 Beer Game

- ✓ **Serious Leap 90:**

Some initial serious gaming trials have already been carried out by Volvo Group in cooperation with several other partners. In a game called Serious Leap 90 players from around the world got to plan a bicycle factory according to lean principles. The players had three minutes to study the flow of the production and could then do changes, which changed the efficiency and flow. Following which he or she is challenged to select two specific changes to improve production. The results of these changes in terms of improved delivery precision and higher profits are played out over another three-minute round.

In training, the advantage is that a round can be played in three minutes, while the game can be replayed whenever and as often as desired. Compared with a traditional lean board game, which requires a minimum of seven and a maximum of nine players per group and per trainer, and takes 6-8 hours, Serious Leap takes less time and has no player restrictions. The trainer may use the game as a teaser or as an energizer, or play it to illustrate lean principles or concepts as part of either on-site or distance training.

(http://www.volvogroup.com/group/global/en-gb/productsandservices/researchandtechnology/transport_in_the_future/Sustainable_production/Serious_gaming/Pages/serious_gaming.aspx)

Figure 2-14 - Serious leap 90

- ✓ **ERPsim:**

The ERP Simulation Game is an innovative "learning-by-doing" approach to teaching ERP concepts. Using a continuous-time simulation, students are put in a situation in which they have to run their business with a real-life ERP (mySAP ECC 6.0) system. Teams of five to six students operate a firm in a make-to-stock manufacturing supply chain and must interact with suppliers and customers by sending and receiving orders, delivering their products and completing the whole cash-to-cash cycle. A simulation program (ERPsim) was developed to automate (i) the sales process, so that every firm receives a large number of orders in each period of the simulation, (ii) part of the production process in order to account for production capacity, and (iii) part of the procurement process to account for delay in delivery and payment. Using standard and customized reports in SAP, students must analyze their transactional data to make business decisions and ensure the profitability of their operations. (http://erpsim.hec.ca/)

Figure 2-15 - ERPsim

- ✓ **PRIME**:

The main objective of the European funded project PRIME is to give business professionals a learning environment where they can experiment with new ideas. In the past, serious gaming has been applied only partially in the business domain, providing semi-interactive case studies based on pre-written storylines, relying on discrete choices, and dealing essentially with training and/or coaching. The complexity of the collaboration, risk taking and negotiation activities intrinsic to work environments, in particular in the global manufacturing business context, raises interesting innovation challenges, which attracted the serious games approach. The underdeveloped project of PRIME addresses this gap by developing a game which gives business professionals in strategic manufacturing a learning environment, where they can experiment with new ideas and learn how to handle the entire life cycle of products and processes for all stakeholders of the organization.

Beside the PRIME software, a concept describing the integration of serious gaming as part of the daily work is developed. This concept is called PRIME-TIME and will support end users in the application of serious gaming within their vocational training procedures.

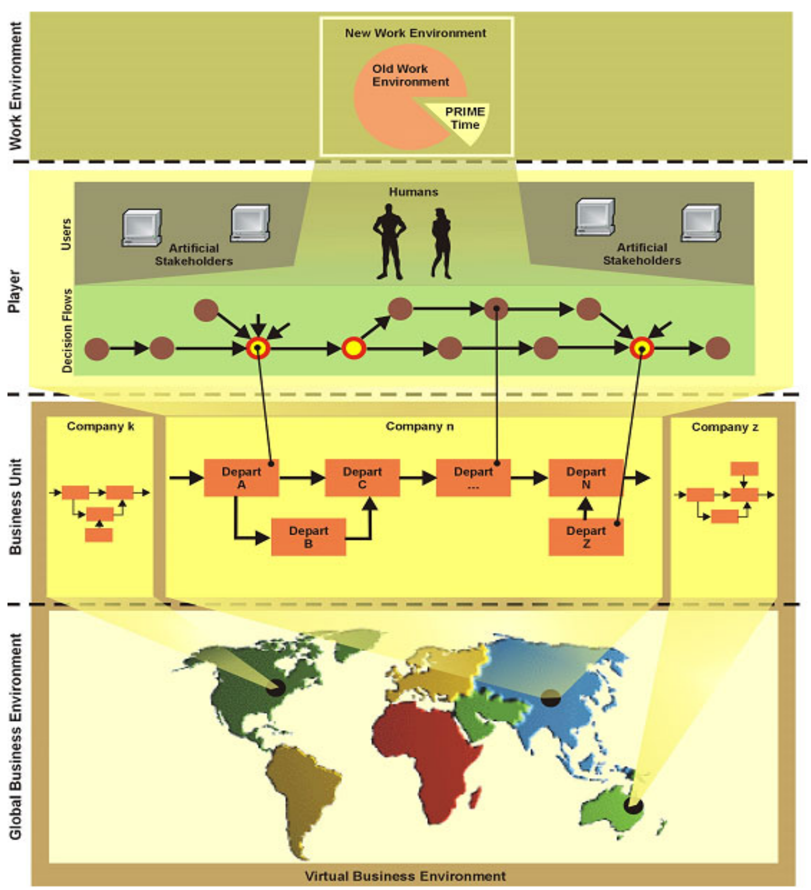

Figure 2-16 - PRIME Concept

PRIME is committed to creating an innovative system and methodologies that enable the following breakthroughs:

- Allowing safe experimentation for decision-making about radical innovations or major changes without the associated risks in real life.
- Empowering the managers with more confidence to embark on an innovation process in the "real world", thus enhancing the innovation culture of the enterprise.
- Increasing the adaptability and flexibility of the enterprise in a multidisciplinary, multi-stakeholder collaborative environment.

(https://www.prime-project.eu/)

Serious Games on sustainability

- ✓ Enercities:

Enercities is an educational computer-game created by the Dutch game developer Paladin Studios. The project has a €1.4M budget, and is funded by the European Commission. The game runs on Facebook and on the game website.

In this game, the player is faced with the challenge of developing an eco-friendly city. Players place buildings on a grid to grow their city. They need to balance energy sources, cash flow, and the city's Economy, Wellbeing and Environment.

The development of the serious game is based on state of the art technologies and insights. The game is fully web-based, 3D perspective (via Unity3D plug-in) and is suitable to play on low-budget computers. The game offers a semi-realistic simulation with game-like visual styles (cartoony) and low entry barriers (easy to understand; multiple levels in order to bring-in more complexity). All these approaches enable a wide distribution of the Enercities serious game across Europe. (http://www.enercities.eu/project/)

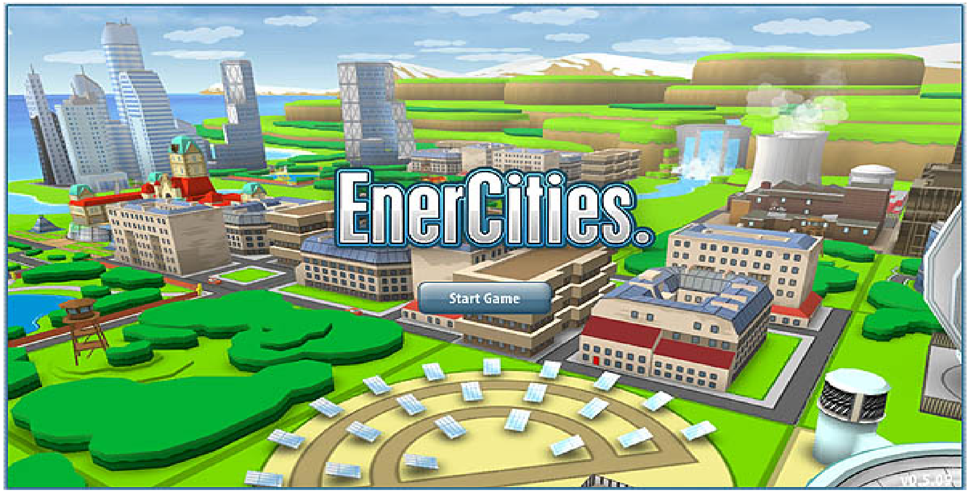

Figure 2-17 - Enercities

- ✓ **CityOne:**

CityOne offers players the opportunity to optimize banking, retail, energy and water solutions via an online, sim-style game in which the player is tasked with guiding industries within a city through a series of missions. Players will make decisions to improve the city by attaining revenue and profit goals, increasing customers' and citizens' satisfaction, and making the environment greener with a limited budget. In parallel, players will learn how the components of business process management, service reuse, cloud and collaborative technologies make organizations in the city system more agile.

For example, one mission involves a city where water usage has increased at twice the rate of population growth, supplies are becoming strained (and possibly polluted); the municipality is losing as much as 40 percent of its water supply through leaky infrastructure; and energy costs are steadily increasing. To complete this mission, the player would be challenged to institute a Water Management System that would include accurate real time data to make decisions on delivering the highest water quality in the most economical way.

Players who promote a more customer-centric business model to the banks represented in their city will discover how mobile payments, dynamic invoicing, and micro-lending can impact business goals. In all of the missions represented in the game, the player will need to determine the best way to invest to meet the financial, environmental and sociological goals of the city's industries while balancing their budgets and the needs of the citizenry. In parallel, players will learn how the components of service reuse, process management, cloud and collaborative technologies make business models more agile.

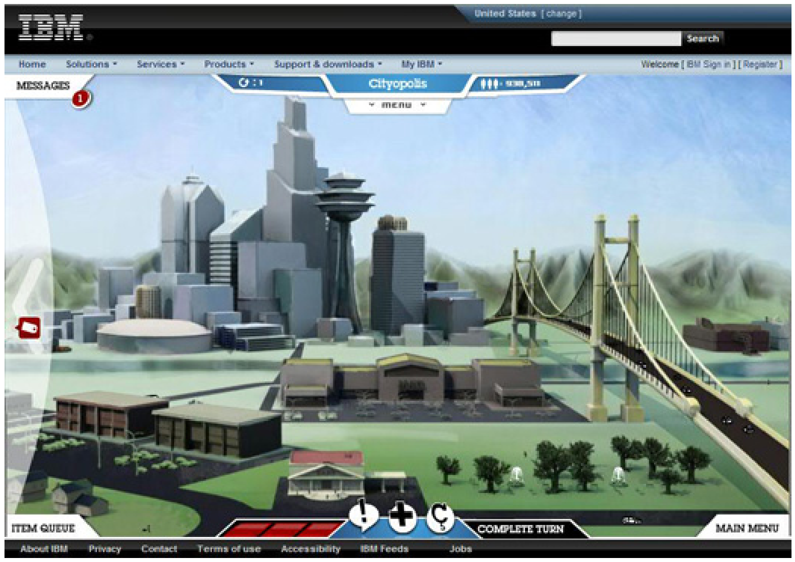

Figure 2-18 - CityOne

The game is also meant to be a conversation starter about the future: what are the catalysts for change and how can investments today prepare businesses for what is to come tomorrow. The characters in the game introduce players to industry progression paths that teach industry professionals the real-world planning they need to take to work smarter.

(http://www-01.ibm.com/software/solutions/soa/newsletter/aug10/cityone.html)

Serious games on Leadership & Management

- ✓ **INNOV8**:

INNOV8, an IBM product, teaches the fundamentals of business process management (BPM) and service oriented architecture using a 3D environment and business terminology. Ninety percent of respondents to IBM's online survey said that playing Innov8 2.0 helped them better understand how BPM technology can help companies increase workforce productivity and resource efficiency.

Inside INNOV8 Online, you will encounter three different game scenarios:

Smarter Traffic -- Evaluate existing traffic patterns and re-route traffic based on incoming metrics.

Smarter Customer Service -- Using a call center environment, players develop more efficient ways to respond to customers.

Smarter Supply Chains -- Evaluate a traditional supply chain model, balance supply and demand and reduce environmental impact and company's carbon footprint.

Players quickly see how practical process improvements can help meet profitability, customer satisfaction and environmental goals while addressing real problems faced by municipalities and businesses today. And when they're done playing, they can compare scores with other players on global scoreboards.

Figure 2-19 - INNOV8

The game allows users to learn the anatomy of a business process model and collaborate with coworkers to change that model and improve business operations. Concepts taught by the game include process modeling, activity monitoring, team collaboration, analysis, and optimization. Players are able to manage and interact with processes by taking advantage of powerful analysis technology and real-time monitoring capabilities.

(http://www-01.ibm.com/software/solutions/soa/innov8/index.html)

- ✓ **The Deloitte Business Simulation Game**

The game enabels companies to experiment with a realistic model of their company and its potential future scanrios. During the business simulation game, the player go through several business cycle, expereincing crtical moments and interdependencies and most importantly they are confronted with the consequences of their decisions. Decisions do not occur sequentially but simultaneously and interactively, just as in the daily business world.

The hands-on learning approach helps to sharpen management skills through practice, feedback from teammates and coaching from experienced facilitators. The feedback as well as the frequent discussions and debates that arise during the game provide exceptional value in the learning process. The game enables learner to experience how to reconcile dilemmas and to respond to short-term priorities while ensuring positive impact on long-term sustainability. Through feedback based on dicisions taken during the game and through reflection among the participants, the game provides a unique collaborative learning experience.

