Mediating skills on risk management for improving the resilience of Supply Networks by developing and using a serious game

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Preface

Given their importance, the need for resilience and the management of risk within Supply Networks, means that engineering students need a solid understanding of these issues. An innovative way of meeting this need is through the use of serious games. Serious games allow an active experience on how different factors influencethe flexibility, vulnerability and capabilities in Supply Networks and allow the students to apply knowledge and methods acquired from theory. This supports their ability to understand, analyse and evaluate how different factors contribute to the resilience. The experience gained within the game will contribute to the students' abilities to construct new knowledge based on their active observation and reflection of the environment when they later work in a dynamic environment in industry.

This game, Beware, was developed for use in a blended learning environment. It is a part of a course for engineering master students at the University of Bremen. As a result of regular use and testing in courses, it has been regularly improved using the design principle of co-creative design and agile prototyping. It is a facilitated, process driven, role play, multi-user (9) simulation game comprising two levels. The first tests with the initial game were carried out in 2006 and 2007, and the first redesigned game has been in use since 2007. The facilitator has a monitoring tool, which allows him/her to monitor the game without taking an active part in the game. It also offers the possibility of actively controlling the game by setting events. The facilitator can also communicate with the players It was found that the game was effective in mediating the topic of risk management to the students espscially in supporting their ability of applying methods, analyse the different interactions and the game play as well as to support the assessment of how their decision-making affected the simulated network. In the first rounds, the game did not so much support the creation of new knowledge, this took mostly place in the debriefing, but with a better in-game feedback and the implementation of a facilitator tool, also this congnitive level was supported.

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DEUTSCHE ZUSAMMENFASSUNG

Aufgrund der zunehmenden Globalisierung, des damit steigenden Wettbewerbs, sowie der verkürzten Lebenszyklen von Produkten, müssen sich Unternehmen kurzfristig auf Veränderungen des Marktes einstellen. Darüber hinaus fordert die Herstellung komplexerer Produkte in immer kürzerer Zeit hohe Anforderungen an die Bereitstellung spezifischen Wissens, welches oft nicht unternehmensintern zur Verfügung steht, so dass Kooperationen eingegangen werden müssen. Damit steigen die Anforderungen an die Geschwindigkeit mit der die Organisation notwendige Informationen und Daten an ihre Mitarbeiter und Kooperationspartner bereitstellen kann.

Unternehmensnetzwerke unterliegen einer erhöhtenStöranfälligkeit. Selbst Störungen, die zunächst nur eine Organisation der Supply Chain betreffen, haben meist direkte Auswirkungen auf das gesamte Netzwerk. Diese Störanfälligkeit wird laut Jüttner et al. (2003) (1) durch eine stärkere Fokussierung auf die Effizienz anstelle der Effektivität, (2) die Globalisierung von Supply Chains sowie (3) eine zentralisierte Produktion und Distribution verstärkt. Darüber hinaus kann festgestellt werden, dass Risiken für Unternehmensnetzwerke „nicht identisch mit der Summe der Risiken der an ihr beteiligten Unternehmen sind" (Kajüter 2003a, S. 112). Zu einer komplexen Aufgabe wird das unternehmensübergreifende Risikomanagement außerdem durch Besonderheiten, die sich durch die Struktur einer Supply Chain ergeben: Zwischen den beteiligten Organisationen bestehen Informationsasymmetrien, und jede Organisation hat ein eigenes Risikoverständnis. Darüber hinaus ist das Risikomanagement in Supply Chains noch nicht ausreichend entwickelt und es existieren wenige ganzheitliche Ansätze. Diese Umstände stellen besondere Anforderungen an zukünftige Mitarbeiter in einem Unternehmensnetzwerkes.

Die Arbeit beschäftigt sich deswegen mit drei Fragen: (1) Welche Kompetenzen sind nötig um das Risiko in Unternehmensnetzwerken identifizieren, bewerten und ggf. Maßnahmen zur Minimierung der negativen Auswirkungen zu etablieren? Diese werden mit Hilfe von Literaturstudien und Untersuchungen mittels Fragebogen identifiziert. Im nächsten Schritt wird dann auf die Frage eingegangen, (2) wie diese identifizierten Kompetenzen vermittelt werden können. Hierzu werden unterschiedliche Lernparadigmen auf ihre Eignung hin untersucht. Basierend auf einer Recherche über gängige Strategien zur Kompetenzvermittlung für komplexe, dynamische Systeme wird ein Blended Learning-Ansatz, unter Nutzung eines simulationsbasiertes Lernspiels, als am besten geeignet eingestuft. Dies führt zur letzten Frage der Arbeit: (3) Wie muss das Angedachte konzipiert werden, um den Teilnehmern die Möglichkeit zu geben, durch spielerisches Erleben das Verhalten und die Entstehung von Risiken in Unternehmensnetzwerke zu verstehen und Kompetenzen zu entwickeln, um diese zu managen? Eine web-basierte Multi-Player Plattform wird hierfür als am besten geeignet angesehen. Daraufhin wurde ein Prozess-gesteuertes Spiel entsprechend adaptiert.

Als Maßstab zur Evaluierung des gewählten Ansatzes, inklusive des Spiels, diente der Lernfortschritt. Im Rahmen der über längere Zeit durchgeführten Evaluierung, wurde das Spiel um einige Funktionalitäten sowie ein Monitoring-Werkzeug ergänzt. Die formativen Evaluierungsergebnisse haben auch zu Änderungen im Kursaufbau geführt, bis die Lernfortschritte zufriedenstellend waren.

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ABET	Accreditation Board for Engineering and Technology
BIBA	Bremer Institut für Produktion und Logistik an der Universität Bremen
BIG	Beyond information given
CISD	Contextualized Interactive Story Driven Development
CMPG	classroom multiplayer presential game
COTS	Commercial of the shelf
DAV	Deutsche Außenhandels und Verkehrsakademie
DeGEval	Deutsche Gesellschaft für Evaluierung
DLA	Deutsche Logistik Akademie
DSS	Decision support system
Supply Network	Enterprise networks
ETA	Event tree analysis
FERMA	Federation of European Risk Management Associations
FTA	Failure tree analysis
GBL	Gamebased learning
GM	Game mechanics
GUI	Graphical user interface
HIWL	Hochschule für International Wirtschaft und Logistik
ICE	International Conference on Engineering, Technology and Innovation
ICT	Information and communication technology
IS	Information System

ISL	International Symposium on Logistics
ISO	International Standard Organisation
IT	Informationtechnology
JOT	Job orinented training
KPI	Key performance indicators
LAMP	Linux Apache-web server, MySQL; PHP
LM	Learning mechanics
MIS	Management information systems
NAE	National academy of engineering
OEM	Original equipment manufacturer
PBL	Problembased learning
PRO-VE	IFIP working conference on Virtual Enterprises
RA	Risk assessment
RCT	Random
RFID	Radio frequency idnetification
RI	Risk Information
RM	Risk management
R&D	Research and development
Supply Chain	Supply Chain
Supply ChainM	Supply chain management
Supply ChainRM	Supply chain risk management
SECI	Socialization, Externalization, Combination, Internalization

SG	Serious games
SGM	Serious games mechanics
Supply Network	Supply network
SPGQ	social presence in gaming questionnaire
SS	Summer term
SWOT	Strength weakness opportunity threat
WAMP	Linux Apache-web server, MySQL; PHP
WS	Winter term
XML	Extendable mark-up language

1 Introduction

During the research, parts of the text have been published in [1, 3, 5-8, 12, 14, 18, 20, 22-24, 27, 30, 38-40]. These are listed in chapter 12.

This thesis is an investigation of the value brought by the use of serious games for teaching engineering students the principals of risk management, decision-making, communication, collaboration and cooperation within Supply Networks.

This introduction reviews the importance of Supply Networks, the need for resilient networks, and why they are important nowadays. Given their importance, the need for resilience and the management of risk within supply networks imply that engineering students must have a solid understanding of how vulnerabilities and risks occur, how they affect and behave in Supply Networks. Furthermore, they need to learn how to manage these in dynamic systems. An innovative way of meeting this need is by using serious games. Serious games allow an active experience on how different factors affect the resilience in Supply Networks. They allow students to apply knowledge and methods acquired from theory on Supply Network resilience. The use of serious games supports their ability to understand, analyse and evaluate how different factors contribute to resilience through active participation. The experience gained within the game will contribute to the students' abilities to construct new knowledge based on their active observation and reflection of the environment when they later work in a dynamic environment in industry.

1.1 Motivation

Manufacturing today is a complex process, involving several stakeholders, often located around the world [Wiendahl & Lutz, 2002;Braziotis & Tannock, 2011], forming Supply Chains or Supply Network. Supply Chains and Supply Network have several commonalities, but also some differences. In general, it can be stated that Supply Networks are more complex, non-linear and dynamic than Supply Chains. Regarding the vulnerability and the resilience of Supply Chain and Supply Network, it is therefore reasonable to assume that Supply Networks are even more vulnerable than Supply Chains, since there is a higher need of trust, with less planned integration leading to less predictability. However, even though the complexity and non-linearities are higher, it can be said that Supply Chains can be seen as a Supply Network with reduced complexity and vulnerability [Braziotis et al., 2013]. In this work, I will therefore only use the term Supply Network, unless a differentiation is required.

The goal of a Supply Network is the optimisation of logistical and production processes [Jüttner, 2005; Pfohl, 2002]. Contemporary supply Networks are becoming longer, leaner and more brittle [Christopher & Peck, 2004], involving more cooperation and collaboration [Barrat, 2004; Braziotis & Tannock, 2011]. Due to the large number of involved entities, Supply Network are becoming more vulnerable and inflexible with increased probability for occurring risks of higher costs and reduce the reliability of on-time deliveries [Jüttner, 2005; Peck, 2003; Pfohl, 2002;Sørensen, 2005]. Thus, companies are looking for solutions for reducing the impact of such risks [Bratziotis&Tannock, 2011; Pettit, Fiksel, & Croxton, 2010].

In strategic management, resilience has been defined as a process capability [Fiksel, 2003; Reinmoeller & Van Baardwijk, 2005]. Resilience can be defined as "the capability to self-renew over time through innovation" [Reinmoeller & Van Baardwijk, 2005, p. 61]. Christopher and Peck [2004] provide another definition distinguishing between robustness and resilience. They define resilience as "the ability of a system to return to its original state or move to a new more desirable state after being disturbed" [Christopher & Peck, 2004, p. 2], which is similar to the definition of Fiksel - "the capacity of a system to tolerate disturbances while retaining its structure and functions" [Fiksel, 2003 online]. Based on these definitions, it can be concluded that it is necessary that the stakeholders take a proactive role from beginning when forming resilient Supply Networks. According to Pettit et al. [2010] and Peck [2003], a proactive configuration of resilient Supply Networks can be supported by a management being aware of risk management strategies and is able to identify and assess the different types of risks in a network. Factors specifically affecting the resilience of Supply Chains are globalisation of the network, specialised factories, centralised distribution, increased outsourcing, reduced supplier base, increased volatility of demand, and technological innovation [Christopher & Peck, 2004; Jüttner, 2005; Pettit et al., 2010, p. 2].