The aim of this game is to accelerate the implementation of Corporate Responsibility and Sustainibility (CR&S) within organization and to develop CR&S leadership. The learner will enabl to balance the qualitative and quantitative dimensions of people, planet and profit within the context of a business enterprise. Learning and leadership development is focused on the reconciliation of dilemma's around short term profit versus long term profit, gaining insight into CR&S complexities and competencies to manage CR&S risks.

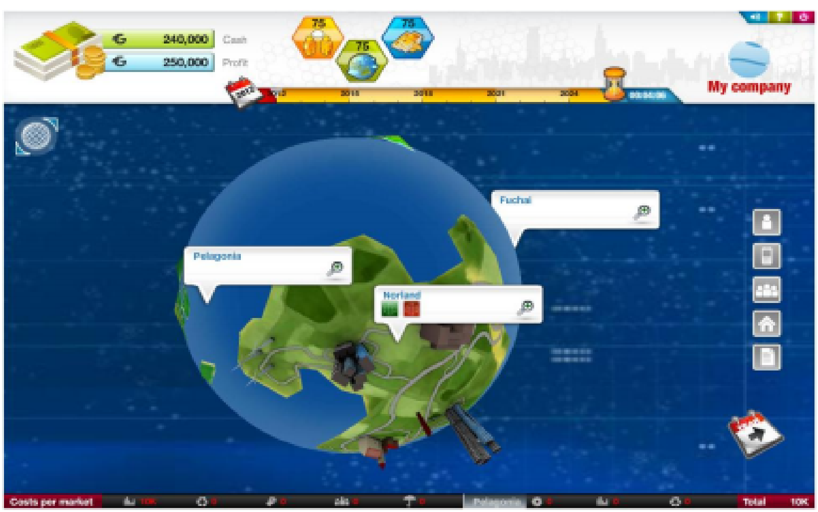

Figure 2-20 - The Deloitte Business Simulation Game

(http://www.deloitte.com/view/en_NL/nl/services/online-services/business-simulation-game/index.htm) &
(http://www.deloitte.com/view/en_GX/global/f99d60d6decb8210VgnVCM100000ba42f00aRCRD.htm)

2.3 TARGET Project:

2.3.1 Concept and objectives:

The global competition for highly skilled people has led to increasing acceptance by organizations, as a key business strategy, of the need to retain and re-train their existing staff through some kind of tailored competence development that reduces the lead-time for a learner to achieve target productivity: the "time-to-competence" (TTC). Today, the main route to shorten TTC is a bespoke (hand-crafted) face-to-face or blended course, which tends to be resource-intensive (expensive to create and deliver).

The main aim of TARGET is to research, analyze, and develop a new genre of Technology Enhanced Learning (TEL) environment that supports rapid competence development of individuals, namely knowledge workers within the domains of living labs (innovation), project management and sustainable global manufacturing. In addition, considering the rich diversity of the Enlarged European Union (EEU), TARGET pays particular attention to cross-cultural aspects of RCD. TARGET addresses the ever increasing need to reduce the time-to-competence of human resources within organizations and to facilitate the transfer of knowledge both within a community and organizations.

An important aim in TARGET was to avoid developing another complete TEL platform, which would require the resulting platform to compete with an already established competitive market of existing solutions catering the needs of the enterprises concerning the human resource management landscape of services and tools. Consequently, the TARGET approach was to leverage the Service Oriented Architecture (SOA) alongside the "mash-up" paradigm to define an open framework of components can be put together in different destination platforms. As an example, one may consider the ROLE platform or even a well-established solution like iGoogle as feasible destination platforms for deployment of the TARGET platform.

The TARGET takes a strong approach of "learning by doing" or "active learning", such as Problem Based Learning (PBL). Therefore, an individual is confronted with stories where they are confronted with a complex situation that requires the use of particular set of competences. These stories are the core of what is considered a knowledge asset, which may be carefully crafted with specific learning objectives, dynamically created by the system or may result from the capture of a running TARGET session. A story is experienced by the individual when engaged with the serious game component.

The TARGET learning process begins with the creation of a personalized learning plan, which supports either self-directed or goal-oriented learning. In the former case, the individual builds their learning plan from selecting existing stories, either crafted or captured. Alternatively, a learning plan may be created by defining the competence gap to be addressed, which results from the analysis of the personal and organizational requirements, taking into account the current set of competences that the individual possesses. Irrespective of how the learning plan is devised, it consists of a set of one or more stories. Associated to each learning plan is a learning strategy, which cannot be changed once the plan is finalized. The learning strategy determines what stories will be part of the curriculum embodied in the learning plan. In addition, the learning strategy dictates at each instance which story to be experienced by the learner.

Within the TARGET platform, the user's activities are continuously monitored, correlating the collated data with their learning plan, competence profile and performance outcome, which subsequently contributes to the refinement of the user's learning plan. The changes to the learning plan are determined by the associated learning strategy.

Figure 2-21 - TARGET Integrative Framework

TARGET achieves a step change in what can be done through TEL, by integrating five significant developments into the TARGET integrative framework:

- ✓ **Threshold Concepts**

Threshold Concept is an essential conceptual building block in progressing in the knowledge of a particular domain. A Threshold Concept has the following characteristics:

- ✓ **Transformative**. A conceptual and ontological shift in the individual's understanding;
- ✓ **Irreversible**. Once acquired, an individual cannot forget a threshold concept, neither return to their previous understanding of the knowledge domain;
- ✓ **Integrative**. A threshold concept reveals hidden knowledge and the inter-relationships between existing concepts;
- ✓ **Troublesome**. On first encounter, a threshold concept is counter intuitive and alien to an individual's common sense;
- ✓ **Bounded**. A threshold concept usually connects knowledge spaces.

Conceptually, one may perceive a Threshold Concept as gateways in a knowledge domain, which once mastered, leads to emergent new knowledge as the individual's understanding is expanded and transformed. The main use of Threshold Concepts within TARGET is to keep the curriculum design minimalistic, capturing the gems that are of essence and transformative making individuals think as a practitioner (e.g.: "think like a project manager").

- ✓ **Knowledge Ecology**

Knowledge Ecology implies that knowledge is seen as a dynamic, polycentric system corresponding to self-organizing knowledge ecosystems that provide the infrastructure in which information, ideas, and inspiration can travel freely to cross-fertilize and feed on each other.

- ✓ **Cognitive Minimization**

Cognitive Minimization is the process in TARGET that draws upon Cognitive Load Theory stating that a learner's attention and working memory is limited. This limited amount of attention can be directed towards intrinsic, germane, or extraneous processing. Therefore, it is necessary to minimize the load on an individual's working memory to optimize the learning process.

- ✓ **Social Communities**

Social Communities based on the seminal work of Wenger on communities of practice as the underlying framework can be thought of as shared histories of learning.

- ✓ **Experience Management with Serious Games**

Serious Games can be deployed as test beds for Experience Management that are highly motivating and emotionally engaging, causing high and long knowledge retention. In TARGET, serious games are combined with digital storytelling techniques thus enabling the community to store and share experiences reflecting complex situations.

The Knowledge Ecology models the structure of knowledge within a particular domain, which can only be truly mastered when the associated Threshold Concepts are overcome. These thresholds are identified by the members of the related Learning Communities, who ultimately contribute to the development and maturing of knowledge assets within the TARGET platform. In order to fulfill the aims of TARGET the following objectives will be met:

- ✓ **Conceptual Framework**:

This objective defines the conceptual blueprint of TARGET, identifying the main concepts involved, namely the integrative framework, competence development using serious games, a hybrid learning process that integrates mentoring and peer-to-peer learning of communities of practice, the evaluation process combining competence performance with psychophysiological framework, cognitive learning paths that are adaptive and pedagogical agents to support the learning process;

- ✓ **Knowledge model**:

The objective is to define the model, and respective ontologies along with the content creation model, that relates the game scenarios, concept thresholds and competences. The model will accommodate the “wisdom of crowds” to contribute towards the maturing of knowledge.

- ✓ **TARGET Learning Process**. The objective is to define the process supported by a pedagogical framework for the use of the TARGET platform, highlighting the interplay between the various stages of the process.

- ✓ **TARGET Platform**. The TARGET platform supports the TARGET Learning Process, consisting of multiple tools and services, which can be extended. The core service is the Virtual Business Environment (VBE), a serious game targeting the domains of project management and innovation.

- ✓ **Pedagogical Agents**

The game scenarios that drive the experience management of the user are defined on the existence of roles, which are to be assumed by users. However, pedagogical agents are available to assume unfilled roles within a game scenario. The role shapes and configures an agent, which becomes a character to engage with user(s) in the corresponding game scenario. In addition, the baseline pedagogical agent framework will also support personal mentors to support the activities of a human mentor thus ensuring continuous availability of the mentoring process for users.

- ✓ **TARGET Community:**

TARGET aims to establish and foment a sustainable community revolving around the TARGET environment, involving stakeholders of the following nature:

- ✓ **Learner**. This stakeholder corresponds to the users of the TARGET community that engage with the TARGET Learning Process supported by the TARGET Platform.

- ✓ **Mentor**. This stakeholder consist of both certified (individuals recognized by certification authority) and reputable (individuals recognized by the TARGET community) mentors;

- ✓ **University**. This is an organizational stakeholder that corresponds to universities that adopt to deploy TARGET in some measure
- ✓ **Enterprise**. This is an organizational stakeholder that corresponds to enterprises that adopt to deploy TARGET in some measure
- ✓ **HRM Integration**:

This objective consists of the development of a phased integration strategy of TARGET within an organization, ranging from just extraction of competence profiles from the HR system to full seamless integration. The work will be based on a prototype implementation.

- ✓ **Evaluation Framework**:

The objective is to define the TARGET evaluation framework of learner's competence development, which can different levels of sophistication depending on the cost and the resulting effectiveness. The simplest implementation of the framework is based on performance indicators measurement whilst the most complex relies on psychophysiological measurements. The users will be recruited from within the partner organizations, namely the universities, the large enterprises and living labs. In addition, users will be recruited from the partner networks.

2.3.2 Methodology

Within the context of TARGET, the approach taken reflects upon James Baldwin's paradox "in order to be social you have to be individual and in order to be individual you have to be social" (James Baldwin 1898), thereby treating learning as a non-linear process moving away from a dichotomy of individual and social aspects of learning, whilst emphasizing dialogue and transformation (e.g.: Threshold Concepts Framework). As reflected in Figure bellow, the TARGET Learning Process builds upon the four phases of Plan, Execute, Evaluate and Reflect.

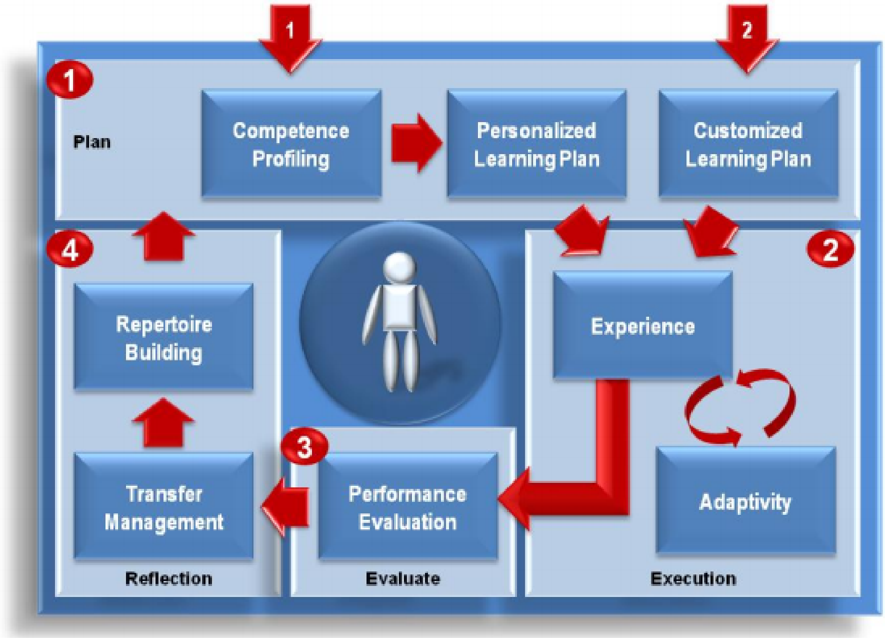

Figure 2-22 TARGET Learning Process

For each phase, TARGET has one or more processes to support the learner:

- ✓ **PLAN**

The TARGET Learning Process begins with the learner deciding if they wish to do goal oriented learning (entry point 1) or self-directed learning (entry point 2). In the case of goal oriented learning, the learner defines their current competence profile and their desired learning outcome in the form of outlining their target competence profile (Competence Profiling Phase). The result of profiling leads to the creation of a learning plan (Personalized Learning Plan Phase) based on custom stories tailored to the particular needs of the learner. Each story captures a business context, which may also involve defined characters with particular roles. The process of creating the learning plan is governed and shaped by a learning strategy that is chosen by the learner. In the case of self-directed learning, the learner builds their learning plan from the experiences of others within the community

- ✓ **EXECUTION**

This phase involves the learner selecting a role within a Story, resulting in an experience. Whilst engaged with the Story, the system provides an environment where the learner engages with other characters (either controlled by another learner or a Non-Player

Character) and the environment, enacting their decisions. These decisions will have an impact which will affect and change the situated context of the Story (Experience Phase). Whilst experiencing a Story, the system will monitor the actions of the learner, taking into account the desired learning outcomes, thus making changes to the Story if necessary (Adaptivity Phase). As examples, these changes may be modifying the personality of a Non-Player Character to be more confrontational or delaying tasks within a project.

- ✓ **EVALUATE**

In this phase, the learner is presented with the assessment of their competence during the experience in the form of a timeline manner. The ability of looking back on their decisions by reviewing how the story unfolded whilst cross-referencing the assessment of their competence at each point in time, allows the learner to evaluate their performance leading to reflection (Performance Evaluation Phase).

- ✓ **REFLECT**

The TARGET learning process supports the learner in externalizing the tacit knowledge acquired during the Execution of stories, thereby contributing to the creation of knowledge assets. Here the learning community plays an important role in the process with the support of recognized mentors as facilitators (Transfer Management Phase). The social aspects address the need of an ability to deal with flux and instability, and to thrive in situations of flux (Kelly 1994). Learning is here seen as an ecology; the constant interplay between the knowledge worker and their context. Through the engagement with others and reflection, the learner will internalize their experience, thus enabling them to enhance their repertoire (Repertoire Building Phase)

The TARGET platform (Figure 2-23) embodies the TARGET Learning Process, which takes a strong approach of “learning by doing” or “active learning”, such as Problem Based Learning (PBL). However, the aim of TARGET is not to define a radically novel learning process, but to leverage the five elements of the Integrative Framework to support the rapid personalized competence development of individuals.

The approach taken in TARGET is to avoid developing another complete TEL platform, which would require the resulting platform to compete with an already established competitive market of existing solutions catering the needs of the enterprises concerning the human resource management landscape of services and tools. Consequently, the TARGET approach leverages the Service Oriented Architecture (SoA) alongside the "mash-up" paradigm to define an open framework of components can be put together in different destination platforms. As an example, one may consider the ROLE platform or even a well established solution like iGoogle as feasible destination platforms for deployment of the various TARGET components that combined form the TARGET platform.

Each phase of the TARGET learning process is supported by a set of well-defined services embodied into components that are event driven, thus loosely decoupled from one another with some sharing functional dependencies. This means that the TARGET platform need not be entirely deployed as an integrated solution, but only subsets of the supported functionality. However, one needs to ensure that those components sharing functional dependencies are deployed together otherwise they may be operational at run-time but not work as required.

The adopted architectural design enables the platform functionality to be extended from the baseline features developed within the scope of the TARGET project and to replace existing components with alternate ones, provided there is compliance to the interfaces and the communication mechanisms.

The TARGET platform is geared towards a relatively thin client, which manages the flow supporting the TARGET learning process and provides interfaces for the different components. So within the context of the project, the learner engages with the TARGET platform through a web-based client, which interacts with the different TARGET components residing on the backend server. The decision to adopt a web based solution minimizes adoption barriers associated to the deployment of technological solutions in corporate environments. However, it is possible for an organization to consider the deployment that is not necessarily web-based.

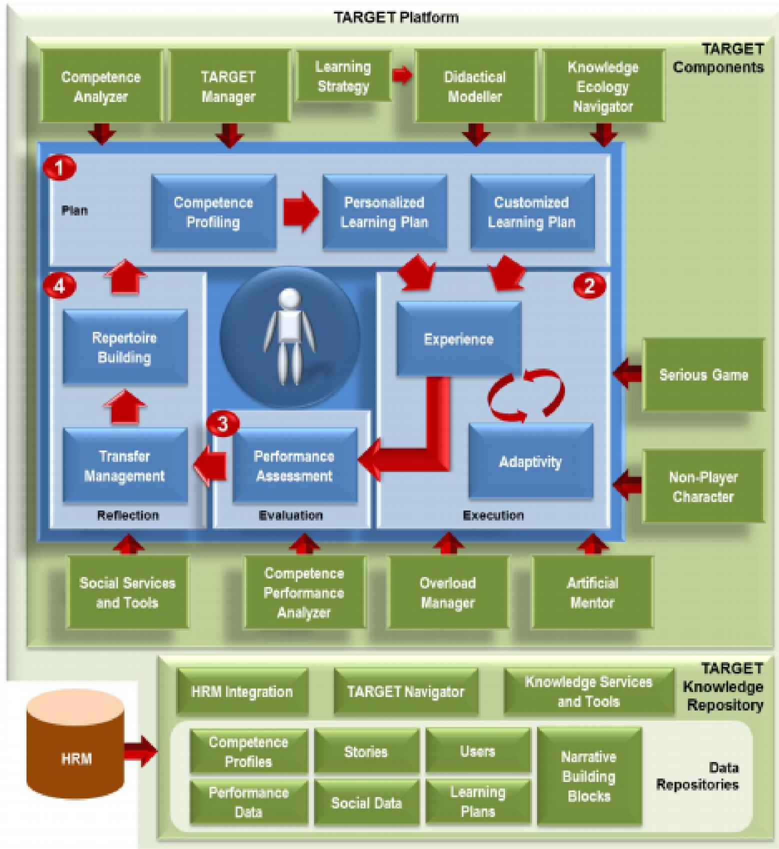

Figure 2-23 The TARGET Learning process Supported by TARGET Platform

Although not evident in the diagram of Figure 2-23, the TARGET Learning Community plays a crucial role in the TARGET learning process, namely with regards to reflection phase. The community will assess the outcomes of the competence development cycle to identify and formalize emerging behaviors in the form of patterns (and anti-patterns) to support successful competence development, thereby facilitating the process of knowledge management. In addition, the TARGET Learning Community ensures the sustainability of the TARGET process by contributing to TARGET repositories. This is achieved through the support of the TARGET platform to capture the current state of a serious game session as a new knowledge asset, at the core of which is an experience of a story to be shared amongst the wider community. The knowledge asset gains in value in its lifecycle, beginning by emerging in sharable form (possibly multi-variate) through group processes that include being annotated by both learners and mentors (externalization). Next, the asset is refined through analysis of its elements, followed by integration of different viewpoints, and re-annotation. Even intractable problems (wicked problems) can be handled in this way, becoming knowledge assets. All content generated becomes part of the infrastructure, being easily accessible, open, modifiable, and redistributable using multiple interchangeable formats to ease integration in external digital libraries. However, in some cases, the ownership of knowledge restricts the scope of accessibility and TARGET supports the necessary security model to foment the trust of organizations and individuals. The TARGET platform provides the TARGET Learning Community with a set of social tools and services.

3 Research objective

In previous chapter a broad literature has been reviewed regarding two important concepts of sustainability and serious gaming. We discussed definitions, initiatives, advantages and challenges of each concept separately. Later also we had a description of TARGET project.
As more and more social and environmental externalities are making their way onto a company's balance sheet, sustainable manufacturing has evolved to identify and manage these concepts otherwise will face unforeseen costs regard them. In other hand, The global competition for highly skilled people has led to increasing acceptance by organizations, as a key business strategy, of the need to retain and re-train their existing staff through some kind of tailored competence development that reduces the lead-time for time-to-competence.

According to this research a few samples of serious games in the field of manufacturing and sustainability in separate way exist. However what seems to be ignored in previous is to develop a serious game as a tool of rapid competence development in the field of sustainable manufacturing.

Traditional training methods mainly focus on transferring explicit knowledge to students. These methods however, would never enhance skills like system thinking or communication skills to have better performance in a job. One of the main aims of designing and providing a serious game is not only to deeply understand the specific knowlege by experimental learning opportunities but also is to let the student obtain certain competencies to perform a job in real situation. By using serious games the student would have a more active role in learning process. The scenario of serious game would have an enabler role in obtaining the intended skills and competencies as well as professional knowledge to carry out the job.

Designing a scenario mainly consist of the transformation of learning goals into specific elements in a scenario. To create a consistent scenario, guiding principles are needed to provide the scenario design process.

Beside design of a single scenario, the design of a set of scenarios is also very important. A scenario in a training curriculum will never be independent but will always be set of scenarios. This set will address the various topics that the student should learn. In order to achieve the most effective learning, this set of scenarios should progress in such a way that each scenario that is executed at a certain time matches the competencies of the participants at the same time.

The design of a scenario and the set of scenarios for training curriculum are not two independent design activities and there are relationships between them. Training curriculum prescribes when certain topics and tasks should be trained and what level of complexity. This puts a restriction on the elements of a single scenario. However this is not in the scope of this report.

Put together, the research objective is defines as follow:

The object of this research is to formulate guiding principles for assisting scenario designers to develop a scenario for serious gaming according to TARGET project's requirements and in the field of sustainibilie manufacturing. The design will focus on transforming the learning goals to scenario elements and arranging the design process.

Reseach question

This objective can be translated into the following main research questions:

1- *What are competences for a sustainability manager in a manufacturing context and how do people acquire these?*
   Acquiring competencies (a combination of knowledge, skill and behavior used to improve performance) is one of the fundamental goals of the scenarios for which the guiding principles are formulated. What exactly are these competencies?

2- *How learning goals (competencies) can be translated into elements of scenario?*

3- *How to organize the process of scenario development?*

The respond to these question answer on how the learning goals (competencies) can be translated into the elements of scenario, and how to organize the design process. The scenario should be described within a manufacturing and sustainability context and their various components should be explored.

4 Proposal of scenario development methodology for serious gaming

In this chapter the proposal of scenario development methodology for serious gaming is submitted trying to consider all of the essential steps. The following methodology is proposed in the context of sustainable global manufacturing.

During this chapter four main categories of sequential steps have been identified which should be passed to develop a scenario for serious gaming. This methodology aims to be a guideline in the process of scenario development. These categories are as follow which have interconnection with each other:

Figure 4-1 four main categories of sequential steps to develop the scenario

4.1 Defining stakeholders of the game:

The first step in the scenario development would be determination of different stakeholders' group of the game. The first group is the user group which has essential role in determination of the content of the serious game. The other group would be designer teams which are going to create the scenario.

4.1.1 Defining user group of the game:

Determination of the target learner of the scenario is the most important factor to understand the expectations from game; defining the expectations is the first main issue for designing the serious game scenario.

In the context of sustainable global manufacturing, user groups can be can be divided in two types of groups according to their experience of real work environment conditions. One group is familiar how people deal with each other in work environment and one group is graduated recently and has no clear idea about it. These groups can be respectively industrial students with 2-3 years work experience and recently graduated master students or MBA students.

4.1.2 Defining designer group of the scenario

Beside the general design group who have general knowledge about the subject or have technical information on how the software and hardware will support the game and what constraints this platform would have, design a scenario must be also in a close cooperation with a team of subject matter experts. This group of people with up-to-date operational knowledge can help design team to acquire “tacit knowledge” which is less clear for others and most of the time it is buried deep inside the minds of domain experts who have experienced different situations before in real work environment.

The ultimate scenario should subsequently have educational value, technical feasibility and characteristics of reality.

4.2 Which competencies are going to be learnt?

4.2.1 Competences in Sustainable Global Manufacturing

Before using the serious game to add some competences to the user, the user needs to be familiar with different aspects of sustainable global manufacturing. The game would be used after a series of lectures on the following areas:

- Sustainability and its dimentions and initiatives
- Sustainable manufacturing, design and supply chain
- Methods and tools of sustainibility
- Introduction to ISO 14000 and ISO16000
- Introduction to EMAS
- Introduction to GRI
- Introduction to LCA
- Introduction on other standards and methos of sustainibility

The serious game scenarios on the context of sustainble global manufacturing would be based on mentioned standards and methods.

Later the developed serious game will be used to learn and experience virtually the practical implications of a standardized work in companies.

The reason for choosing standards embedded in the context of the game is due to the fact that they provide guidelines, measures and best practices. For a company it is one of the best ways to approach sustainability and its challenges. Also using standards provides the opportunities to external and internal stakeholders to benchmarking. The alternative is to develope a sustainability vision and policy by themselves. It will be a less credible approach and will require more time and efforts.