In order to be able to build resilient Supply Networks, a technical infrastructure that allows data collection and information exchange needs to be in place [Braziotis et al., 2013]. In Supply Networks, organisations cooperate and collaborate with each other. Based on previous organisational experience and different viewpoints, specific decisions are made that affect the resilience of an organisation. Pro-activeness requires that an employee analyses and assesses the information available and makes decisions based on this [McDonough, 2000]. The decision-making process can involve several persons coming from different business units or different companies, and thus Supply Network risk management is trust based [Webber, 2002] and often involves teams with different knowledge [Christopher & Lee, 2004; Jüttner, 2005; Manuj & Mentzer, 2008]. The aim is to have an holistic view on all risks, and also to take different risk perceptions and risk tolerances into account [Jüttner, 2005]. The decision made influence both the organisation itself and partner organisations [Barrat, 2004]. Thus, for complex systems, it is less a question of finding the one single optimal solution, but rather finding a suitable solution minimising threats and strengthening opportunities in a given place and time [Jüttner, 2005]. This corresponds to thoughts from organisational leadership. Cotu [2002, p.1 online] refers to a statement made by Dean Becker: "More than education, more than experience, more than training, a person's level of resilience will determine who succeeds and not". The next section analyzes which skills are likely to be relevant and how an educational institution can support the development of resilient leaders, and the challenges in the education of these future employees.

1.2 Problem statement

Supply Networks (SN) are complex and the information and data exchange take place at different levels. Braziotis et al. [2013] conclude that there is a need for a holistic information management for Supply Network. Oosterhout [2008] introduces three different levels in order to explain the complexity of modern Supply Networks. The **bottom level** comprises the physical flow of material. At this level, different tracking and tracing technologies can be used, in order to collect data from different stakeholders. Depending on the involved systems' interoperability and the will of the organisations to share data, other partners may reuse this data to reduce the risk of occurrence of unexpected events. Examples of the technologies currently in use are: electronic seals, RFID, sensor networks, etc.used to collect relevant data. Regarding the resilience, at this bottom level this would be more in line with the Information Technology (IT) terminology, in which resilience describes the system's ability to cope with errors during execution - i.e. the robustness of the system [Christopher & Peck, 2004]. The **transaction level** looks at the information flow. At this level, the main topic is Supply Network visability. This is still very poor, since often only the first, eventually also second tiers have access to the relevant information given by the OEM, thus challenges are often related to data access and exchange, as well as integration [Christopher & Peck, 2004; Pfohl, Köhler, & Thomas, 2010]. At the **governance layer**, the focus is on monitoring and assessing the information and material flows. At this level, there is a need for methods for identifying, assessing, managing and monitoring risks. However, the stakeholders (suppliers, authorities, logistic and infrastructure service providers, manufacturers, customers, etc.) do frequently have different risk perceptions and tolerances (compare section 2.1), which may influence the risk treatment and mitigation strategies. Furthermore, there is often an asymmetric information flow between participants leading to different possibilities of identifying and monitoring risks. Furthermore, since most stakeholders are involved in different, often global Supply Networks, they will have different interests [Kajüter, 2003; Kajüter, 2007; Jüttner, 2003].

In addition to the business complexity, a number of behavioural factors come into play and make the challenges that an organisation faces even larger. First, the bounded rationality of the economic actors [Simon, 1997] is a supplemental element, which exacerbates the situation. Second, decision makers, as is typical with human beings, are prone to the misperception of feedback [Sterman, 1989]. This means that their performance in complex and dynamic systems is hindered by nonlinearities, time delays and feedback structures [Sterman, 1989]. Third, decision-making in dynamic systems is hard because it calls for dynamic decision making, that is, a stream of decisions closely depending on one another. Last, decision makers are also limited by the magic number seven plus or minus two [Miller, 1956]. This number sets the maximum number of pieces of information, which people can consider simultaneously while evaluating a problem.

Dynamic systems such as Supply Networks compel their workforce to be faced with ever-changing working environments [Baalsrud Hauge, 2006]. Preparing an organisation for the new requirements requested by dynamic networks is therefore not only a matter of finding suitable technical solutions, but also of qualifying the employees and preparing organisational structures. Successful co-operation relies much on the ability of the participating organisations to learn and to act in a dynamic environment. Such a living and learning organisation can be characterized by the possibility and space for the development of creativity and individuality in and outside the organisation [Fuchs- Kittowski & Rosenthal, 1998]. As the employee is the person in an organisation that performs collaboration, the organisation's success will mainly depend on his/her capabilities to learn and act in a dynamic environment [Windhoff, 2001]. However, the complexity in Supply Networks makes it difficult to predict the impact of decisions made. Consequently, future Supply Network managers need to be trained in making decisions under uncertainty and to reflect on how these decisions impact on the Supply Network [Manuj and Sahin, 2011]. Typical risks for Supply Networks are related to collaboration, connectivity, information sharing, and communication, etc. [Peck, 2005; Pfohl, Gallus, & Köhler, 2008; Sheffi, 2005; Waters & Donald, 2007]. This requires that employees working at different levels at the stakeholders' sites in the Supply Chain are able to operate in a dynamic environment and to understand the impact of their decisions and actions both within their organisation and on their partners. Consequently, educational institutions need to aim at preparing their students as best as possible for these dynamic working environments and to give them the opportunity to acquire risk management skills during their studies.

Within business schools, knowledge transfer is often based upon research rather than practice [Starkey & Tempest, 2005]. For students, management of Supply Networks is mostly addressed at a theoretical level. However, the literature reports some difficulties in delivering and developing knowledge applicable in dynamic environments in traditional lecturing [Cheville & Bunting, 2011; Denny Davis, Beyerlein, Thompson, Gentili, & Mc Kenzie, 2003; Kerns, Miller, & Kerns, 2005], so other teaching methods and tools targeting direct participation of the students are increasingly used [Chryssolouris & Mavrikios, 2006; O'Sullivan et al., 2009 Baalsrud Hauge et al., 2012a]. Game-based learning (GBL) [Ebner & Holzinger, 2007; Gee, 2003; Prensky, 2003] has been introduced in several engineering and business schools. GBL has the advantages of simulating realistic contexts; it is experiential – allowing the students to learn through experience, to experiment with different decisions and to learn from the resulting feedback. The games used for this purpose, often called serious games, are games that educate, train and inform [Michael & Chen, 2006]. The term Serious Gaming was coined by David Rejeski and Ben Sawyer in 2002 (Serious Game Initiative, n.d.). Serious games have been defined as entertaining games with non-entertainment goals.

1.3 Research Focus and Research Importance

As stated in the beginning of this text, Supply Networks are becoming larger and more brittle, and also the complexity of production is increasing [Davis & Jack, 2005; Baalsrud Hauge et al., 2012b]. This leads to new requirements from the industry on their future employees, and consequently to changes regarding the educational needs. In the literature there are several indications on what an engineer needs to know and which skills (compare section 2.2.1 for definitions) s/he should have when leaving university [Cheville & Bunting, 2011; D. Davis, Beyerlein, Thompson, Gentili, & Mc Kenzie, 2003; Mc Masters & Komerath, 2005; ABET, 2006]. The Accreditation Board for Engineering and Technology (ABET) has defined a set of 11 high-level competences (comprising skills, knowledge and abilities, see discussion in section 2.2.1), which an engineer should have command of when leaving engineering school. Such competences are, amongst others, applying knowledge of mathematics, science and engineering, identifying and solving engineering problems, applying advanced engineering tools, communicating effectively, as well as to be able to carry out teamwork [ABET, 2006]. These are complex competences and comprise professional engineering skills and knowledge as well as managerial skills and knowledge (like entrepreneurship, decision-making, risk management skills) and social skills (like communication, collaboration, leadership skills). These competences are recognised by some authors as being more important than the pure technical competences [Gentili, Davis, & Beyerlein, 2003; Kerns et al., 2005; Mc Masters & Komerath, 2005; O'Sullivan et al., 2009]. Most engineering classes are delivered in the traditional way, being teacher-centric and ending with an exam. This has traditionally been a good solution, since an exam is very suitable for evaluation of gained knowledge. However, exams are less suitable for evaluating the improvement regarding methodological and social skills as well as tacit knowledge. In addition, looking, for instance, at a decision-making process in an organisational function, the same decision can be appropriate in one case (place and time dependent), and wrong in a different case. This work is looking at how to improve the competences that will help employees to support the creation of resilient Supply Networks. Furthermore, they must be able to apply risk management methods, taking place and time into account. These aspects are discussed in more detail in section 3.1.

The understanding and coping with the impact of the same decision are context based and represent something the student has to learn and practice. Thus teaching methods and tools that involve active participation of the students have been explored [Chryssolouris & Mavrikios, 2006; O'Sullivan et al., 2009; Baalsrud Hauge et al., 2012a]. GBL, i.e. the use of games to support the learning process [Breuer & Bente, 2010] has a long tradition as a teaching method [Faria et al., 2008]. Serious Games (SG) and simulations have been used in the business and management area for a long time at several business and engineering schools [Bunse & Ziegenbein, 2007; Haapasalo & Hyvönen, 2001; Lewis & Maylor, 2007; Senge, 1990; Tan, Tse, & Chung, 2010]. The advantages of GBL have been addressed by several authors [Amory, 2007; Prensky, 2006; Quinn, 2005; Razak, Connolly, & Hainey, 2012; Riedel & Baalsrud Hauge, 2011;Kiili, 2005]. They have been demonstrated to provoke active learner involvement through exploration, experimentation, competition and co-operation [Bellotti et al. , 2010; Gee, 2003; De Grove, Mechant, & Van Looy, 2010; Lewis & Maylor, 2007; Tan et al., 2010]. They also address the competences needed in the information age: self-regulation, information processing skills, networked cooperation, problem solving strategies, critical thinking and creativity.

1.4 Research Aims and Research Questions

Risk management and Supply Network resilience are topics with increasing interest. Analysing recent reported events indicates that Supply Networks are not able to react suitably to unexpected events, and have difficulty handling the complexity and dynamics. In addition, the management is often under-informed about the risks that may arise [Pettit et al., 2010]. Jüttner [2005, p.139] states "Thus, while faced with new challenges of what appears to be an increasingly 'uncertain' environment, practitioners have little guidance on their Supply Chain RM approaches". Risk management in supply networks requires decision-making competence. Managers need to make decisions in this complex and dynamic environment, i.e. there is a need for future employees to not only apply risk management methods, but also to observe, understand, analyse and assess how different factors impact on the Supply Network. Based on this they have to construct their own understanding and be able to make the right decision in a given situation. Consequently, it is necessary to give them the opportunity to acquire managerial skills during their studies. The complexity of supply chain decision-making is very high. Manuj and Sahin [2011] discuss several models and different aspects from various perspectives. Furthermore, they point at the relevance for training and experience [p. 537] and refer to two quotes from some of their interviewees saying they only learn from experience. Based on this, they postulate three propositions saying that experience, training and problem understanding are cognitive abilities for reducing the complexity. They conclude that the managers have to understand the complexity of and how decisions affect a dynamic network. They emphasise that this requires mangers to have improved problem solving skills [p.543] and that this can be improved by training within the work place. At the same time they also state that "Academic institutions.... must broaden their SCM curriculum and teaching pedagogies to prepare future managers to handle complex decision problems" [p.544].

The research questions addressed in this work are therefore:

- Q1: Which competences does an employee need in order to contribute to the resilience of the Supply Network s/he is working in?

- Q2: How can these competences be developed during engineering education in such a way that future employees have the requisite understanding and capability to act?

- Q3: How to design a game-based course allowing the student to actively apply methods and experience how different vulnerability and capability factors affect differently on an Supply Network?

Previous works [Schwesig, 2005; Windhoff, 2001; Angehrn et al., 2009; Forrester, 1958; Knoppen et al., 2007; Lewis & Maylor, 2007; Nienhaus et al., 2006] show that games can be used for conveying topics that cannot be taught purely theoretically and that this gives the students an opportunity to gain experience in a safe environment. Thus, it can be expected that a blended learning concept, in which a game plays a central role, is suitable for teaching risk management in Supply Networks.