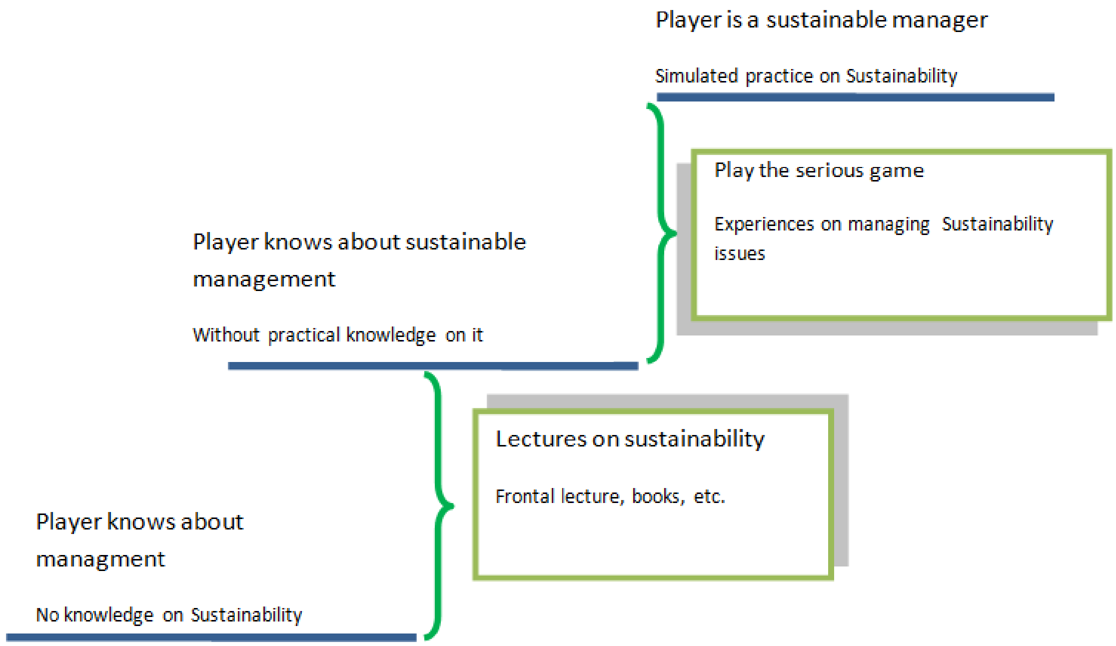

Figure 4-2 - Players-gap filled by sustainable global manufacturing serious game

Identified generic competences in the field are as follow:

(the list bellow is generated through a workshop in TAREGT project's meetings)

- ✓ Personal commitment to sustainability
- ✓ Systems / holistic thinking
- ✓ Development of a sustainability strategy and related policies
- ✓ Communication of a sustainability strategy in the organization and fostering sustainability culture
- ✓ Implementation of a sustainability strategy
- ✓ Formation and leadership of multidisciplinary teams (multidisciplinary cooperation)
- ✓ Review, evaluation and reporting of strategy implementation

4.2.2 Choosing the overarching competency:

After identification of generic competences in the field, the predominant and overarching competences must be determined according to the expected outcomes of the game and the defined user group. Later it is possible to make these overarching competencies more complex by adding more complications.

In the context of sustainable global manufacturing the overarching competence can be "the ability to conduct a standard method of sustainability in a manufacturing enterprise".

4.3 The main body of methodology for scenario development

The general flowchart for main tasks of designing group in generating the serious gaming scenario according to learning goals are as follow:

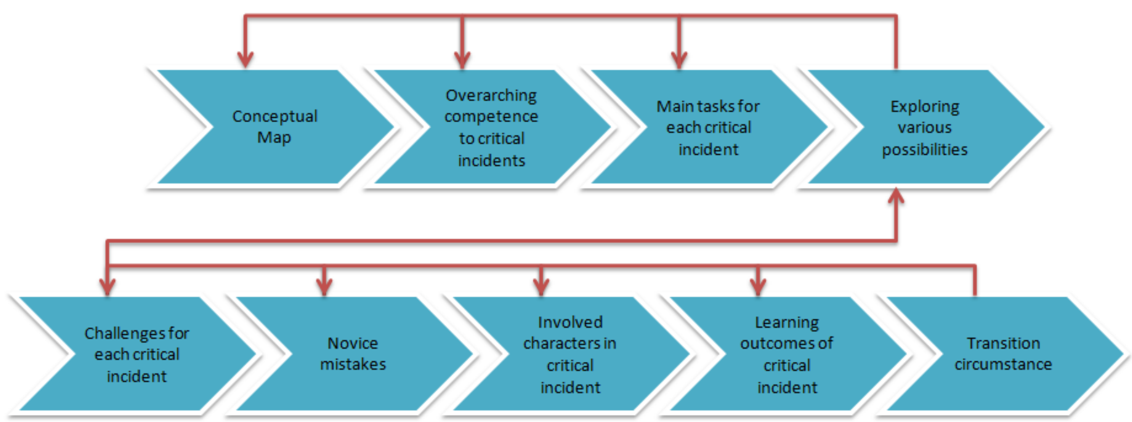

Figure 4-3 - Main body of methodology

The initial conceptual map and the following activities to develop the scenario need continuous revaluation. This revaluation would have two different feedback giver groups.

The development team of scenario is responsible for these evaluations time by time who are general designers, domain experts and technical persons.

The feedback of the students who are the users of the game must also be considered after first release of the game.

In overall, correction actions are based on the facts like the following issues:

- ✓ What learning outcomes have not been considered in the scenario and there is a value to add them to scenario?
- ✓ Which flows of activities are hard for user to follow and need to breakdown?
- ✓ Which activities are perceived to be so simple by user and need to roll up?
- ✓ What changes should be done according to technical restrictions in programming phase?
- ✓ …….

4.3.1 Designing a conceptual map

To provide more structured way in designing process, and creating more effective scenarios it seems necessary to provide a conceptual design first of all. Most of the time the designers have general idea about what is going to be teach and to model in the scenario but it is rather unclear how this should be done. The conceptual design can prevent scenario designers focusing too much on his/her own perception and to prevent missing any aspect in the scenario. Without it, there would be no way for all users to understand completely or agree upon the representation.

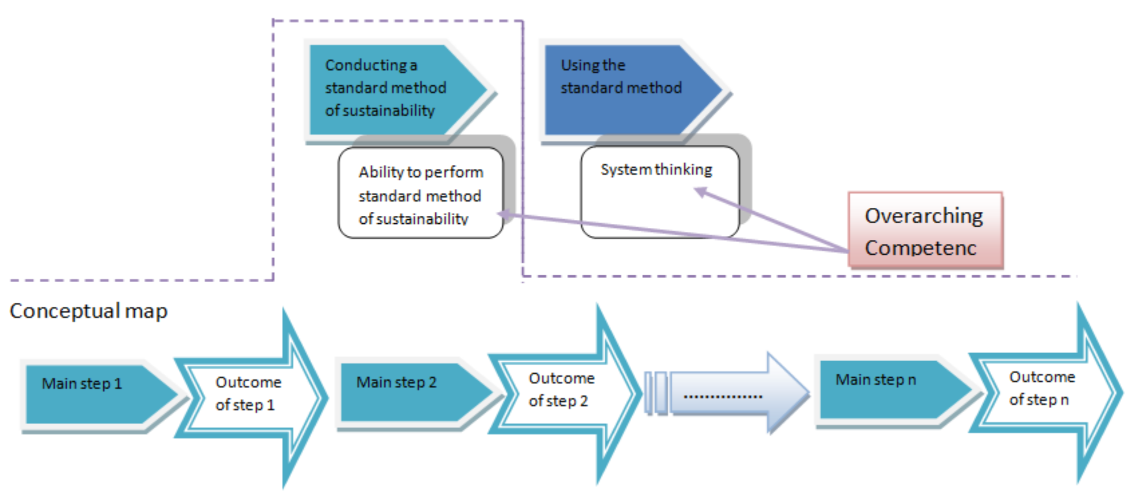

Figure 4-4 Conceptual map structure

The conceptual design as a high level map will help the designers group to better understand general structure of scenario, the flow of the process, critical and high level decisions and consequences of each decision.

4.3.2 Break downing the overarching competence into critical incidents:

A critical incident can be described as an incident that makes a significant contribution—either positively or negatively— in the process of performing scenario. In other words, the critical incident enforce you to stop and think, or it raises questions for you.

The overarching competency which in this context is "ability to perform a standard sustainibility method" must breakdown to its main components.

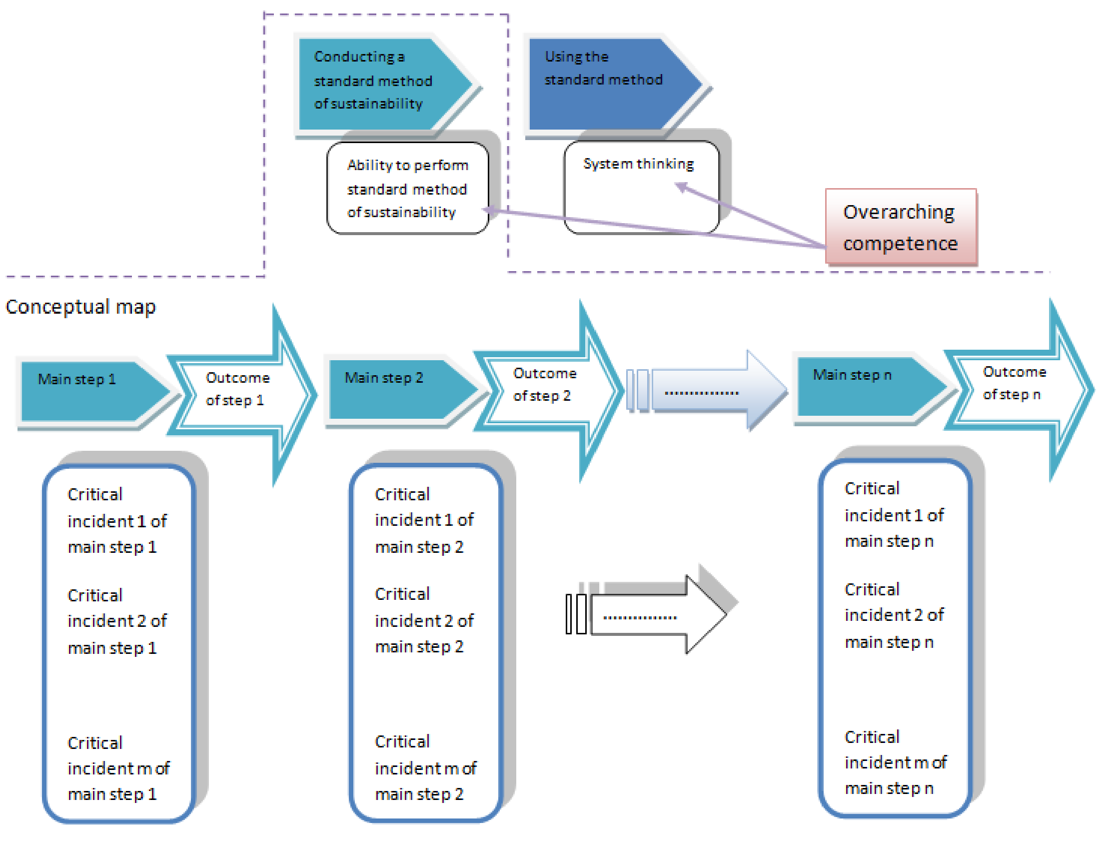

Figure 4-5 - Relationship between Critical incidents & conceptual map

4.3.3 Defining the main task/decision(s) for each critical incident:

Once the critical incidents are defined it is time for identifing the main tasks and decisions to perform each critical incident step by step. Each critical incident consists of certain number of tasks and a certain degree of complexity to making decisions. At the start, reaching the essence of the situation is recommended.

4.3.4 Exploring the various possibilities:

Various possibilities of how to complete identified task or/and reach the desired decision should be discovered. This is to explore possible instantiations of the story and give the basis for refactoring and the generalization.

The total amount of possibilities for each task and decision should be kept in a rational level. If the number of them is too much, it produces stress, demoralization in the player. In other hand if the number of possibilities are too low, the scenario would has a straight forward flow, however, it makes player feel bored and that is also demotivating factor.

4.3.5 Identifying challenges to proceed each critical incident:

In principle this is what intended to teach by serious game. To better understanding, for each revealed challenge a clarifying explanation is needed. Indeed the challenging items are mostly critical decisions which must be taken in each stage of the game to proceed. By clarifying the challenges to perform each critical incident the typical mistakes a novice player can do will be defined.

A list of possible challenges for conducting a standard method on the domain of sustainability can be as follow:

- ✓ Selecting the parameters of method
- ✓ Defining the scope of process of conducting standard method
- ✓ Level of Precision of measures used for parameters of method
- ✓ Identification of input/output for each main phase of method
- ✓ Choosing the appropraite indicators/reporting categories

- ✓ Choosing the appropraite method of Data retrieval
- ✓ Dynamical re-scoping
- ✓ Executing the process in the right/most efficient order
- ✓ Any other challenge specific for each method

4.3.6 Identifying typical mistakes that a novice make and their roots:

For each defined challenge, identification of corresponded typical mistakes that a novice will make must be recognized and the reason must justify; why they would do it is necessary to determine. In the following, description of strategies that more experienced people would implement to avoid those mistakes is needed to be clarified. By the help of them the main stream of the game which has the maximum value added would be defined.