The main objective of this thesis is therefore to develop a game-based course (i.e. the curriculum and the game) that support the development of the students' competences in such a way that the student will be able to transfer the gained knowledge into real settings later and thus be able to:

- Construct knowledge on risks and risk management in Supply Networks so that this can be applied in a dynamic environment;

- Analyse information available according to place and time;

- Assess the information;

- Apply risk management methods in an Supply Network context;

- Learn to develop risk mitigation strategies in the context of an enterprise network;

- Understand the impact of different capability and vulnerability factors, and their interrelation on the Supply Network

- Learn to make decisions under uncertainty in a Supply Network.

In order to achieve this, the sub-objectives of the research is to:

1. Identify the factors impacting on the resilience of Supply Networks
2. Identify the types of risks.
3. Develop a curriculum for a course on Supply Network risks and resilience.
4. Conceptualise, design, and implement a game for this course.
5. Furthermore, using an agile and iterative development approach, the game will be evaluated to see if it fulfils the learning goals and based on the evaluation results, it will be improved to better match the learning goals.

1.5 Methodology overview

The methodological approach for this thesis is as follows:

1. Indentification of needs and requirements regarding the relevant competences making organizations and employees resilient (decision making, problem solving, communication and collaboration skills, etc.).
2. Identification of the needs for risk management education (literature review and desktop study). Based on these findings, a questionnaire was developed aiming at collecting data from industry and academia on the relevance of competences regarding risks, risk decision-making and risk management in Supply Networks.
3. Based upon the identified educational needs, a curriculum was designed and the learning goals were established.
4. This was followed by developing the game concept and the design, and by implementing the game and putting it into operation in a course.

The game and its curriculum were used in a SCRM course over a period of 5 years at the University of Bremen. An evaluation method was developed to assess how well the game and the course met the learning goals.

The evaluation results show that in the first versions of the game the students' achievements were lower than expected. Hence, an iterative improvement process was used for the game, as well as the blended learning concept so that it achieved the learning goals at a satisfactorily level (See Figure 1).

1.6 Thesis Structure and Outline of the Chapters

Chapter two is the state of the art in supply chain management (SCM), Supply chain risk management (SCRM); Supply Chain resilience (ch. 2.1), Learning theories (2.2), GBL (2.3), SG development (2.4) and review of available games (2.4).

Chapter three describes the educational requirements and needs, and curriculum development. Chapter four deals with the conceptualization of the game. Chapter five describes the implemented scenario and chapter six deals with the evaluation. The evaluation results and the game and curriculum improvements are described in chapter seven. Finally, the conclusion in chapter eight synthesises the results of the research and indicates some relevant issues for further work (see Figure 1).

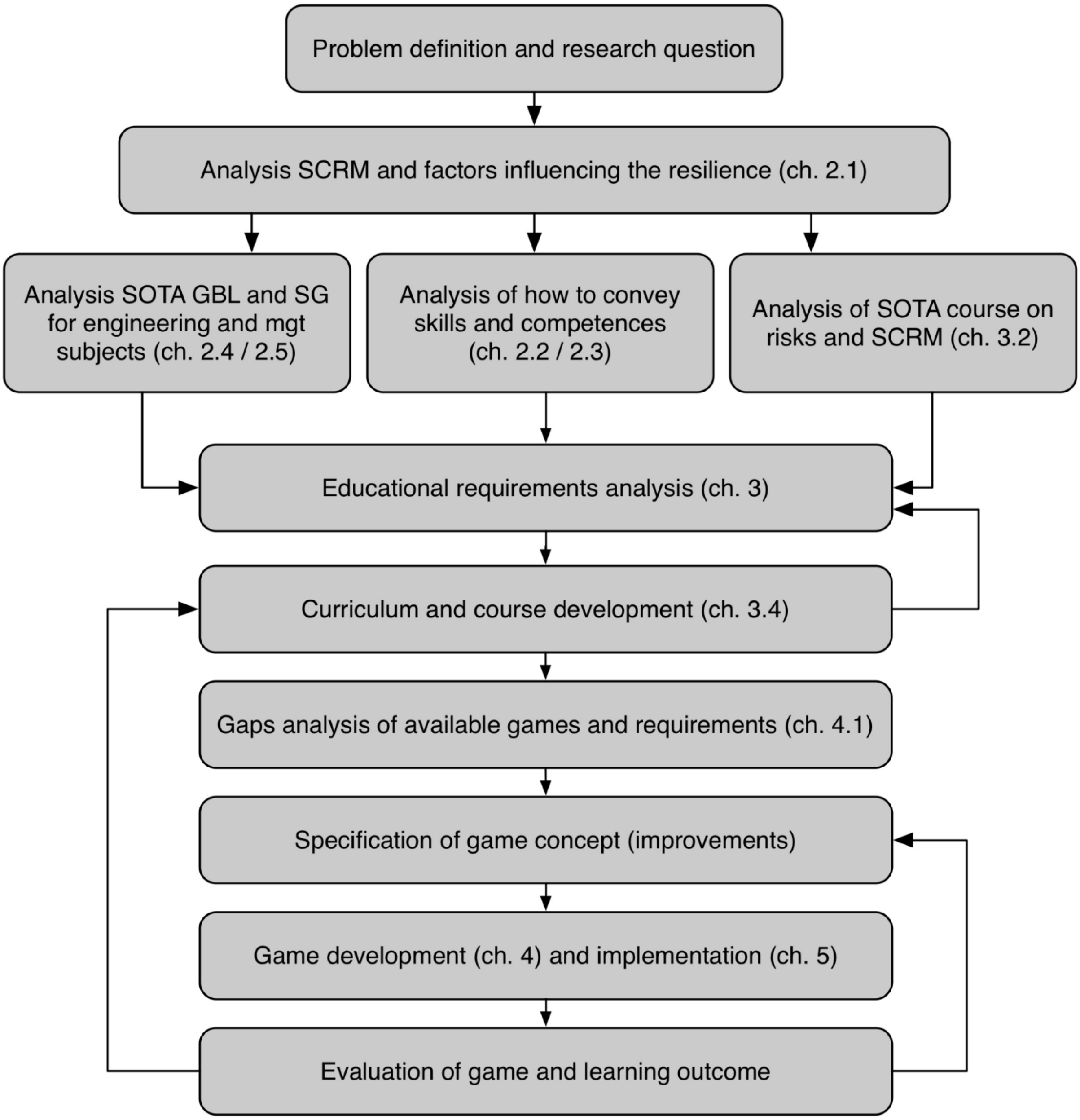

Figure 1: Research methodology and structure of the thesis

2 State of the art

During the research parts of the text have been published in [1-41]. These are listed in chapter 12.

This chapter elaborates in more detail the topics mentioned in chapter 1. The main objective is to derive the possibilities to increasing the resilience in Supply Networks. The focus is on employees' possible contribution. First, section 2.1 defines resilience in Supply Network and discusses the challenges arising through the increased dynamics. Furthermore, it outlines the relation between resilience, risks and management of risks in Supply Network, before it outlines the implications this have for future employees. The future needs are discussed and derived in more detailed in section 2.2. Based on a literature review, the main competences are defined, this partly answers research question one regarding which competences they need. In order to address research question 2, on how these competence can be conveyed, section 2.3 presents different learning paradigms, their usage, their advantages and the limitation. Based upon this analysis, section 2.4 investigates the use of game-based learning within management and engineering education, as well as outlines the challenges in the evaluation of learning outcome for competence development and the construction on new knowledge. Based upon this state-of-the art analysis, it suggests an answer to research question 2, and outlines that a game based course might be an option for conveying skills on risk management. Consequently, the following section discusses how serious games (SG) are to be designed and build. It also formulates some of the challenges well-known existing within the design and development of SG. Section 2.6 concludes the findings of this chapter and refines the research questions and outlines the research methodology.

2.1 Resilience in Supply Network

The goal of Supply Networks is the optimisation of logistical and production processes [Jüttner, 2005; Pfohl, 2002]. The disturbance or interruptions of logistic processes is however of predominant importance. Although much effort is spent in global Supply Networks for fast and in-time sourcing and delivery in order to improve the capabilities of the Supply Networks, past events have shown that global Supply Networks are very vulnerable. An example is the impact of the earthquake in Japan on July 16th, 2007. One of Toyota's suppliers for a small part had to close down all production sites for a week, since they all were located in the same area and thus they were not able to deliver any parts. Toyota had to shut down 12 of its domestic assembly plants, leading to production delays [Pettit et al., 2010].

The ability for efficient delivery and the capability to adapt the global Supply Network to fit the customers' need are a must. Manufacturers are therefore seeking suppliers that are able to collaborate in global networks that are continuously adjusted to a dynamic market and sourcing situation. Such networks, if successful, can be termed resilient networks [Christopher & Peck, 2004].

2.1.1 Definition of Resilience in Supply Networks

As briefly described in the introduction chapter, different perspectives of the term resilience exist in the literature. This chapter will analyse the factors influencing the resilience from a Supply Network perspective. In the introduction, a brief definition of resilience was given, but within Supply Chain management, there are different understandings of this term. However, the four main definitions from the early research on Supply Chain resilience cover most of the aspects. These are:

- Ability to react to an unexpected disruption and restore normal operation [Rice & Cantiato, 2003]
- Ability of a system to return to its original state or move to a new, more desirable state after being disturbed [Christopher & Peck, 2004]
- Containment of disruption and recover from it [Sheffi, 2005]
- Capacity for complex industrial systems to survive, adapt, and grow in the case of turbulent change [Fiksel, 2006]

The different authors agree upon that resilient organisations are sensing, innovative, networked and prepared. Derived from these definitions, vulnerability and capability of Supply Networks play a significant role for resilience in Supply Networks. The vulnerability of global Supply Networks is mainly due to the inability of such networks to react fast and flexibly to suddenly occurring events [Peck, 2003; Pettit et al., 2010; Jüttner, 2005; Christopher and Rutherford, 2004; Sheffi, 2005; Peck, 2005; Wagner and Neshat, 2010; Wagner and Bode; 2006].

In the literature, different components of vulnerability and capabilities have been considered. Pettit et al. [2010] give quite a complete overview on the different factors. Vulnerability comprises turbulence, deliberate threats, external pressures, resource limitation, sensitivity, connectivity and supplier/customer disruption. Relevant capabilities factors are flexibility in sourcing and fulfilment, capacity, efficiency, visibility, adaptability, anticipation, recovery, dispersion, collaboration, organisation, market position, security, financial strength. These have been considered by different authors who have strongly contributed to advances in the field of research on resilience of Supply Chains [Pettit et al. 2010]. However, most authors have considered turbulence, threats, sensitivity and connectivity, but none of the five mentioned [Christopher and Peck, 2004; Christopher and Rutherford, 2003; Sørensen, 2003; Sheffi, 2005], have considered resource limitation. Regarding capabilities - all authors have identified collaboration, but none the market position.

In times of turbulent business environments, the only dependable advantage is the capacity to anticipate events and trends, and adjust accordingly. Hamel and Välikangas [2003] call this *"strategic resilience"* – the ability to reinvent business models and strategies before being forced to do so by external circumstances.

The definitions presented above are typically used for describing the resilience of Supply Networks. However, for managing resilience within a company, definitions deriving from a manag persperial perspective provide slightly different aspects. In strategic management, resilience has been defined as a process capability. In order to reinvent themselves, companies need to overcome barriers to change and develop multiple sources of competitive advantage. Resilience can be defined as "the capability to self-renew over time through innovation" [Reinmoeller and van Baardwijk, 2005, p.61], or from a leadership perspective, Stoltz puts it as the "ability to bounce back from adversity and move forward stronger than ever" [in Pettit et. al., 2010, p. 4].

Deduced from these definitions of resilience, it can be stated that resilient objects (networks, organisations, individuals) are proactive, learning and adaptive (to the requirements of the changing environment) as Coutu [2002, p.1] puts it; "in how to survive before the fact". Research [Christopher and Peck, 2004; Sheffi, 2005; Hamel and Välikangas, 2003; Fiksel, 2006; Pettit et al., 2010] indicates that some general building blocks underpin resilience in Supply Networks: resilient manufacturers must have the capability to adapt to a dynamic environment, continuously innovate, collaborate efficiently and to identify and manage risks and opportunities.

2.1.2 Risks in Supply Network

Proactive risk management as suggested by several authors [Christopher and Peck, 2004, Pettit, 2010; Peck, 2005; Jüttner, 2005; Sheffi, 2005] will make it possible to discover risks with low impact but with a tendency to increase impact if undiscovered and untreated. Risks are of different nature and depending on where in the Supply Network they arise their influence on the resilience differ [Jüttner, 2005; Pfohl et al., 2010,], consequently also how to deal with them differs. This section discusses different types of risks and how they influence the Supply Networks.

In this work, risk is as explained in chapter 1, defined as *"Risk is an event or succession of events having an impact on the objectives of an organisation or activity" (ISO AS/NZS 4360:2004)*, a deviation from a goal, i.e. symmetric risk definition is used. Consequently, as to each of the factors defined by Pettit, there are related risks. The risk can be defined as the combination of the probability of an event and its consequences [Hängii, 1995]. In order to calculate the exact risk, it is necessary to know both the impact of an event as well as the probability of its occurrence.

Finch [2004] categorise the risks with respect to the source. He classifies the risks in the application level, organisational and inter-organisational level. This view is supported by Jüttner [2005]. She divides the risks in internal, external and Supply Networks risks that can be further categorised into types of risk such as strategic, financial, operational, hazard, etc.

Supply Networks risks (in the literature often only examined under the aspect of Supply Chains and network) are of inter-organisational nature. The higher the connectivity and complexity, the larger impact a deviation will have [Christopher and Lee, 2004]. These risks are inter-organisational. Ritchie and Brindley [2004] relate them to three different sources: environmental, internal risk sources (organisational) and network risk sources. The network risks sources are of special importance for organisations actively involved in Supply Networks. Peck [2005] introduces a layered model with four different levels (see Figure 2):

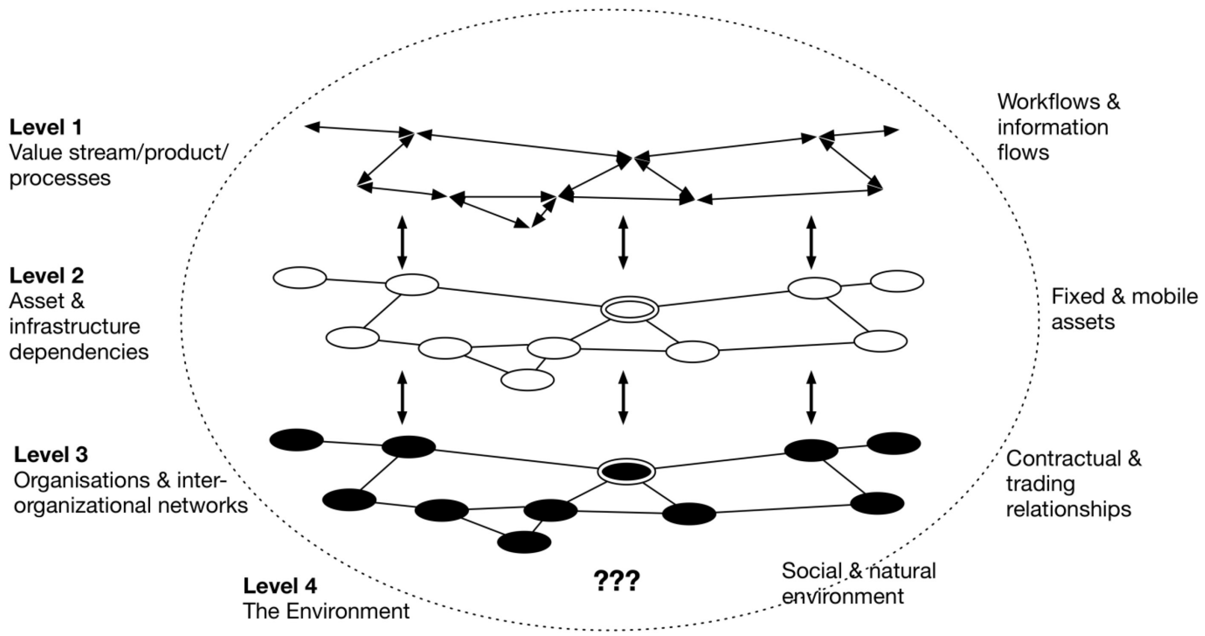

Figure 2: Supply Network risks- drivers or sources [Peck, 2005, p. 218]

Regarding competence development, especially the levels one and three are of interest, whereas level two is important for security aspect. These risks maybe further divided into supply (upstream) and demand (downstream) risks for a single enterprise. Internal risks can be further divided into process and control risks [Peck, 2005]. The network risks may also as the common enterprise risks be divided into further sub-classes in accordance to different criteria. Jüttner [2003] categorises these risks according to the three different causes they may have:

- Chaos, i.e. risks which occur due to the lack of trust, incomplete information, and lack of a general understanding of Supply Networks or because of unnecessarily interactions/disturbance in the structure of the network.

Chaos may also be termed nervous in the literature [Christopher and Lee, 2004].

- Lack of resources/properties, i.e. risks that occur because there is confusion about the owner of a resource. Thus, the responsibilities are uncertain. The impact might be higher inventory costs or price reduction.

- Slackness is caused by a general lack of responsibility in Supply Networks with respect to flexibility and changes among the participants. This is a quite common source for risks in global Supply Networks.

Christopher and Lee see the lack of trust among the partners as the main reason and is caused by lack of overview and control regarding their position within the network. Cavinato [2004] has a different view. He divides the Supply Chain into five sub-chains in which risks can occur: Physical processes (transport of goods etc.); Financial processes; Information processes; Relational processes; Innovation processes. Hallikas and Virolainen [2004] define enterprise risks depending on discontinuity of supply; price escalation; technological access risks; quality risks; opportunity risk; stock and flow risks. In Oosterhout's layered model (see section 1.2), risks as defined by Cavinato as well as Hallikas and Virolainen would be related to level 1 and 2, whereas by using the classification of Christopher and Jüttner, the risks would be more of nature of level 2 and 3.

Figure 3 summarises the different views and visualises the complexity of the nature of risks.

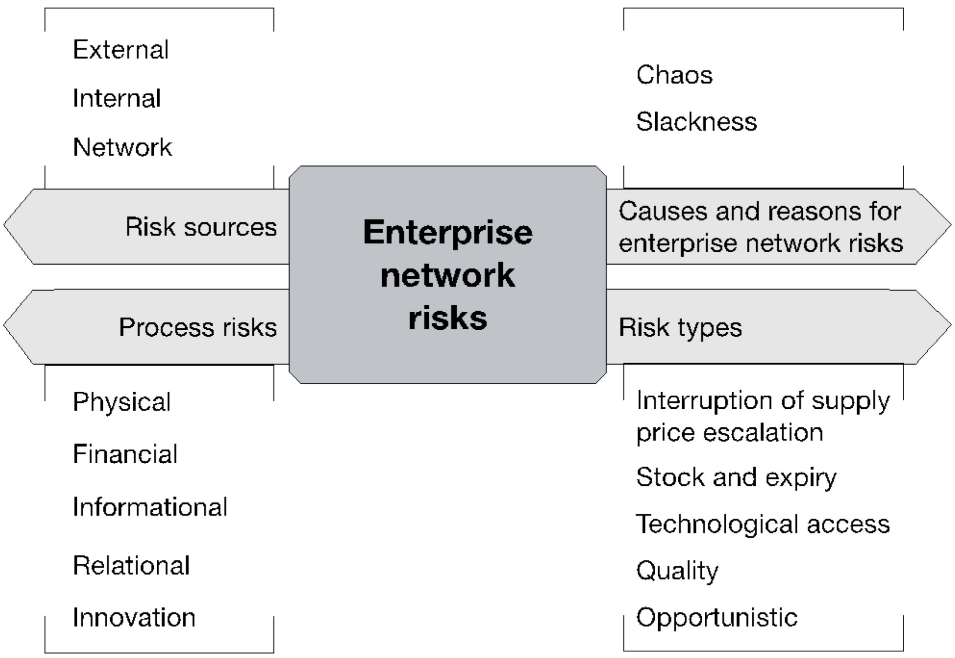

Figure 3: Supply Networks risks

Collaboration risks are risks which result of the direct collaboration between two or more partners. These risks are a class of enterprise risks and are therefore mainly inter-organisational [Wildemann, 2005]. Collaboration can be both vertical and horizontal, depending on the organisational form of the Supply Network (compare chapter 2.1). For vertical collaboration, Barrat [2004] defines the following possible two risk sources: strategically risks and cultural risk. Under cultural risks, he understands trust, mutuality, information exchange as well as openness and communication. Within the area of strategically collaboration risks he defines technology), business case, Intra-Org. Support und Corporate Focus.

Cooperation-specific risks include the risks resulting from the intentional actions of cooperation partners differing from the actions agreed upon, explicitly or implicitly. Cooperation-specific risks have been classified by Seiter [2006] into *conflicting behaviour of a partner*, *opportunistic behaviour of a partner*, and the *withdrawal of a partner*. The impact of these risks will depend on the level of cooperation, and on if it is a cooperation or collaboration. The challenges of this type of risk is that conflicting and opportunistic behaviour of a partner (both organisation as well as individual employee) is difficult to identify at an early stage, because such risks having a minimum impact at an early stage, but may rise in consequences if not managed [Seiter, 2006].

Furthermore, the decision-making process can be considered as a risk to cooperations and collaboration, especially if carried out by a single company. Thus, for risk management in Supply Network, several authors suggest that decision-making should be a collaborative process [Jüttner, 2005, Sørensen, 2005, Pfohl, 2002]. Decisions pose a risk for conflicts when the goals of two enterprises cannot be achieved (goal antinomy). Therefore, the partner's influence in the decision-making process is of critical importance.

2.1.3 Collaboration

The trend in network collaboration is towards "distant collaboration", where B2B technologies reduce the need for tight vertical integration [Richard and Devinney, 2005]. The result is decoupled and loosely integrated networks able to form new Supply Chains immediately - a main characteristic of resilient Supply Networks. Collaboration including joint planning and problem solving is an issue, and a study carried out by Min et al. [2005] show that companies are committed to their collaborations. Business to business (B2B) technology enables complex business processes across distinct operating entities. This allows participants along the entire Supply Network to share decision-making, workflow and capabilities. Furthermore, the technology enables participants to collaboratively design, build, sell and service products faster, more efficiently, and more cost effectively on a global scale.

The configuration of a Supply Network only partly describes the collaboration form. The cooperation can be described in terms of integration, the scope of the network, as well as in terms of the strength of the inter-organisational bond [Jagdev and Thoben 2001; Braziotis and Tannock, 2011]. A more detailed description can be found in [Jagdev & Thoben, 2002, Norrmann, 2004; Christopher and Peck, 2004 Brindly 2004, Seiter, 2006, Sell, 2002; Kopfer and Bierwirth, 1999; Schönsleben, 2000; Chopra, 2007; Camarinha-Matos, 2005]. Consequently, how companies collaborate is a key issue for resilience, since depending on the structure of the network, different risks appear and also the impact of the risks varies (Figure 4)

Supply Chain networks are characterised by vertical interdependences between the partners.