Challenges	Mistakes	Root of mistakes
Selecting the parameters of the method	Choosing the wrong/ too little/too much parameters Unbalance between overall quality, time and cost of project Choosing planned vs. real process execution facts	Not getting info from right source Misleading by other workers specially managers Having no clear idea of overall process Not balancing overall time, cost and quality when deciding the parameters
Defining the scope of process of conducting standard method	Broad/focused boundaries wrong/not relevant indicators/reporting categories	No clear idea about the goal of the project Not getting info from right source Misleading by other workers specially managers Having no clear idea of overall process Not balancing overall time, cost and quality when deciding the parameters
Level of Precision of measures used for parameters of method	Incorrect use of measurement units Incorrect unit of measurement Biased measurments	Lack of precision of player No clear idea on importance of accuracy of unit of measurements in final result Misleading by other workers
Identification of input/output for each main phase of method	Mistake in identification of input/output	Lack of holistic view of interviewed person Lack of holistic or systematic view of player Incomplete definition of the process
Choosing the appropraite indicators/reporting categories	Mistakes in selection of indicators/reporting categories	Player have a wrong idea of each category Player has focused too much/too less in details of each category

Choosing the appropriate method of Data retrieval	Mistakes in data retrieval	Player has no idea of availability of data Player has problem in interacting with involved people and getting information from them Player just conduct desk work instead of shop floor visit Player interviews with wrong person Players interviews with not adequate number of peoples Player interview with not appropriate combination of peoples in meeting
Dynamical re-scoping	Mistakes in re-scoping	Player changes her/his mind too frequently Players do not re-scope when needed Player cannot determine insufficiency of captured data
Executing the process in the right/most efficient order	Mistakes in executing the process in the right order	Player has not ability to find most efficient order Player has narrow view and cannot see the different possibilities to conduct each phase
Providing a complete report and analyzing it	Deriving wrong conclusions Report is beyond the scope and goals Report is below the scope and goals Focus only on environmental issues Focus too much on categories	The player has no ability to provide a report appropriate to top management level The player has narrow view and can not see the different issues to report The player has no ability to analyze The data used to analyze were wrong and insufficient data

Table 4-1 - challenges, corresponding possible mistaks and their roots

Based upon the learning goals, challenges for conducting the process, their corresponding mistakes which a novice user is likely to make and the routes for these mistakes together are the backbone of scenario design. The designing team by using them can develop different flows for the single scenario which at end would produce different outcomes in the term of total quality, time and cost. In order to choose the right activity for a specific challenge it is necessary to have an overview of the possibilities of different mistakes.

These cause and effect relationship can later be used to give feedback to the user of her/his performance.

4.3.7 Defining the characters involved in critical incident:

If the critical incident involves participation of more than one character (who is normally the user of the game), the way they deal with each other and what are their role in carrying out the specific activity must be identified.

In one hand, the characteristic of all of non-playable characters must be clear for user of the game. A profile for each non-playable character must be defined and be in the access of the user. For example their position in organizational chart, their implicit role in the organization, their relationship with others, their attitude to any change related to sustainability, their power and leadership effect on other personnel, and some information in this matter must be defined.

In other hand, their role in performing any specific activity involved in critical incident must be defined. For example are they sources of information, do they collaborate with the user in this activity, are they adversaries to user and competing for something with him/her, are they a cause of stress or conflict?

All of these characteristics would affect the flow and possibilities of progress of the process.

4.3.8 Defining the learning outcomes of each critical incident

The designers of the game should always ask themselves what are the learning outcomes of each critical incident. If they are too many, the critical incident must breakdown into smaller components. If there is no outcome for any critical incident, that critical incident must be reviewed.

4.3.9 Finding how the transition from one critical incident to other take place

By considering the critical incident in line with the others, how the transition from one to other may take place would be exposed, and the probable precedence would be defined. If so, the results and consequences of not following the correct order by user would appear.

4.4 Defining performance indicator for main activities of each critical incident

According to main challenges, corresponding possible mistakes and their roots, a set of performance indicators must be defined to assess the performance of the user. The indicators must measure the effect of the performing specific activity on overall time, cost and quality of the process conduction. A specific flow of activities must be defined first as the optimum route and any deviation from this route must be measured. This route is what an expert user would follow for conducting the process.

5 Applicability of scenario development methodology for Life Cycle Analysis serious gaming in TARGET project

In the previous chapters research objectives and initiatives for this research are represented. Moreover a proposal for the methodology of scenario development in the field of serious gaming was introduced and described which include some sequential steps. Each step of the methodology was described in detail in theoretical way, however as previously explained the ultimate objective is to apply it in real scenario development process in order to make the whole process more efficient and make it more agile.

Consequently an application phase is required in order to confirm the methodology applicability.

The used platform for development of the serious game is TARGET platform which is described in detail in chapter 2. The applied subject for developing a serious game scenario is LCA which is chosen as the first storyline of sustainability methods serious games by the managing team for develop the scenario.

The main phases of the LCA conducting which are introduced in details in chapter two are goal definition and scoping, inventory analysis, impact assessment and interpretation. As pointed out by Schrage, there is no use to have a map with a ration of 1:1, the domain expert team has decide to remove some of the steps in each phase of LCA conducting process to make it more smooth and reachable via performing a game. Of course this removal has no negative effect on the perception of the user of the overall steps of LCA and has done just for some activities which do not need specific and fundamental decision making action by user. Meantime the names of inventory analysis and impact assessment phases have been changed respectively to data collection and calculation to have more simplification.

In this chapter we will try to check the usability of the introduced methodology in the real scenario development process.

5.1 Defining stakeholders of the game:

For defining the stakeholders of the game we need to define the user group and design group of the scenario.

5.1.1 Defining user group of the game:

In the context of sustainable global manufacturing, user groups can be divided in two types of groups according to their experience of real work environment conditions. One group is familiar how people deal with each other in work environment and one group is graduated recently and has no clear idea about it. The main factor in the following categorization is based on the expectation of the player on how it is hard to get information from stakeholders in real world and from the non-playable characters in the game's virtual environment.

These groups can be respectively industrial students with 3 years work experience or recently graduated master students or MBA students:

- ✓ **Master students:**

  Master student has supposed to have no experience of real industrial environment and he/she is not so familiar with behavioral dynamics.

- ✓ **MBA students:**

  MBA student is assumed to have maximum 2 years of work experience.

- ✓ **Industrial student:**

  Industrial student has assumed to have more engagement in real working areas and has atleast 3 years working experience

Among these groups of users, the MBA Student has choosen as the ultimate user of the LCA serious game in the TARGET project.

5.1.2 Defining designer group of the scenario

The involved people in the scenario development phase for LCA serious game of TARGET platform are as follow:

- ✓ LCA experts
- ✓ Manufacturing industry experts
- ✓ Technical experts
- ✓ Serious gaming experts
- ✓ Social science experts
- ✓ Members with background knowledge on LCA domain, manufacturing and serious gaming

5.2 Which competencies are going to be learnt?

5.2.1 Competences in Sustainable Global Manufacturing

In this project it is assumed that the students are familiar with different aspects of sustainable global manufacturing. The game would be used after a series of lectures on:

- Sustainability and its dimentions and initiatives
- Sustainable manufacturing, design and supply chain
- Methods and tools of sustainibility
- Introduction to ISO 14000 and ISO16000
- Introduction to EMAS
- Introduction to GRI
- Introduction to LCA
- Introduction to other methods ans standards on the domain of sustainibility

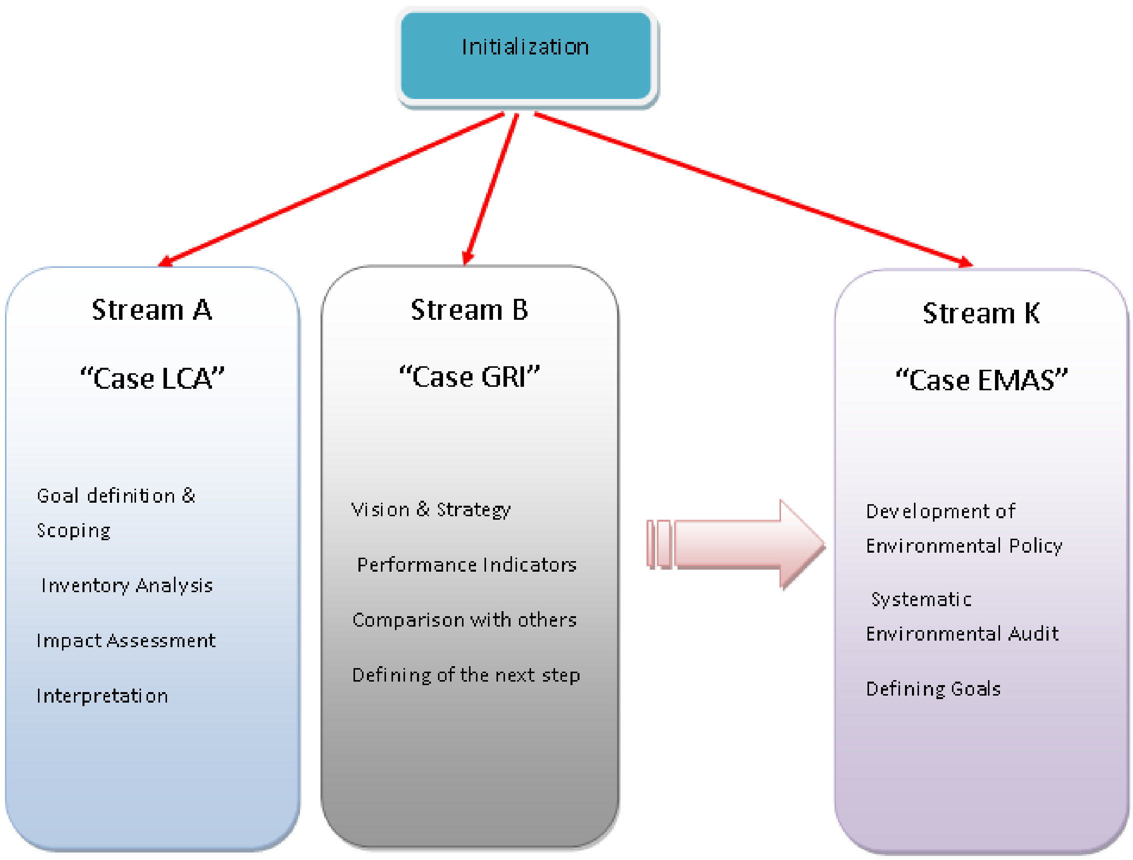

Figure 5-1 - The overall storyline of the serious game for sustainable manufacturing in TARGET project

In this case, the serious game scenarios on the context of sustainble global manufacturing would be initialized on LCA method and the developed serious game would be used to learn and experience virtually the practical implications of LCA conducting.

The reason for choosing LCA method is due to its standard structure which its applicability in different manufacturing sectors has been proven.

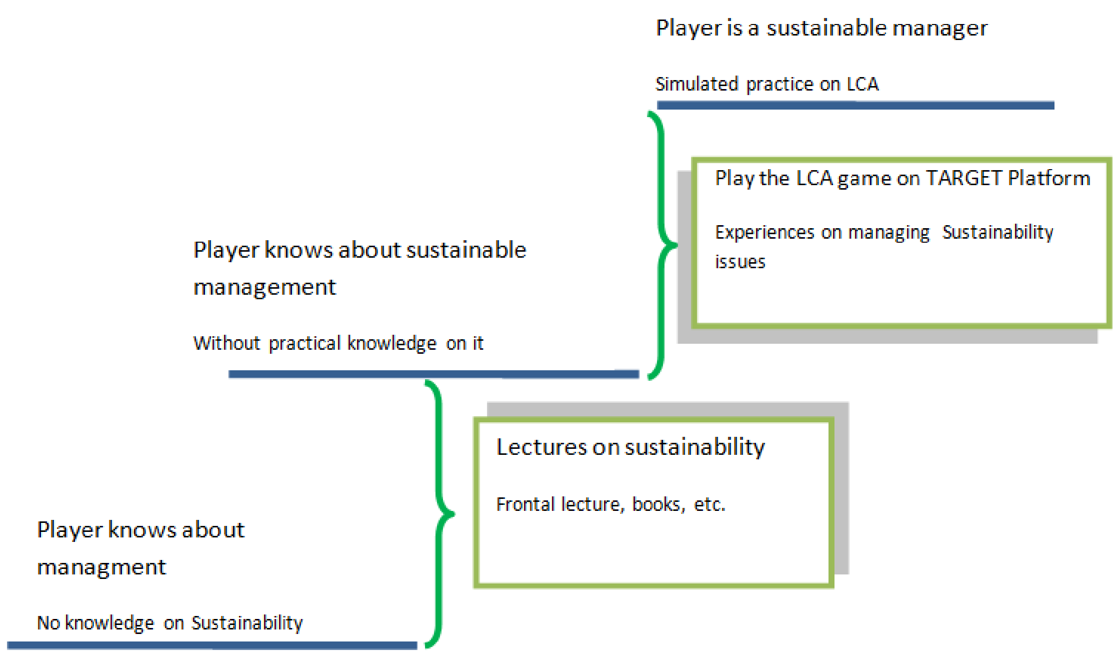

Figure 5-2- Players-gap filled by LCA serious game of TARGET

As mentioned in the previous chapterd, generic competences in the field are as follow:

- ✓ Personal commitment to sustainability
- ✓ Systems / holistic thinking
- ✓ Development of a sustainability strategy and related policies
- ✓ Communication of a sustainability strategy in the organization and fostering sustainability culture
- ✓ Implementation of a sustainability strategy
- ✓ Formation and leadership of multidisciplinary teams (multidisciplinary cooperation)
- ✓ Review, evaluation and reporting of strategy implementation

5.2.2 Choosing the overarching competency:

Ability to perform the LCA process in real world is ultimate objective of engagement of the player in the LCA serious game. To perform the LCA process, the individual needs to conduct the LCA process and later use it.

"Ability to Perform LCA" and "System Thinking" are respectively overarching competences of "LCA conducting" and "LCA Using" sub-processes in performing LCA process. LCA Using is not in the scope of this research.

5.3 The main body of methodology for scenario development

The main steps followed in the TARGET project by the team of designers for the scenario development have been described below.

The designer group as mentioned before has named the main steps of LCA conducting respectively "Definition & Scoping", "Data collection", "Calculation" and "Interpretation".