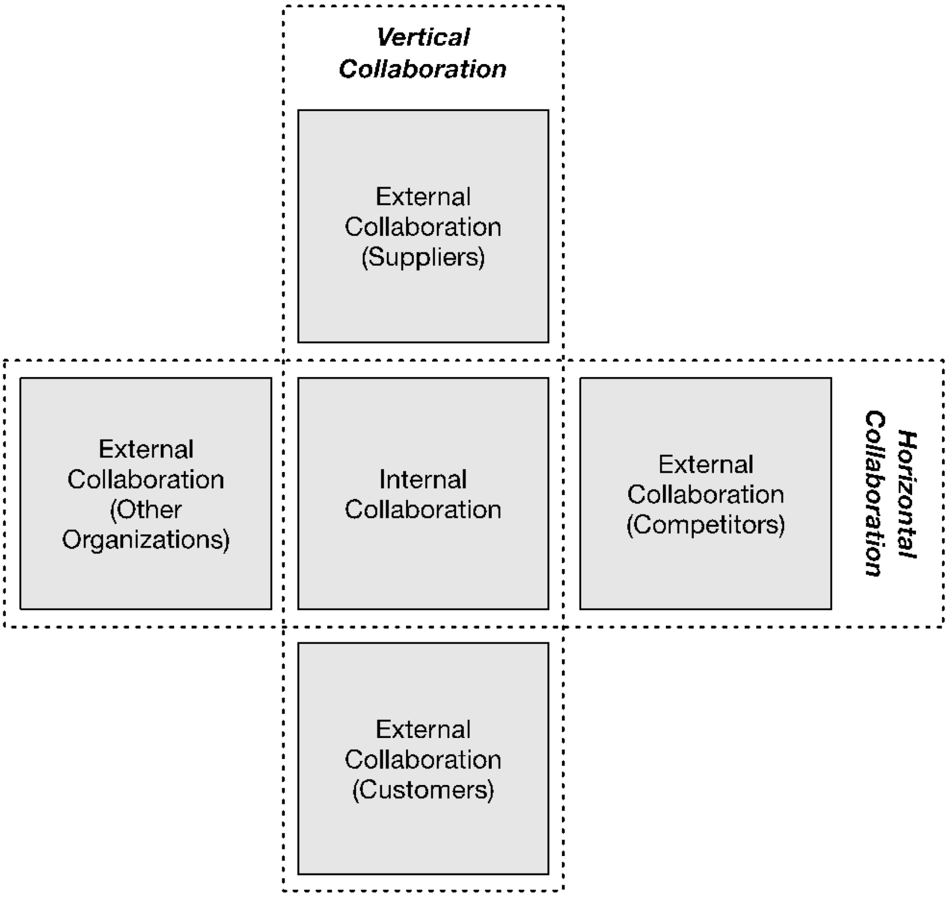

Figure 4: Collaboration types [Barratt, 2004]

The impact of collaboration risks is very dependent on the collaboration form. Due to the usual legal contract situation, collaboration risks are usually easier to handle in vertical collaboration (Supplier- customer relation), than in horizontal collaboration (partners producing a product in collaboration), see Barrat [2004].

2.1.4 Management of risks in Supply Networks

Successful co-operation relies on a seamless information flow between all partners, as well as the ability of the participating organisations to learn and to act in a dynamic environment. Important parameters are the capability to derive information out of an autonomous organisation as well as the capability to collect and process information from outside the organisation. As described in the introduction the employee is the one in an organisation who makes the decisions either at individual or group level, performs and lives the collaboration by carrying out tasks individually, or in cooperation and collaboration with both internal and external colleagues.

Risks may be considered in two different ways: One looks at risk as a solely negative deviation of an event, whereas the other view looks at risks as a possibly positive or negative deviation of an event [Hängii, 1995; Pfohl, 2002; Peck, 2005]. The first view is typical for classical risk management, focussing on hazards, whereas the other view is coming from decision theory [Christopher and Peck, 2004]. According to the definition used for risk in this thesis, it is necessary to know both the probability and the impact of an event. In dynamic systems like Supply Networks, this is mostly not possible, because the complexity and the number of interdependencies are so high. Thus, it is therefore usual to speak about opportunities and threats instead of negative and positive impacts of a risk [Pfohl, 2002]. Braun adds a different dimension, defining that risk is divided in two components - an informational, neutral component and a subjective component [Helten, 2002]. The consequence of this definition is that risk is not a specific size, but depends on the goal.

Every decision contains risks for not doing the right thing [Götze, 2001]. Embedding of risk and risk management as core managerial functions is a long-term exercise to ensure that risk consideration is at the heart of the decision-making process. Risk management is the process where organisations methodically address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across the portfolio of all activities [Peck, 2003; FERMA, 2008]. It may be considered as a central part of any organisation's strategic management and is critical for their success [Romeike, 2004; Kirchner, 2002; FERMA, 2008].

Failure to consider risk issues may give rise to serious consequences. Additionally, the question arises of how to ensure consistency of approach across a wide range of organisational units. The embedding of risks within business processes of Supply Networks requires the identification and evaluation of all significant risks and the development of an appropriate management strategy. Sometimes it requires specific knowledge, and thus the decisions need to be made at different organisational levels [Fraser and Henry, 2007], however with keeping the management board aware and informed. This is often a weak point [Council of Competitiveness 2007]. Traditionally, most methods are focussing on risk reduction, and thus not so suitable for being applied in dynamic environements, where being aware of opportunities is important. Operating in a dynamic environment requires the ability to observe, analyse, assess and draw conclusions on how risks occur and how they affect [Slywotzky and Drizik, 2005; Rice and Caniato, 2003; Kajüter, 2003; Peck, 2003; Jüttner et al., 2003].

Pettit et al. [2010], as well as Peck [2005], suggest using pro-active risk management for improving the resilience. This recognizes that forecasting is limited in dynamic systems. Hence, it is difficult to build models and to set decision-making rules. Consequently, risk must be avoided, prevented and reduced. The essence of this approach is that all risks and their interrelationships are considered on a proactive basis, driven by potential risk and not by events (although organizations must learn from events). Where the orthodox approach to risk management is governed solely by event push (reactive), this approach advocates the need for “risk pull” as well. The response of risk management should be to assess, through constant monitoring, prediction and organizational learning from past problems (internal and external), the likely risks to the organization.

The objective of risk management in Supply Networks is to ensure that all activities within the network may be carried out as planned, based upon a seamless material flow throughout the network [Waters, 2007]. This does not only require a common risk management strategy, but also that each organization has implemented its own strategy and that the members of the network do not have conflicting goals [Macharzina, 2007].

The partners often have different risk perceptions and tolerances, which influence the risk treatment strategy. Furthermore, there is also an asymmetric information flow between participants in the Supply Network and most partners are involved in different, often global, distributed networks, so that each organization has different risk perception and prioritizes differently [Kajüter, 2003a]. However, in order to achieve the best possible result, one holistic strategy needs to be developed. Thus, Supply Network Risk Mangement (SNRM) differs from organizational risk management. The way of making decisions is different since all perspectives and needs of the different stakeholders need to be taken into consideration.

As for an organisation, the SNRM process comprises four elements - the identification, the evaluation, the development of a risk concept for the entire network and the development of suitable risk reduction strategies [Jüttner et al., 2003]. As for risk management within an organisation, the identification of the risks is one of the main challenges, above all if the risks are dependent on various sources, which is quite common for Supply Network risks. Thus, the assessment of network risks is complicated and requires a full understanding of both the network structure as well as of the complexity and its dynamic behaviour. This is only possible through high transparency and visualization. This requires first of all transparency and visualisation for all stakeholders in the network. Transparency implies immediate flow and availability of correct information between partners in a global logistics network to support decisions regarding design, planning and operations (execution). Visualisation is a method of communication that allows one to combine several types of data in the process of understanding and learning. Visualisation is a means to understand the coherences vital to be able to control the outputs, which are represented by visual systems.

The challenge in the definition of a risk concept is that every single Supply Network entity will have different impacts of the same risks, depending on the collaboration and trust forms. Thus, it is not possible to use a standard concept. Far more important is to support the decision makers in their way of handling risks in Supply Networks [Jüttner, 2003]. As explained in the introduction, one reason for the vulnerability of Supply Networks is the focus on efficiency, even though both efficiency and effectiveness should be considered [Jüttner et al., 2003]. Globalization, outsourcing, centralized distribution as well as the reduction of suppliers and stocks [Jüttner, 2005; Peck, 2005; Bode and Wagner, 2006; Svensson 2002; Christopher and Peck, 2004; Sørensen, 2003; Sheffi, 2005] are drivers. Miller [Miller, 1992] has defined five different risk mitigation strategies for single companies and Jüttner [2005], Peck and Christopher [2004] conclude that four of them are applicable in the Supply Network context:

- Avoidance if the risk is unacceptable. This means that for hazardous risks, or risks with high negative impact, all possible actions should be undertaken in order to avoid the risks. This is a typical approach for safety and security issues, and sees risks only as a negative issue.

- Risk control would be the strategy if possible to control contingencies from various risk sources. I.e. this strategy allows the management to actively control risks and thus be able to also take opportunities, but at the same time the organisation is not put at risk. It is an active strategy, and quite often implemented since it gives freedom to the decision makers.

- With a cooperation strategy, the objective is to reduce the uncertainty by having joint agreements. In the case of a Supply Network, this would lead to a focus on higher transparency and visibility including information sharing and joint contingency plans. This strategy is quite similar to the strategies applied for risk reduction in large projects.

- Flexibility is the last strategy and can be explained as the possibility of a Supply Network to respond flexibly to market and environment changes. “It increases responsiveness while leaving the predictability of factors unchanged” [Miller, 1992, p 324]

As discussed in the previous chapter, it is necessary that the employees are able to carry out the task of managing risks in Supply Networks. In order better define what he needs for this, next section discusses the differences between skills, abilities, competences and knowledge.

2.2 Competences

This section will define competences and review what the literature reports as necessary competences for future employees working in Supply Network and with production in distributed environments.

2.2.1 Definition of competence, skills, abilities and knowledge

Hoffmann [1999, p. 275] says "competency has no widely accepted single definition" and refers to and discuss how Jubb and Rowbotham, [1997] understand the meaning of competences. According to Hoffmann [1999, p.276] "A review of the literature showed three main positions taken toward a definition of the term. Competences were defined as either:

1. observable performance [Boam and Sparrow, 1992; Bowden and Masters, 1993];
2. the standard or quality of the outcome of the person's performance [Rutherford, 1995; Hager et al., 1994]; or
3. the underlying attributes of a person [Boyatzis,1982; Sternberg and Kolligian, 1990].

Some authors used more than one of these positions to define the concept [Boyatzis, 1982; Rutherford, 1995; Rumsey, 1994; Ulrich et al., 1995Hoffmann, 1999]. Parry defines competency as a cluster of related knowledge, attitudes, and skills that affects a major part of one's job; correlates with performance; can be measured; and can be improved [1996]. In this work, definition number three is used. A persons attributes includes his skills, abilities and knowledge [Hoffmann, 1999; Perry, 1996]. It is a definition which is more in-line with constructivistics and cognitivitstics learning theories, since it looks more at the input than the output, and is also suitable for more complex tasks [Hoffmann, 1999] like managing risks. A more thorough discussion on different views of competences can be found in [Pate et al. 2003; Hoffmann, 1999; Norris, 1991; Snyder and Eberlinger, 1992; Greeno et al.; 1984, Jeris and Johnsen, 2004; Kolb et al., 1986 and Weinert 2001].

Pear [1948, p. 92] defines skill as "the integration of well-adjusted muscular performance", however, this term has been further developed also comprising other areas. In this work, skill is seen from cognitive perspective. Relevant frameworks developed by Anderson [1981, 1982, 1983, 1987], Fitts and Posner [1967] and

Rasmussen [1983, 1986]. In this work, the definition by Procter and Dutta [1995, p.18] is used and seen as “goal-directed, well – organised behaviour that is acquired through practice and performed with economy of effort”. They distinguish between motor skills, perceptual skill, problem solving skills and response selection skills. The most relevant skills to be trained for improving the resilience are perceptual and problem solving skills.

Ability is the competence to perform an observable behaviour or a behaviour that results in an observable product [Grant, 1996; Norris, 1991; Bartram et al., 2002]. Finally, “Knowledge is sometimes viewed as if it was a concrete manifestation of abstract intelligence, but is actually the result of an interaction between intelligence (capacity to learn) and situation (opportunity to learn)“ [Winterton et al., 2005, p. 9]. Knowledge is often divided in tacit and intangible knowledge [Collins, 2000], in general and specific knowledge [Weintert, 1999] or in declarative and procedural knowledge. This is in-line with Gagne’s hierarchical model from 1962 [Gagne, 1962], which is often referred to in GBL. In the frame of this thesis the term knowledge is used when data and information can be applied in an activity oriented way [Back, 2002], i.e. it comprises both declarative and procedural knowledge. An example of how knowledge can be understood within the subject of resilience in Supply Network is that the declarative knowledge would be what the candidate knows about for instance communication risks (characteristics, where and how they arise i.e. factual knowledge), whereas an example of procedural knowledge would be how to apply this knowledge in context. It is expected that the game mainly will contribute to improving the last form.

2.2.2 Discussion on needed competences

Today manufacturing is often a complex process, involving several partners around the world. This process leads to the need for changes in educational requirements. The Accreditation Board for Engineering and Technology (ABET) has defined 11 competences that an engineer should have at command when leaving engineering school. Such competences are, amongst others, applying knowledge of mathematics, science and engineering, identifying and solving engineering problems, applying advance engineering tools, communicating effectively as well as to be able to carry out teamwork [ABET, 2006].

In particular, it is necessary to prepare students for work in a dynamic, global and highly competitive environment. Thus, manufacturing and engineering education needs to focus on developing the competences required by new generations of employees; adapting the educational content and its delivery mechanisms to the new requirements of knowledge-based manufacturing, the provision of integrated engineering competences, including a variety of soft skills, and the promotion of innovation and entrepreneurship [Taisch, 2011, p.11]. In order to achieve this, it is necessary to focus more on multi-disciplinarity and integrated engineering competences [Taisch, 2011].

Several authors have highlighted the need for the following abilities:

- **Collaboration and cooperation**, **interpersonal abilities** (including trust, the ability to build relationships, understand different cultures), work on common problems and tasks, define and resolve conflicts and negotiation [Barrat, 2004; Braziotis and Tannock, 2011; Schwesig, 2005; Windhoff, 2001].

- The ability to **cope with changes**, both at an organisational as well as an individual level, is one of the most important capabilities for a resilient organisation as stated in the literature [Davis, 2006, Rice and Caniato, 2003, Peck, 2003, 2005, Sheffi, 2005, Christopher and Peck, 2004, Jüttner, 2005]. At the individual level this means that the employees need to be able to anticipate changes, continuously **learn and develop, transfer, adapt and create new knowledge** and assess different alternatives depending on the changing environment [Busch-Vishniac and Jarosz, 2004; Falkenburg, 2005; Kerns, 2005; Waldorf et al., 2006; Katehi, 2005; Stewart, 2005; O'Sulivan et al., 2009; Hira, 2005; ABET, 2006; Beverly, 2005; Rolstadas, 2002]. It is however not enough that the individual employee has this ability, also the organisation needs to be able to cope with such changes [Schwesig, 2005, compare learning organisation Fuchs-Kottowski, 1998].

- The ability **to communicate** in different contexts, as well the ability to **express themselves** so that the partner **understands the meaning**, exchanging required information with others, the ability to express ideas and thoughts in such a way that a common understanding can be achieved are abilities relevant for supply networks [Schwesig, 2005, Constable and Somerville, 2003; Eckel, 2003; Kerns, 2003; Katehi, 2003; Gentili et al., 2003; Johnson, 2005; Davis et al., 2003; ABET, 2006; McMasters and Komerath, 2005; Beverly, 2005; Waldorf et al, 2006; Felder and Silverman, 1988; McKenzie, 2004].

- In order to increase the organisational capabilities, the employees need to be able to work in teams, i.e. they need to be able to **overcome and solve conflicts, share information**, **carry out work** both in **collaboration and in cooperation** [ABET, 2006; Cheville et al., 2011; Eckel and Kezar, 2003; Kerns et al., 2005; NAE, 2004; McMaster et al., 2005; Davic et al., 2003;].

- Ability to solve problems in different ways: This implies that the employee, or the team of employees, should be able to identify, understand, analyse, develop and formulate alternatives and create solutions. [ABET, 2006; NAE, 2004;; Kerns, et al., 2003; Prince and Felder, 2006; Levy, 2002; Beverly, 2005; McMasters and Komerath, 2005; Bransford, 2007; Rolstadas, 2002; Lumsdaine, 1995; Cheville and Bunting, 2011; Johnson, 2005; Azadivar and Kramer, 2007; McKenzie, 2004].

- In order to operate in a dynamic environment, future employees need to have the ability to **identify, monitor and assess changes** of different factors being relevant for sustainability. In order to be able to **make decisions** it is necessary to have competences in applying methods for assessing and evaluating alternatives s and thereby taking different goals and strategies into account [Chryssolouris and Mavrikios, 2006; McMasters and Komerath, 2005; ABET, 2006; Johnson, 2005; Rolstadas, 2002; Falkenburg, 2005Seely, 2005; Duderstadt, 2009; Cheville and Bunting, 2011; Kenney et al., 2005; Beverly et al., 2005; Chang et al., 2011; Falkenburg, 2005; Davis et al., 2003; O'Sulivan et al., 2011; Beverly et al., 2005].

Section 3.1 will discuss in more detail what is necessary regarding to decision-making and risk management in enterprise network.

Different skills, knowledge and abilities cannot be taught in the same way, thus the next section will look at different learning theories and under which circumstances these will be used.

2.3 Learning theories

The Supply Chain networks described in chapter 2.1 show that these are undergoing rapid changes and that they are complex with a high degree of interdependencies both between the involved organizations and individuals. Collaboration is based upon the relationship between humans and their environments. For a person operating in a Supply Chain network, this actually means that the person needs to deal with a dynamic environment. However, experiments have shown that people can only handle seven, plus or minus two variables at once [Miller, 1956]. This is less than needed, thus people make decisions based upon their perceptions or misperceptions of their environment (cognitivism), or based upon their experiences (constructivism). The complexity of dynamic systems is a problem [Duke, 1974; Dörner, 1989]. Thus, it is difficult to understand, assess and forecast the impact of the interference with a complex, holistic and dynamic systems. To reflect the complex aspects in a learning system means that appropriate pedagogical strategies are needed.

2.3.1 Pedagogical paradigms

Three major pedagogical paradigms for learning exist:

- Behaviourism,
- Cognitivism

- Constructivism.

These paradigms have different strengths and weaknesses. In order to achieve different learning objectives related to different SNRM and resilience of Supply Networks one learning paradigm may be used for one objective, another for a achieving a different objective.

Behaviourism

Behaviourism did play the most important role in the field of learning psychology until the middle of the 20th century. Behaviourism assumes a learner is essentially passive, responding to environmental stimuli. The learner starts off as a clean slate (i.e. *tabula rasa*) and behaviour is shaped through positive reinforcement or negative reinforcement.

It is based on experience with animals and works with the relation of stimuli and response [Reinemann and Maurer, 2005]. It views learning as changes in behaviour. These changes in behaviour occur as a result of the individual responding to stimuli, and the consequences the responses yield. This process is called *conditioning*; [Reinemann and Maurer, 2005; Baumgartner and Payr, 1994].

Several types of learning exist. The most basic form is *associative learning*, i.e., making a new association between events in the environment. There are two forms of associative learning: classical conditioning (made famous by Pavlov's experiments with dogs) and operant conditioning [Watson, 1913; Watson, 1924; Baumgartner and Payr, 1998].

Behaviourism does not consider learning as knowledge transfer or knowledge building structures within the learners. Behaviouristic mediation strategies expect that the teacher exactly knows which content he should mediate and that he is an authority. His didactical challenge is therefore to find suitable stimuli and intervention variables (the repetition) and to support these with adequate external feedback. Although this paradigm had the hegemony until the 1960's, it could not explain the learning process among human beings. However, it is still in use, mainly in the mediation of factual knowledge, i.e. for obtaining professional competences within formal education [Baumgart and Payer, 1994].

Cognitivism

The Cognitivism paradigm is focusing on the learning activities in the mind. Knowledge can be seen as schema, or symbolic, mental constructions and needs to be explored. Learning is defined as change in a learner's schemata. According to cognitivism, learning may be defined as continuous knowledge acquisition. Thus, learning can be considered as the composition and continuous modification of knowledge representations [Steiner, 2012]. Therefore, also the right methods and approaches for problem solving need to taught, and not, as with behaviourism, only the right answers. Approaches and learning theories based upon the cognitive paradigm are therefore mainly used to acquire methodical competences (Procedures and approaches, selection of right method, etc.) [Baumgartner & Payr, 1994].

Learning is making sense of the world. The mind processes perceptions through beliefs and understanding in order to give appropriate responses. Over time, facts, principles and concepts are discovered and internalised. Further, learning processes may construct new learning based on these facts, principles and concepts, or these will have to be reconstructed and deconstructed. It views the learning process as information processing. It can be based on external information, as well as, rule-based changes in the information processing [Windhoff, 2001; Reinmann, 2005]. Examples of these are double-loop learning and the left-hand column method. In double-loop learning, underlying goals, assumptions and programs, enclosed in mental models, are carefully elicited and questioned.

Bloom created a taxonomy for categorizing the levels of abstraction that commonly occur in educational settings, so that learning outcomes can be compared and assessed [Bloom, 1956]. It is based on cognitivism. He defined three domains in for educational objectives:

- Cognitive
- Affective and
- Psychomotor

Cognitive learning refers to the intellectual capabilities that are most relevant for educational applications, the affective domain refers to the players' feelings and emotions and the psychomotor domain refers manual and physical skills. For each of the above-mentioned domains, the model defines a set of competence categories. According to the original taxonomy, cognitive learning outcomes were divided into six categories: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation, i.e. from concrete to abstract. Schulman [2002] and others have criticized Bloom's taxonomy for the lack of theoretical foundations and some revisions have been made [Krathwohl, 2002; Dave, 1975; Harrow, 1972].

Anderson and Krathwhol [Pohl, 2000; Anderson and Krathwhol, 2001] created a new taxonomy based on Bloom's, with minor revisions by reinterpreting the set of verbs, replacing the nouns related to the learning categories in the cognitive domain with verbs, and by inverting the two highest order levels. Their revised taxonomy comprises six categories in order: 1) Remember, 2) Understand, 3) Apply, 4) Analyze, 5) Evaluate, and 6) Create. In the horizontal, knowledge dimensions are presented in four knowledge dimensions from simple to complex: 1) factual 2) conceptual, 3) procedural, 4) meta cognitive knowledge.

Constructivism

A reaction to didactic approaches such as behaviourism, constructivism states that learning is an active, contextualized process of constructing knowledge rather than acquiring it. Knowledge is constructed based on personal experiences and hypotheses of the environment [Kolb, 1984].

It regards learning as a construction of learning out of experience, but differs from the cognitive learning theory with respect to the view of the learner. Constructivism sees the learner as an active agent, not a passive processing unit, and it sees knowledge as a personal and subjective construction, not an internalization of external rules. This is an important distinction between the cognitive learning theory and constructivism. There is no truth “out there”; no knowledge exits independently of the knower.

The view of knowledge as constructed, as opposed to an external entity, makes learning a social activity, occurring as result of the dynamic interaction between the learner and the environment. The social context is very important as individual learning takes place in real situations. [Reinmann, 2005; Baumgartner and Payr, 1994].