5.3.1 Designing a conceptual map

To provide more structured way in designing process, have a common general idea by all designing group members and creating more effective scenario a set of conceptual maps have been designed by the scenario development team. Some samples of these conceptual maps which are designed and used in the TARGET project were as follow:

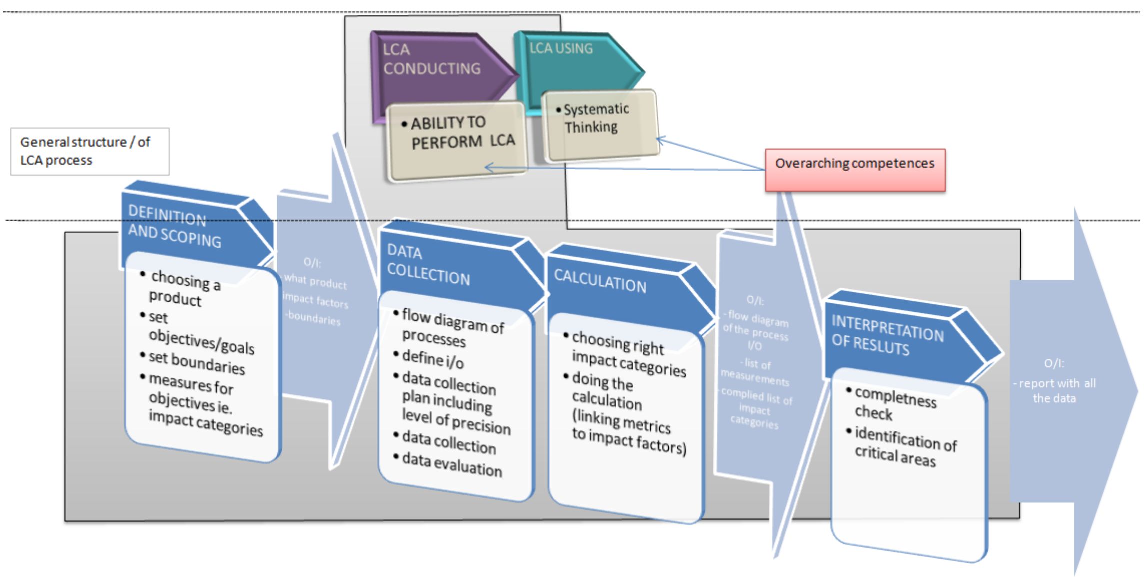

Figure 5-3 Conceptual map of LCA conducting

Also the designer group for each main step of LCA conducting process have generated another conceptual map to show the transactions between non-playable characters and user. In the following, we can see these maps for calculation and interoperation phases.

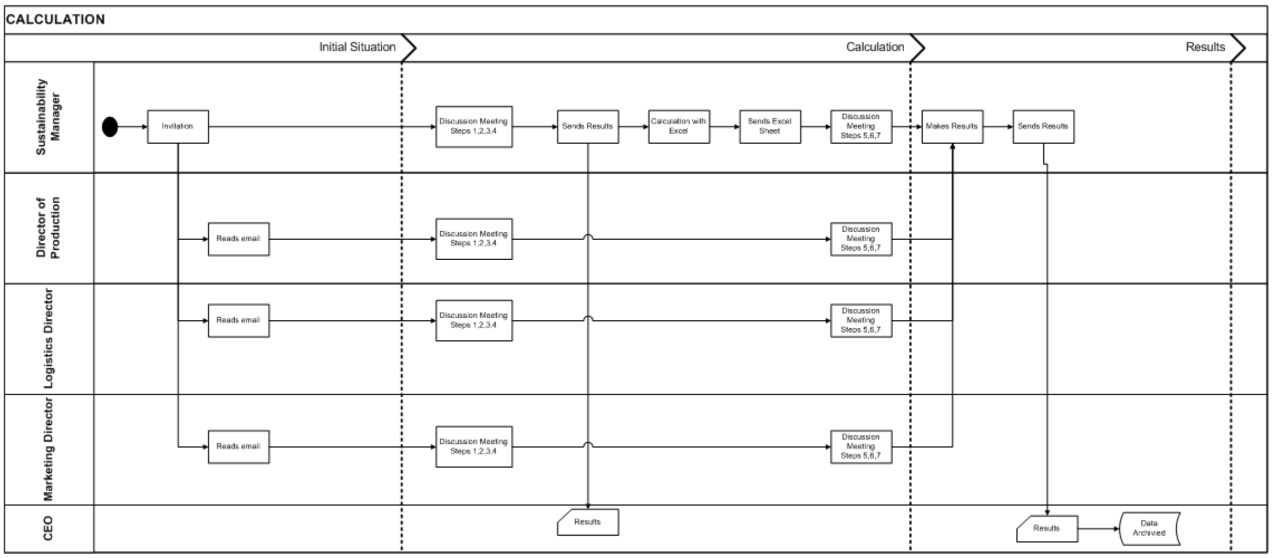

Figure 5-4 - The conceptual map for calculation phase

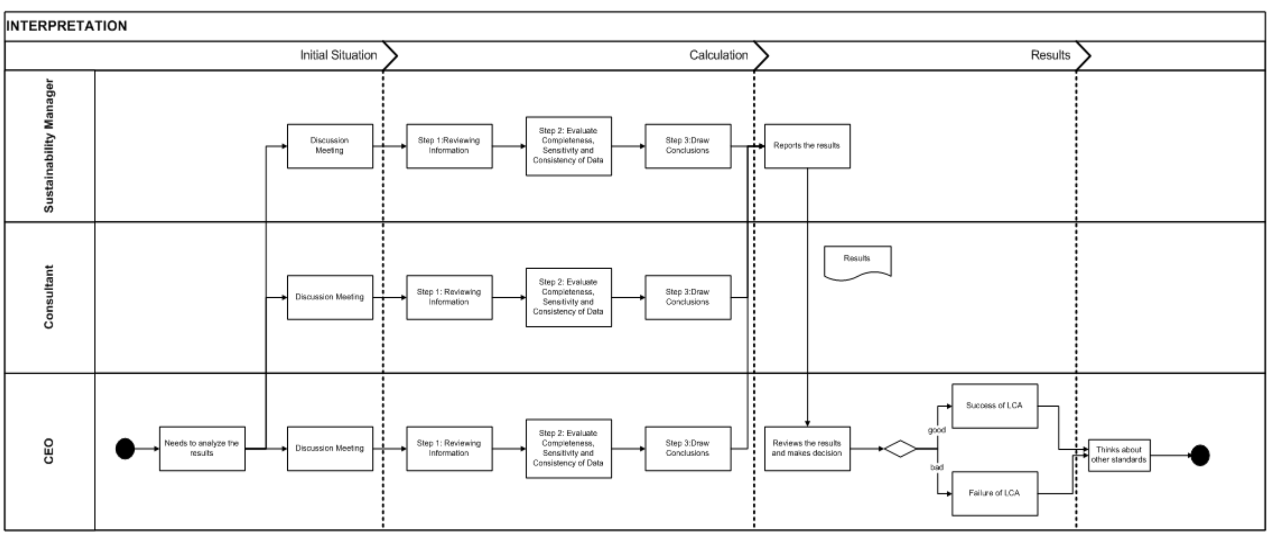

Figure 5-5 - The conceptual map for Interpretation phase

5.3.2 Break downing the overarching competence into critical incidents:

The critical incidents for the four main steps of LCA conducting which are definition and scoping, data collection, calculation and interpretation of results, are as follow:

Critical incidents for "Definition & Scoping" step

- Choosing a product
- Setting objectives/goals
- Set boundaries
- Measures for objectives for example impact categories

Critical incidents for "Data collection" step

- Drawing flow diagram of processes
- Defining input/output of flow diagram
- Data collection plan including level of precision
- Data evaluation

Critical incidents for "Calculation" step

- Choosing right impact categories
- Doing the calculation (linking metrics to impact factors)

Critical incidents for "Presentation and Interpretation" step

- Completness check
- Identification of critical areas
- Reporting

5.3.3 Defining the main task/decision(s) for each critical incident:

Once the critical incidents are defined it is time for identifing the main tasks and decisions to perform each critical incident. Each critical incident consists of certain number of tasks and a certain degree of complexity to making decisions. At the start, reaching the essence of the situation is recommended, so the designer team in order to prevent any non-value adding complexity in the game scenario decided to define only one main task for each critical incident and named them equal with the corresponding critical incident's name.

5.3.4 Exploring the various possibilities:

A number of possibilities defined for the main tasks and decisions by designer team were as follow:

- **Choosing a product**: according to hypothesis of game, product has been chosen by non-playable character of CEO.
- **setting objectives/goals:**
    - Setting them by player
    - Asking the CEO
    - Talking to the other managers asking directly about the goals
    - Talking to the managers asking about important issues and setting goals based on that information goals
- **Setting boundaries:**
    - Concentrating on one department like welding or assembly.
    - Concentrating on the production to reduce the complexity of game: concentration on production has supposed to be optimum solution.
    - Concentrating on the whole supply chain
    - Concentrating on the whole life cycle
- **Drawing flow diagram of processes**
    - Asking no one and drawing the flow diagram by him/herself
    - Asking production manager and shift managers for a meeting in order to draw a diagram
    - visiting shop floor: this can be done by watching a video from shop floor in the virtual environment
    - proceding by a Combination of:
        - ✓ Production manager interview
        - ✓ Shift manager 1 interview
        - ✓ Shift manager 2 interview
- **Defining input/output of flow diagram:**
    - Asking no one and defining input/output of the flow diagram by him/herself

- Asking production manager and shift managers for a meeting in order to find input/output
- visiting shop floor: this can be done by watching a video from shop floor in the virtual environment
- proceding by a Combination of:
  - ✓ Production manager interview
  - ✓ Shift manager 1 interview
  - ✓ Shift manager 2 interview

5.3.5 Identifying challenges to proceed each critical incident:

A list of possible challenges for conducting a standard LCA can be as follow:

- **Selecting the parameters of LCA:**

  Selection of parameters has direct impact on the result of LCA. A wrong choice of parameters can have negative impact on the overall Quality, Time and Cost of the LCA project. LCA player has the challenge of getting information from the right source of information. Player should choose from who he/she wants to get information.

- **Defining the scope of LCA**:

  Player needs to define the scope of LCA in order to outline how to proceed, make an efficient use of time and resources, the final results obtainment and better identification of boundaries. The system boundary determines which unit/department processes are included in the LCA and must reflect the goal of the project.

- **Precision of measures used for LCA parameters:**

  Player needs to define measurment units correctly. Any incorrect or biased data will lead to wrong result and at the end it would negatively impact on quality, time and cost indicators of project.

- **Identification of input/ output in each phase of process:**

  Determination of input/output in each phase will help player to better consideration of required data during each phase. The input are those things that must be present or happended before each phase can start. The output represents what has changed as a result of doning the activities. The out put of each phase is the input for the next phase and in that way we can link sections of processes together to form a larger end-to-end process.

Defining outputs and inputs for each phase is a good check of correct process flow.

- **Process definition:**

  Careful analysis of processes involved in the scope of LCA conducting need a careful definiton for these processes. Conversely, a random approach to check the processes in the scope of LCA, negatively impacts LCA conducting process. The main process in this area is Production process which needs a careful modelling. For modelling the desired processes the player needs to define following issues:

  ✓ The sequential activities to perform the process
  ✓ The needed inputs for each activity which can be raw material, information, energy, water or other kind of resources
  ✓ Outputs of each activity which can be a product, by-product, waste, scarp, heat, etc.

- **Impact catagories selection:**

  Determination and selection of the right impact categories for conducting LCA could optimistically influence the overall time, quality and cost of LCA project.

- **Data retrieval:**

  LCA process is based on data and player's ability to capture complete and accurate data is a source of advantage. The player needs to understand that the data availability has different types and according each type he/she needs to take a policy to get inforamtion accurately and completely.

  Different types of data availibility can be as follow:

  ✓ Data is already existing and available
  ✓ Data is already existing and not available
  ✓ Data is not available
  ✓ Data is kept by certain people in organization
  ✓ Data can be accessed during the meetings

- ✓ Data is available on the shop floor

- **Dynamically re-scoping when needed:**

  Players need to have ability to dynamically re-scope in the case of finding any insufficiency in the captured data.

- **Executing the process in the right/most efficient order:**

  In real word, there are many possibilities to conduct the LCA process. Finding the most efficient order is a challenge for player.

- **Ability to provide a complete report and analyze the results:**

Player needs to provide a complete report for top managers in accordance with the goals and scops of the project to communicate them effectively. Life cycle interpretation is the last phase of the LCA process. The player needs to *analyze* results, reach conclusions, explain limitations, and provide recommendations based on the findings of the preceding phases of the LCA, and to report the results of the life cycle interpretation in a transparent manner. He/ she needs to provide a readily understandable, complete, and consistent presentation of the results of an LCA study, in accordance with the goal and scope of the study.

5.3.6 Identifying typical mistakes that a novice make and their roots:

For each defined challenge, identification of corresponded typical mistakes that a novice will make must be identified and the reason must justify; why they would do it is necessary to determine.

In the following, we can see an overview of mistakes and their roots which a novice LCA user may confront:

- **Mistakes and root of mistakes in selecting the parameters of LCA:**

  <u>Mistakes in selecting the parameters of LCA:</u>

  - ✓ Choosing the wrong/too little/too much parameters
  - ✓ Unbalance between overal quality, time and cost of LCA conducting project
  - ✓ Choosing planned vs. real process execution facts

- ✓ Irrelevance of the parameters

<u>The root of mistakes in the selecting the parametes of LCA:</u>

- ✓ Not getting info from right source
- ✓ Misleading by other workers specially by managers
- ✓ Having no clear idea of overall LCA process
- ✓ Not balancing overall time, cost and quality when deciding the parameters

- **Mistakes and root of mistakes for defining the scope of LCA**:

<u>Mistakes in defining the scope of LCA</u>:

- ✓ Broad/focused boundaries
- ✓ Wrong/not relevant LCA impact categories

<u>The root of mistakes in defining the scope of LCA:</u>

- ✓ No clear idea about the goal of the LCA project
- ✓ Having no clear idea of overall LCA process
- ✓ Not getting info from right source
- ✓ Misleading by other workers specially by managers
- ✓ Not balancing overall time, cost and quality when deciding the parameters

- **Mistakes and roots of mistakes in the precision of the measurs used for LCA parameters:**

<u>Mistakes in precision of the measures:</u>

- ✓ Incorrect use of measurement units
- ✓ Incorrect unit of measurement
- ✓ Biased measurements
- ✓ Focus too much/ too less on data precision

<u>The root of mistakes in precision of the measures:</u>

- ✓ Lack of precision of player
- ✓ No clear idea on importance of accuracy of unit of measurements in final result

- ✓ misleading by other workers

- **Mistakes and roots of mistakes in identification of input/ output for each phase of process:**

<u>Mistake in identification of input/output for each phase of process</u>

- ✓ Mistakes in identification of input/output for each phase of process

<u>The roots of mistake in identification of input/output</u>

- ✓ Lack of holistic view of interviewed person: usually people knowledge does not cover overall end-to-end processes
- ✓ Lack of holistic/systematic view of player
- ✓ Incomplete definition of the product production process

- **Mistakes and the roots of mistakes in process definition:**

<u>Mistake in process definition:</u>

- ✓ Mistake in defining the process sequential activities
- ✓ Mistakes in finding the input elements of each activity and function in the process
- ✓ Mistakes in determining the outputs of each activity and function in the process
- ✓ Mistakes in identifying the needed resources

<u>The roots of mistakes in process definition:</u>

- ✓ Very seldom one person can cover the whole process. Getting info from only one person can cause incomplete process definition.
- ✓ Sitting in the office instead of going to the shop floor.
- ✓ Misleading by managers about the planned process which is usually different from the real process execution

- **Mistakes and the roots of mistakes in selection of impact categories:**

<u>Mistakes in selection of impact categories:</u>

- ✓ Mistakes in selection of right impact categories according to scope and goals

- ✓ Choosing too much categories
- ✓ Choosing too less categories

<u>The roots of mistakes in selection of impact categories:</u>

- ✓ Player have a wrong idea of each impact category
- ✓ Player has focused too much/too less in details of each impact category

- **Mistakes and the roots of mistakes in Data retrieval:**

<u>Mistakes in data retrival:</u>

- ✓ Mistakes in capturing the needed data

<u>The roots of mistakes in data retrival:</u>

- ✓ Player has no idea of availability of data
- ✓ Player has problem in interacting with involved people and getting information from them
- ✓ Player just conduct desk work instead of shop floor visit
- ✓ Player interviews with wrong person
- ✓ Players interviews with not adequate number of peoples
- ✓ Player interview with not appropriate combination of peoples in meeting

- **Mistakes and roots of mistakes in dynamically re-scoping:**

<u>Mistake in dynamically re-scoping</u>

- ✓ Mistake in rescoping the process of cunducting LCA in dynamical manner when needed.

<u>The root of mistakes in re-scoping:</u>

- ✓ Player changes her/his mind too frequently
- ✓ Players do not re-scope when needed
- ✓ Player cannot determine insufficiency of captured data

- **Mistakes in executing the process in the right/most efficient order:**

  <u>Mistakes in executing the process:</u>

  ✓ Mistake in doing the process in right order

  <u>The roots of mistake in executing the process in right order</u>

  ✓ Player has not ability to find most efficient order

  ✓ Player has narrow view and cannot see the different possibilities to conduct each phase

- **Mistakes and roots of mistakes in providing a complete report and analyzing the results**

  <u>Mistakes in providing a complete report</u>

  ✓ Deriving wrong conclusions

  ✓ Report is beyond the scope and goals

  ✓ Report is below the scope and goals

  ✓ Focus only on environmental issues

  ✓ Focus on too much categories

  <u>The roots of mistakes in providing a complete report:</u>

  ✓ The player has no ability to provide a report appropriate to top management level

  ✓ The player has narrow view an can not see the different issues to report

  ✓ The player has no ability to analyze

  ✓ The data used to analyze were wrong and insufficient data

5.3.7 Defining the characters involved in critical incident:

The background story which is chosen to use in the serious game scenario in TARGET project is about a company named “Honeypot”. Honeypot Company has activities worldwide with an investment holding company supporting 21 active Honeypot subsidiaries and joint venture within China.

The company products are heaters, boilers and other home appliances and recently extended to domestic systems and related service.

The turnover of company is around 30,908 millions $.

The initial state

The company has moved part of the production to China where the first investments started 10 years ago. Other parts of the production are still in Europe. Regarding costs it has been a good decision. Quality of products is slightly lower compared to Europe, but slightly affects the sales. The image of the company in terms of sustainability is not good on European market because of some scandals on journals. Due to this fact the market share is slowly decreasing.

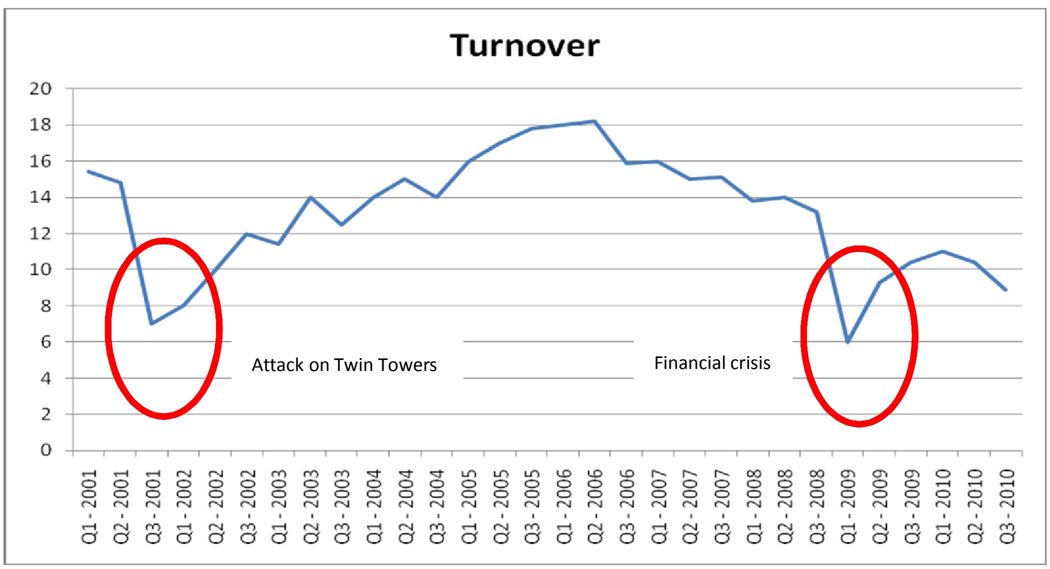

Figure 5-6 - An overview of Honeypot Company's turnover

Story background

The CEO wants to get into the green market due to huge opportunities in this market. He is thinking also to regulations that are going to be in place.

The CEO thinks that sustainability is an opportunity for entering green products market. So he decided to hire a SUSTAINABLE MANAGER (**player**) to delegate the issue.

The hierarchy model of decision making structure in the company is as follow:

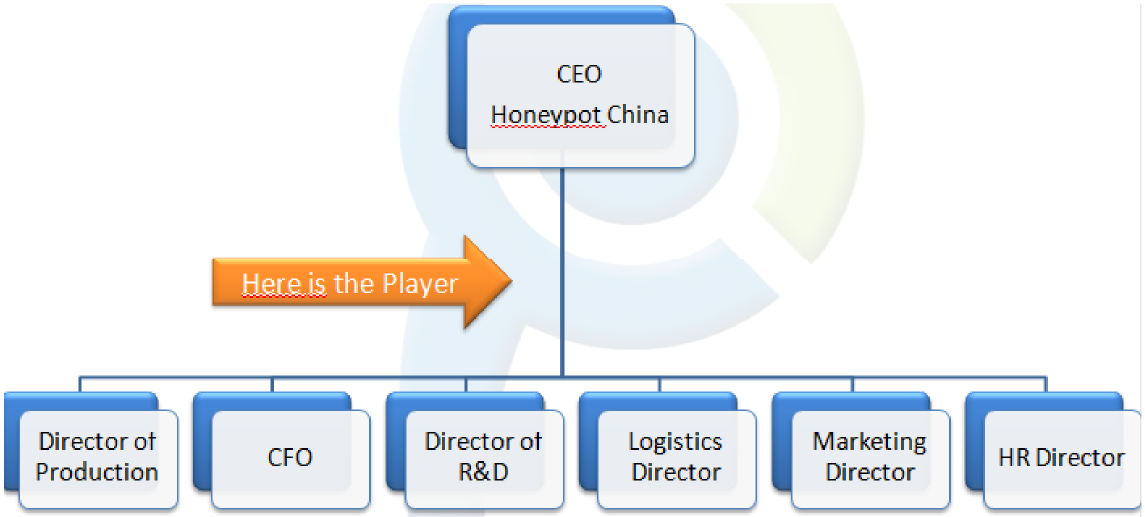

Figure 5-7 - Decision making structure in the Honeypot Company

According to this structure The Player has the responsibility of sustainability development of the company, but he doesn't have the formal Authority and Accountability to act.

Characters involved in the game:

The different characters have different:

- ✓ Aims (theoretical)
- ✓ Position (what do you state publicly)
- ✓ Interest (what he really thinks)
- ✓ Attitudes
- ✓ Measured performances
- ✓ Budget
- ✓ Relation with CEO
- ✓ background

According to the mentioned criteria the characteristics of each character in the game are as follow:

CEO's charecteristics:

- ✓ **Aims (theoretical):** the company has to make more money.
- ✓ **Position**: we have to go green because it's an opportunity for us and our responsibility toward future generations.
- ✓ **Interest**: I want to go green, have that marketing advantage, but I want to spend little money and do low investment.
- ✓ **Attitudes**: visionary with no time, delegates but doesn't support the player because no time.
- ✓ **Measured performances**: profitability of the company (income-costs)
- ✓ **Relation with CEO**: -
- ✓ **Background**: His role will evolve during the game.

Production manager's characteristics:

- ✓ **Aims:** run the production smoothly, efficiently at lower cost possible with higher quality possible.
- ✓ **Position**: agrees on company strategy (what the CEO says); I'm responsible for everything at the end of the day, since the company lives on the production!
- ✓ **Interest**: self centered, goes for himself. He wants to become the CEO, manifest his position among the others, BE THE ONE!!!
- ✓ **Attitudes**: fire fighting, no time to implement new things, fed up from previous improvements programs, fights for the position, ambitious, power driven.
- ✓ **Measured performances**: profitability of the production, efficiency, quality.
- ✓ **Relation with CEO**: difficult; he's powerful, he runs the production, the CEO needs him, so he leverages on that.
- ✓ **Background**: He will start against the sustainability program (useless bullshit).

Marketing manager's characteristics:

- ✓ **Aims:** Selling more
- ✓ **Position**: it's easy to manufacture, the difficult part is selling!
- ✓ **Interest**: he wants that marketing is recognized as the most important function in the company and being the right hand of the CEO.
- ✓ **Attitudes**: narcissistic, creative, open, sociable
- ✓ **Measured performances**: number of sales, number of contacts.
- ✓ **Relation with CEO**: friendly and open.
- ✓ **Background**: He is for sustainability! He likes the new guy. He hates the production manager, latent conflict; he does not produce what is really needed and disregards his opinion.

CFO's characteristics:

- ✓ **Aims:** make sure financial reports etc. are done correctly. Measures and control the turnover.
- ✓ **Position**: we have to control and keep the budget clear and controlled.
- ✓ **Interest**: no news means good news, I don't like surprises.
- ✓ **Attitudes**: precise, conservative,
- ✓ **Measured performances**: the correctness of financial reports, order, turnover, profit.
- ✓ **Relation with CEO**: loyal
- ✓ **Background**: A little scared of the new sustainability thing. He wants to go slowly with small changes. He is scared by costs, interested by the opportunity.

<u>R & D director's characteristics:</u>

- ✓ **Aims:** create innovation, new products and opportunities
- ✓ **Position**: we can take the company new directions, but we don't have enough money to work on our brilliant ideas!
- ✓ **Interest**: he wants his ideas to be realized and successful
- ✓ **Attitudes**: wants prestige, all the company must admire his brilliant ideas; he wants a smart team with him, delegates.
- ✓ **Measured performances**: lead time, number of projects, ROI
- ✓ **Relation with CEO**: tension but common vision
- ✓ **Background**: he likes the idea of sustainability. It will need lots of innovation! He likes the marketing guy, even if he thinks he is an idiot. Good but cold relations with production guy.