In constructivism, with the learner placed at 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 environment, the pedagogical approach favours hands-on and self-directed activities, which 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. The learners who 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.

Comparison of the learning paradigms

Table 1 gives a short summary of the differences between the three learning paradigms described in this section.

Table 1: Paradigms of learning [source Baumgartner and Payr, 1994]

Category	Behaviourism	Cognitivism	Constructivism
Brain is	Passive box	Information processing instrument	A closed information system
Knowledge is	Saved	Processed	Constructed
Knowledge is understood as	A correct input-output relation	An adequate internal information processing process	To operate with a situation
Learning objective	Right answers	Right methods to find the answers	To tackle complex situations
Mediation of	Professional knowledge	Methodical knowledge	Experiential knowledge
Paradigm	Stimulus-Response	Problem solving	Constructivism
Strategy	Teaching	Observe and help	Cooperation
Teacher is	Authority	Tutor	Coach, Trainer
Feedback	Externally predetermined	Externally modelled	Internally modelled
Interaction	Fixed predetermined	Dynamic, depending on the learning model	Autonomic, circular
Learning process is	Repetitive	Continuous modification process	Actively driven by the participant her/himself

All the three learning paradigms have the application area in which they work better than the others do. Behaviouristic and cognitive teaching approaches can be used to mediate specific knowledge of action patterns [Kerres 1998; Baumgartner and Payr, 1994] or procedures and methodologies as well as their correct selection and application to solve a well-defined problem [Baumgartner and Payr 1994]. Constructivism is better to use in areas where it is necessary to construct new knowledge, like in a dynamic environment.

2.3.2 Learning theories and models

Based upon the above-described learning paradigms, different learning theories and models have been developed. The following describes briefly some of these models and theories mostly used for higher education and vocational training.

2.3.2.1 Problem based learning

Problem-Based Learning (PBL) is based on a cognitive, and to some extent constuctivitic learning paradigm [Barrows, 1996, De Grave et al, 1996]. It is an instructional method of hands-on, active learning, centred on the investigation and resolution of messy, real-world problems [Belland et al. 2009; Duffy and Cunnigham, 1996]. The teacher acts as a facilitator and the student as the problem solver [Blumenfeld et al, 1991, Hmelo-Silver, 2007].

Rather than having a teacher providing facts and then testing student's ability to recall these facts via memorization (Behaviourism), PBL attempts to get students to apply knowledge to new situations, and the teacher acts as facilitator. Students are faced with contextualized, ill-structured problems and are asked to investigate and discover meaningful solutions [Oberski et al. 2004; Pea, 2004]. The effectiveness of PBL and the learning outcome for students is controversial. Meta-analysis carried out on different aspects were conflicting [Hung, 2011]. Proponents of PBL, like Hmelo-Silver [2007] and Schmidt et al. [2007] mention that the effectiveness of cognitivism is proven, and thus also for PBL, others argue that it might just be effective for some sort of learning, not for all. In line with this, a several mention the effectiveness for training problem solving skills [Dabbagh and Denisar, 2005, Strobel and Barneveld, 2009]. More sceptical researchers, like Kirschner [2006] argue that it ignores cognitive loads principles and is ineffective. However, PBL supports collaborative learning which is important for acting in a Supply Network. Thus, even though the effectiveness of this method might not be indisputable, it is a method that fosters active participation, collaborative learning, in practice shown to be engaging for the students.

2.3.2.2 Experiential learning

This section outlines briefly approaches describing individual and organisational learning

Individual learning

The theory of experiential learning is based upon the paradigm of constructivism. David A. Kolb postulated: "learning is the process whereby knowledge is created through the transformation of experience" [1984, p. 38]. He has based his work on the work first carried out by Dewey and Piaget. Since learning is based on an individual's experience, there is no need for a teacher, but there is of course a chance for the individual not drawing the right conclusion, so the process is supported by a facilitator (shown as coaching in the figure).

The experiential learning theory presents a cyclical model of learning, consisting of four stages shown below. One may begin at any stage, but must follow the steps in sequence shown in Figure 5.

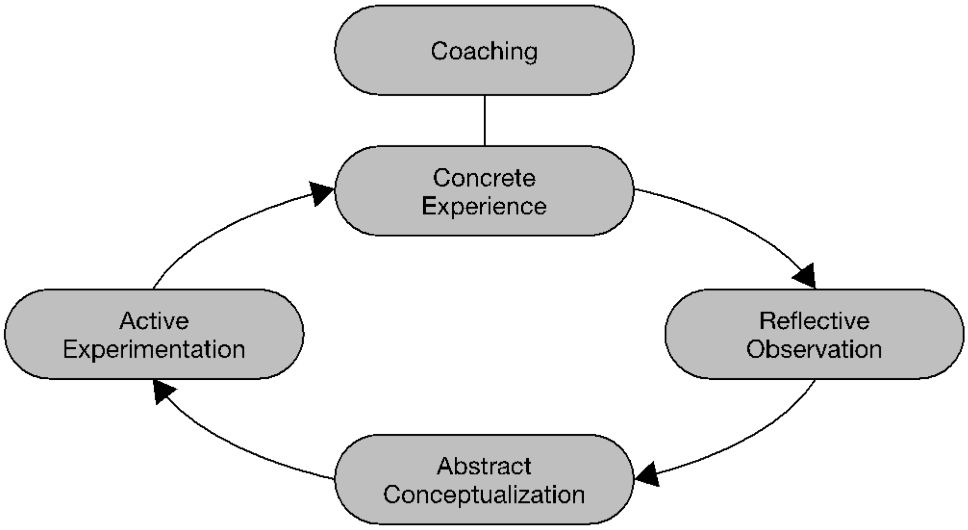

Figure 5: Kolb's Experiential Learning Cycle. [Kolb, 1984]

Kolb's four-stage learning cycle shows how experience is translated through reflection into concepts, which in turn are used as guides for active experimentation and the choice of new experiences. The first stage, *concrete experience*, is where the learner actively experiences an activity such as a lab session or fieldwork. The second stage, *reflective observation*, is when the learner consciously reflects back on that experience. The third stage, *abstract conceptualization*, is where the learner attempts to conceptualize a theory, or model, of what was observed. The fourth stage, *active experimentation*, is where the learner is trying to test a model, theory, or plan for a forthcoming experience.

Organisational and inter-organisational learning

Organisational and inter-organisational learning are of vital importance for today's organisations. Based on extensive literature review, Pawlowsky [2001] has identified the following common process phases:

- The identification of relevant information, and/or the creation (generation) of new knowledge by combination [Nonaka 1994, Lundberg 1989].
- Some mode of exchange and diffusion of knowledge either from the individual to the collective level or on the collective level [Duncan et al. 1979, Huber 1991].
- The integration of knowledge into existing knowledge systems on a collective and/or individual level or into procedural rules of the organization.
- The transformation of the (new) knowledge into action and application in organisational routines in order to have an effect on organisational behaviour e.g. developing new products and services.

Schwesig [2005] discusses the relevance of this for Supply Networks and concludes that organisational learning should be seen from a multi-level perspective comprising of the individual, group, organisational, and inter-organisational level. This is in line with like Pawlowsky [2001], Inkpen and Crossan [1996] as well as Nonaka [1995]. It will enable us to consider the main levels of action within an enterprise [compare findings in Schwesig, 2005].

In chapter 2.1 different factors affecting the resilience of the Supply Chain are discussed. Furthermore, a resilient entity (Supply Network, organisations, individuals) was said to be proactive, learning and adaptive, which has several similarities with the definition of learning organisation discussed above. This stresses the need of continuous learning, which constitutes the true competitive advantage for organisations. Moreover, the learning rate of the organisation must be higher than that of competitors so that the former can survive. In addition, a main capability of resilient networks is related to the organisational aspects. This includes, according to Pettit's et al. framework [2010] also training of individuals, teams and organisations.

The next section will present game-based learning as an educational approach and discuss how this approach is used in order to mediate the relevant competences.

2.4 Serious Games and game-based learning

Today's rapidly changing business environment, with fast technological and organisational developments poses a challenge to companies and individuals. Education based purely on passive learning seems not to fully support the development of the competences regarded as necessary for engineering and business students. Thus, several business and engineering schools use more active methods like game based learning involving the use of cutting edge information and communication technologies (ICT) [O'Sullivan et al., 2011; Chryssolouris and Mavrikios, 2006, Baalsrud Hauge et al., 2012]. Faria et al. [2009] show the progressive adoption of cutting edge technologies (e.g. virtual reality and artificial intelligence) and an increasing use of such tools within US universities. However, the European situation is less investigated and appears more fragmented, although interesting examples are available [Anghern et al., 2009; Mantakas, 2010; King and Newman, 2009; Gamlath, 2009; Hunecker, 2009; Riedel and Pawar, 2009].

Serious Games are games that educate, train and inform [Michael & Chen, 2006]. The games are intended to provide an engaging, self-reinforcing context in which the motivation and education of the participants takes place. The inherent expectation is that the application of serious gaming technology can ameliorate European competitiveness [Oliveira et al., 2006]. David Rejeski and Ben Sawyer coined term Serious Gaming in their white paper Serious Games Initiative [2002]. Serious Games have been defined as entertaining games with non-entertainment goals [Serious Game Initiative, 2002; Raybourn, 2007]. Simulation games, which is the type of games often used for educational purposes in engineering and management can be seen as a sub-type of serious games.

Semini et al. [2006] pointed out that simulation games can be seen as an extension of simulations. However, he also addresses that games are more suitable than simulations to teach decision-making in Supply Chains, due to the explorative environment. Tan et.al [2010] suggest using both games and case studies in the teaching whereas Falkenberg [2012] stresses the need of case studies. In both cases it is about learning from experience and practice. Creating knowledge by gaming has proven to be particularly effective whenever soft skills are essential and traditional learning methods fail [Windhoff, 2001]. Simulation games are learning processes or environments that help activate double-loop learning [Bakken et al., 1992] since time and space are compressed, and hence, the feedback structures existing within the system can be deducted risk-free [Senge 1990, p. 312-338]. The advantage of these learning environments is that they make cause and effect relationships more visible to the user. Simulation games enable accelerated learning, what Probst and Büchel [1994, p.17] called “learning by doing”, and Senge [1990, p. 313] “learning through doing”. Simulation games are generally case-based computer models, which are used with the objective to answer effectively the issue raised by the case such as the optimization of profits, costs or lead times. The player can choose among a tremendous realm of policies, try them out; and get the interactive feedback. During this process of trial and error, users are supposed to acquire experiential learning.

There are already several games conveying skills on risk management, thus in order to identify potential existing games that could be used, games were drawn from a number of sources and categorized according to Riedel and Baalsrud Hauge [2011]. The scope of the domains was restricted to Serious Games, which addressed business/industry, engineering, production, and Supply Chain/logistics. A categorisation of the identified Serious Games was developed in order to analyse the characteristics - the aspects they covered and those they do not cover.

The first analysis was to determine the simulation level of the identified Serious Games. The gap is clearly visible – inter-organisational and discipline based simulations. Most of the simulations in the inter-organisational category are for emergency/ disaster planning, there are also hardly any business or industry simulations/Serious Games. There are also only a few Serious Games for specific techniques. Technical systems like production lines have been successfully simulated with computers for decades, but simulations and games of social systems, for example organisational change processes, are still manual, relying on human specialists for facilitation.

In the field of business and engineering education, Serious Games are mostly used in a workshop setting [Angehrn and Maxwell 2009] and mostly either Kolb’s experimental learning cycle [Kolb, 1984] or Nonaka's SECI [Nonaka, 1990, 1994] model is used for the implementation of a game in a course. The games seek to enhance the learning motivation as well as to simulate real enterprises [Popescu et al, 2012]. Most of the Supply Chain games are facilitated; i.e. a blended learning setup is used, and the debriefing is not within the game, but outside the game [Luccini, 2012]. The learning outcome is therefore not only dependent on the game itself, but also on the facilitators' ability. The learning results are not only based on the game, but on the course setting.