<u>Logistic managers' characteristics:</u>

- ✓ **Aims:** ensuring internal logistics functionality
- ✓ **Position**: our logistics service is one of the best in the company
- ✓ **Interest**: I want to stay in my position and retire in 8 years
- ✓ **Attitudes**: protecting his unit, very satisfied with job, I've done a lot for a company, so what can I do more?
- ✓ **Measured performances**: delivery time, inventory level
- ✓ **Relation with CEO**: working 25 years together, close connection
- ✓ **Background**: He likes the idea of sustainability, but no modification in his area! He hates the production manager due to conflict on deliveries, and the R&D manager is his best friend.

HR manager's characteristics:

- ✓ **Aims:** find best human capital for company and improving competencies of employees
- ✓ **Position**: We should invest in our employees also during downfalls
- ✓ **Interest**: keeping employees
- ✓ **Attitudes**: big mama, very social
- ✓ **Measured performances**: employee growth rate, amount of training programs
- ✓ **Relation with CEO**: hate and love
- ✓ **Background**: he likes the idea of sustainability, because it has a social dimension! He wants budget for training employees.

The role of each of the non-playable characters partially has been defined by the designer team.

5.3.8 *Defining* the learning outcomes of each critical incident

The corresponding outcomes for each critical incident in the game scenario have been shown in table below:

Critical Incident	Outcome
Setting objectives and goals	Reporting the objectives to the CEO
Setting boundaries	Filling in the boundaries/scope of LCA to virtual tool (software)
Production process's Flow chart definition	Completed flow diagram with Input/Output
Input/Output definition	Flow chart with only relevant Input/Output circled in red
Data collection	Input to LCA tool (software)

Choosing Impact Categories	Input to LCA tool (software) and automatic calucaltion
Interpretation of results	LCA Report

Table 5-1 – the learning outcome of each critical incident

5.3.9 Finding how the transition from one critical incident to other take place

By considering the critical incident in line with the others, how the transition from one to other may take place is exposed, and the probable precedence is defined. If so, the results and consequences of not following the correct order by user will appear.

The general precedence of activities of LCA conducting process with the different possibilities for activities is shown in the following flow chart:

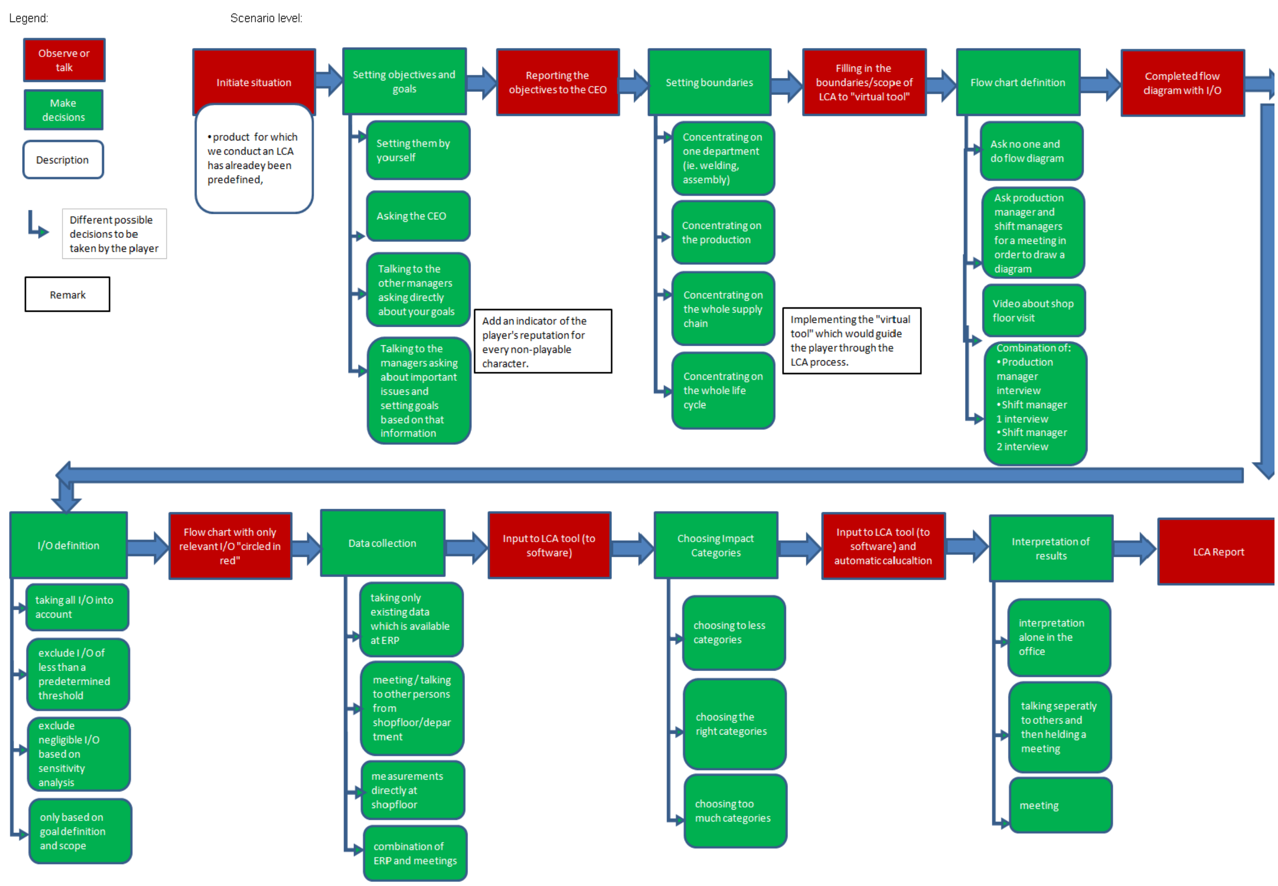

Figure 5-8 The LCA conducting process

5.4 Defining performance indicator for main activities of each critical incident

According to main challenges, corresponding possible mistakes and their roots, a set of performance indicators has been defined to assess the performance of the user. The indicators measure the effect of the performing specific activity on overall time, cost and quality of the process conduction. A specific flow of activities is defined as the optimum route and any deviation from this route must be measured. This route is what an expert user would follow for conducting the process.

The effect of task/decision on overall Time=T, Cost=C and Quality=Q is also illustrated beside some of the task/decision. Optimum solution has no increase or decrease in T, C and Q. (T=−, C=−, Q=−)

- **Choosing a product**: according to hypothesis of game, product has been chosen by non-playable character of CEO.
- **setting objectives/goals:**
  - Setting them by player (T=↘, C=↘, Q=↘)
  - Asking the CEO (T=↗, C=↗, Q=−)
  - Talking to the other managers asking directly about the goals (T=↗, C=↗, Q=↘)
  - Talking to the managers asking about important issues and setting goals based on that information goals (T=↗, C=↗, Q=↗)
- **Setting boundaries:**
  - Concentrating on one department like welding or assembly. (T=↘, C=↘, Q=↘↘↘)
  - Concentrating on the production (T=−, C=−, Q=−)
    To reduce the complexity of game concentration on production has supposed to be optimum solution.
  - Concentrating on the whole supply chain (T=↗↗, C=↗↗, Q=−)
  - Concentrating on the whole life cycle (T=↗↗↗, C=↗↗↗, Q=↗)
- **Drawing flow diagram of processes**
  - Asking no one and drawing the flow diagram by him/herself (T=↘, C=↘, Q=↘↘↘)

- Asking production manager and shift managers for a meeting in order to draw a diagram (T=↘, C=↘, Q=↘)
- visiting shop floor: this can be done by watching a video from shop floor in the virtual environment (T=↘, C=−, Q=↗)
- proceding by a Combination of: (T=−, C=−, Q=−)
  - ✓ Production manager interview
  - ✓ Shift manager 1 interview
  - ✓ Shift manager 2 interview

- **Defining input/output of flow diagram:**
  - Asking no one and defining input/output of the flow diagram by him/herself (T=↘, C=↘, Q=↘↘↘)
  - Asking production manager and shift managers for a meeting in order to find input/output (T=↘, C=↘, Q=↘)
  - visiting shop floor: this can be done by watching a video from shop floor in the virtual environment (T=↘, C=−, Q=↗)
  - proceding by a Combination of: (T=−, C=−, Q=−)
    - ✓ Production manager interview
    - ✓ Shift manager 1 interview
    - ✓ Shift manager 2 interview

5.5 The proposed LCA game scenario

The LCA game scenario after carrying out all of the steps in the proposed methedology is as follow: (it is necessay to mention that some of the activities has been reiterated due to some feedbacks after the evaluations time by time by the desinger group)

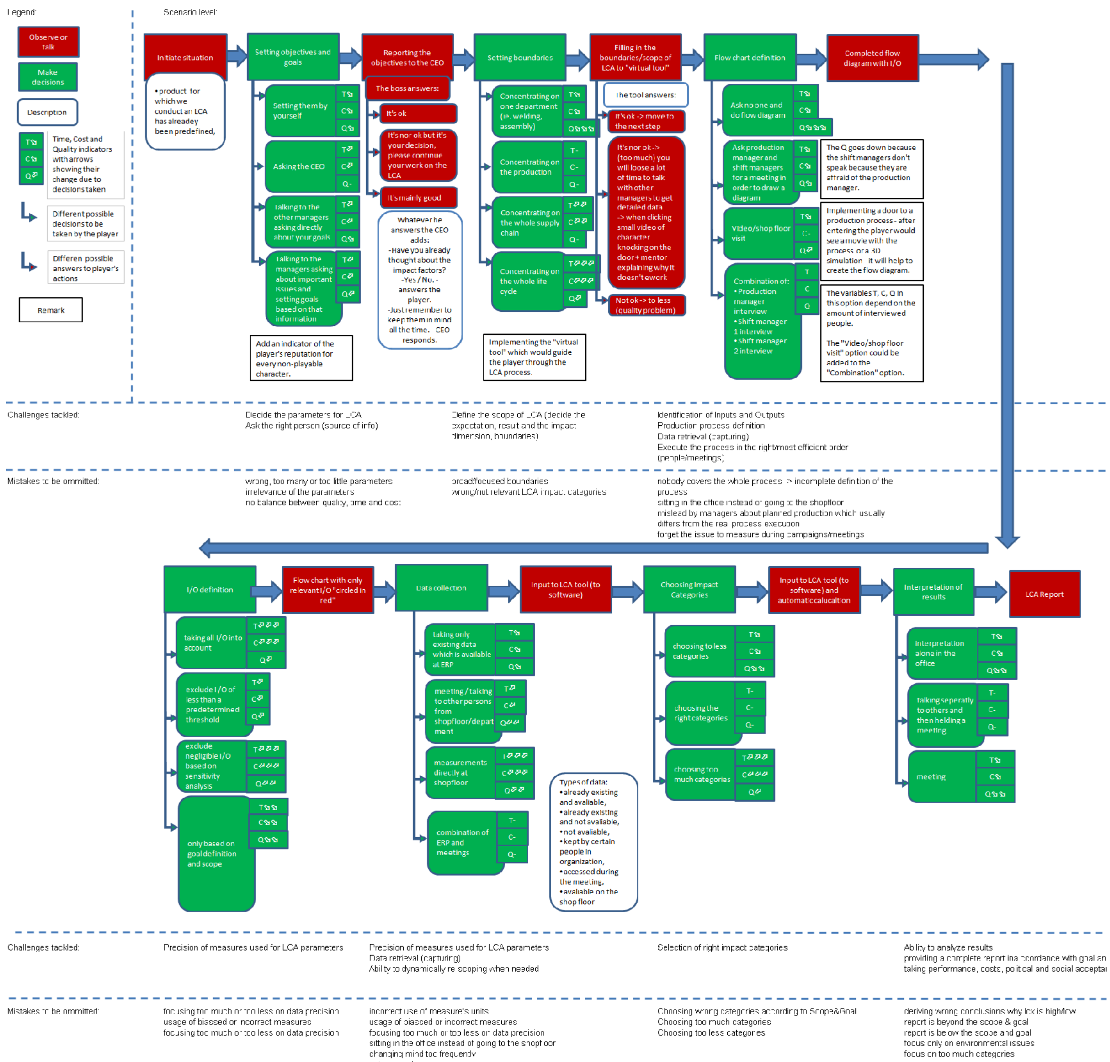

Figure 5-9 proposed LCA game scenario flowchart

6 Conclusion

As previously described in the research objective there is a lack of developed serious games on the domain of sustainable manufacturing as a tool of rapid competence development in this field.

This research mainly tries to help the designers of serious game scenario to prevent try and error approach and gives them a methodology as guidelines in scenario development process to have more agility.

As mentioned before, the applicability of the proposed methodology is tested through application of it in the development of the serious game scenario in the TARGET project for LCA conducting.

However, the real validation of the proposed methodology will take place in the constant application of these guiding principles in scenario development activities in the domain. Also for identification all missing elements using the end resulted serious game by real users is needed. Only in this way we can understand how to improve this methodology.

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