The analysis shows that the Serious Games that have been identified address multiple techniques, multiple groups of people and multiple disciplines. In fact, many of the games address several aspects simultaneously and they could have been placed in other categories as well – they have been placed in the main category that applies to them. Most real life business skills involve both technical and social aspects, thus this multi-disciplinarily and multi-person dimensions of Serious Games for business/industry should be expected.

The next analysis that was conducted was to determine the skills that are mediated by the different Serious Games [Baalsrud Hauge et al. 2012a, Riedel & Baalsrud Hauge 2011]. A non-exhausting list of games is in Annex A. A pre-selection was made based on short description of topics, and 30 games were analysed in more detailed and according to multi-player, teaching topic, etc. (see Table 2). The analysed games are based on publicly available information and is non-exhaustive. The games analysed are developed for distributed and cooperative productions (like COSIGA; Share etc.), or for Supply Chains (supply net game, beer game, TAC Supply ChainM etc.). The games focus on conveying different skills to the players. A more detailed analysis can be found in [Riedel & Baalsrud Hauge, 2011].

The table below classifies 30 games according to different criteria. The four columns marked are according to the discussion above of specific importance.

Table 2: Overview of relevant games (X= is covered, (x) is partly covered)

Game Name	Distributed Work	Knowledge Management & Sharing	Product Manufacturing	Mediation of Skills				Target group: decision makers/Engineering students
				Innovation/ Product Development	Decision/ Project Management	Supply ChainM and Logistics Skills	Risk Management	
COSIGA	X	(X)	(X)	X	X			E
GLOTRAIN	X	(X)	X	X	X			E
LOGTRAIN		X			X	X		E
PRIME	X		X		X	X		E/D
SHARE	X	X	X	X				E
SPIKO	X				X	X	X	E
SUPPLY NET GAME		X				X		D/E
City car	X	X	(X)		X			E
REFQUEST	X	X		X				E
Business networking game	X	X	X		X	X		E
EIS		X		X	X			E
SimLab™ Process simulation	X	X		X	X			E
SimLab™ GloVEd	X	X		X	X			E
Simbu		X	X	X		X	X	
Beer game	X	X				X		E
KITS	X	X	X					
MINT	X	X	X	X	X	X		E
Chain	X	X			X	X		E
TAC-Supply ChainM 07(Chen)	X				X	X		E
MARGA Industry	X	X			X	X	X	D
Top sim gen. mgt.	X				X	X	X	D
Top sim global	X	X			X	X	X	D
Top sim project mgt					X		X	D
Top sim logistics	X	x				X		E
PROST	X	X	X	X		X		E
Marga Service	X	X			X	X	X	D
Delta design game			X	X				E
Int. logistic mgt. game					X	X		E
Fish bank LTD					X		X	
Shortfall	X			X				

As already explained above, the business management games are very relevant but not applicable for the target group. Looking at the other games, esp. the MINT game, the TOP SIM logistics and the chain game seem relevant, and a closer look on those verified this. Especially, the MINT game comprises most of the elements and could have been extended to also including risk management. This game is embedded in a in a large learning context [Augustin, 2000]. Thus extending the game about new elements would make it more complex. Also some of the other games comprise relevant elements. These games are less complex, and thus an extension migt be possible, without overloading the game play. Games that seems to be suitable for such an extension are COSIGA; Glotrain, SImbu, Share and Prost.

2.5 Game design and development

SGs are games designed for purposes other than mere entertainment [Greitzer, 2007; Prensky, 2003; Gee, 2003; Michael and Chen, 2006, Harteveld, 2011, Bellotti et al. 2010]. SGs with educational purpose include explicit learning objectives and aim to achieve specific learning outcomes [van Eck, 2006] and "use pedagogy to infuse instruction into the game play experience" [Bellotti et al. p.22, 2010, Greitzer et al.; 2007, Gee, 2007]. Serious games are played in a specific context, and this makes the learning process in games more efficient than without a context [van Eck, 2006, Rogoff, 2003, Gee, 2004]. In Garris et al [2002], it is mentioned that learning can be seen as a multidimensional construct, and that there are different attempts to classify learning outcomes - like skill-based, cognitive and affective outcomes.

Learning outcomes are the goals to be achieved from playing the serious game. An intended learning outcome is a particular combination of capability and subject matter. The success of serious games can be measured according to how well the game supports the learning objectives and how well it is possible to measure the learning outcome, but not all games are good for all learning outcomes [van Eck 2006]. Many educational games have been used primarily as tools for supporting the practice of factual information [Killi, 2005], thus being boring [van Eck, 2006]. "The nature of action-based drill and practice games may lead to behaviour, where players tend to try actions with no reflection on outcomes" [Killi, 2005]. Innovations in technology as well as advances in the field of education have provided a basis for games to be appropriated for teaching and learning [Van Eck, 2006, Bellotti et al. 2010a].

Based on literature, van Eck [2006] refers to mainly three ways of how serious games are adopted into higher education: "have students build games from scratch, have educators and/or developers build educational games from scratch to teach students, and integrate commercial-of-the shelf (COTS) games into the class room" [van Eck, 2006, p. 6]. According to van Eck [2006], option two can be considered as a “Holy Grail”, but is costly, time consuming and requires, a multi-disciplinary team in order to deliver a good game [Seager et al, 2012]. For this thesis, only option 2 and 3 were taken into consideration. COTS are games that are not primarily developed for a specific course, but are used for supporting, delivering and/or assess learning [van Eck, 2006]. However, not made for teaching, they require adaptation and a careful analysis regarding content, suitability for fitting the learning objective etc. It is currently the most cost effective GBL solution, but a prerequisite is that a suitable game is commercially available and can be integrated. More details on integration of COTS can be found in [van Eck, 2006, Kerres et al, 2009 Bellotti et al., 2010a, Baalsrud Hauge et al., 2013b].

2.5.1 Game design process

The most common way of designing SG is still option 2, so in the following the game development process will be analysed in more detail.

Serious games must be appealing and pleasant to play, in order to be compelling for the audience. This requires a design process that pays particular attention how educational content is represented and learning takes place [Kiili et al. 2012; Hald, 2007; Baalsrud Hauge et al. 2013a]. The anticipation is to create games that are attractive and motivational but also have the capability to educate while increasing the level of participation and engagement [Corti, 2006 Squire, 2003]. Klopfer and Osterweil [2013] compare this process with baking and point out the difficulties of getting the right mixture of media, immersion, styles of games, learning goals, mixtures of content etc., since this is context and audience dependent. Furthermore, they refer to five tips (do not be too ambitious, go low tech, think of your audience, get full time staff and concede screwups (p.295)) regarding the conceptualization and design of games. Van Eck [2006], Kerres et al [2009] and Bellotti et al.[2010a] refer to situated cognition, i.e. learning with games takes place in a meaningful and relevant context, and is thus more effective than if the learning takes place outside the context. As described above in section 2.3, games can either be used in a blended learning concept, or as a stand-alone solution. For complex processes like decision-making, or for other complex challenges focusing on competence development, stand-alone solutions are seldom used. Games used for educational proposes within engineering are mostly embedded in a workshop-setting, using a blended learning concept [Angehrn and Maxwell 2009; Crookall, 2005; Garris et al., 2002; Kerres et al., 2009]. This has to be considered already at the concept stage of the game [Kerres et al. 2009].

2.5.2 Guidelines for game design

The question to be addressed here is therefore how to design good games for decision making? Games for decision making should allow to train the process. However, the games have to be so reduced in the complexity that the player can see the impact of the decision on himself, his company and his partners. Furthermore, the game needs be so flexible that when the time and place changes, i.e. the context changes, the same decision has to lead to a different result visible to the player. This requires quite a detailed mirror of the processes with enough variables. Seager et al. [2012] as well as Hald [2007] point out that it is necessary to include all stakeholders in the development process. The design and the development process requires in addition that mechanics, story, aesthetics and technologies are considered. For education games, the learning objectives also have to be included [Kiili et al. 2012] and be played without a too long introduction [Kerres et al., 2009].

The principle of flow is important for motivation and engagement. It describes a state where the subject experiences a perfect balance between challenge and ability [Csikszentmihalyi, 1990; 1997, Killi, 2005; Behr et al., 2008; Kiili et al. 2012]. Kiili et al. [in Gala2013] describe a flow model with five factors that should be considered in the game design: clear goals, challenge, feedback, sense of control and playability. In addition, this model takes into account context, leaning objectives, learners' characteristics, representation of content and the pedagogy, as relevant factors affecting the design of the learning experience. According to the cognitive load theory [Sweller 1988; Kiili et al.2012] a cognitive overload leads to a lower learning outcome, since the working memory is overloaded. Westera et al. [2008] point out that a typical problem is that too many objects without relevance for the learning objective are included, thus distracting more than supporting the learning.

Games for decision-making do require a large degree of freedom and a high degree of realism. This can cause a considerable increase in the level of cognitive load among players. Thus, achieving a good balance is a significant design challenge. Certain techniques are required to decrease cognitive load among players. Engagement is very important in this context, as it helps the students to keep concentration on the presented topic. Malone and Lepper have identified five factors of specific relevance for engagement [Malone, 1981; Malone and Lepper, 1987a,b; Rieber, 1996]: challenge, fantasy, curiosity, control, and interpersonal motivation.

Gee [2003] published different principles to be followed for good design. The 36 principles he listed range from the active, critical learning principle, committed learning principle to the insider principle [Gee, 2007]. These principles can serve as guidelines in the design process. For successful design of serious games, Sawyer and Rejeski [2002] point out the relevance of taking into account:

- **Engagement:** The design should encourage wider and repeated use, and amplify learning opportunities and strategic thinking among users.
- **Quality/aesthetics:** The design should have appealing visuals and graphics and an intuitive interface.

- **Balance:** The design should have models with the right amount of accuracy and have a solid integration of the educational material with gameplay. Others have later elaborated on this need for a well-balanced design, based on their own experiences in designing SGs [Harteveld, 2011].

A tool that can be used to analyse game is the Mechanics-Dynamics-Aesthetics (MDA) framework, which also has the abovementioned elements. MDA uses those three components to describe games and to explain both the relation to each other as well as the influence these components have on the players' experience. The underlying assumption is that from a designer's perspective the game mechanics will generates the dynamics of the game, which again generate the aesthetics. Players' perspective is the opposite way [Hunicke et al., 2004; Deterding et al., 2011]. This can be used by both analysing existing games in order to find potential improvements as well as to design new.

2.5.3 Game mechanics

Game mechanics are essential for games [Cunningham, Ziechermann, 2011]. There are several definitions of game mechanics in the literature [Järvinen, 2008, Sicart, 2008, Cook, 2006, Björk and Holopainen, 2005, Fullerton et al. 2004, Hinicke et al, 2004]. For the purpose of this thesis, the mechanics are concrete rule sets and other formal properties such as goals, player actions and strategies that aim to produce an enjoyable game [Cunningham, Ziechermann, 2011]. Among the most popular categories of mechanics identified within entertainment games are:

- Rewards: Entertainment games employ a wide variety of rewards that motivate the player's progression (e.g. possessions, abilities, skills, virtual currencies, points, reputation, etc.).

- Resource management: Different types of resources are allocated variable values and the player has to decide upon the best action s/he can take given the available resources and constraints.

- Cascading information: Players are provided with minimal information that enables them to acquire the necessary level of understanding to carry out specific actions within the game.

- Scaffolding: the level of difficulties of the tasks to perform increases according to the competence level of the player, so that the player have the feeling of controlling the situation, but still feel challenged.

- Collecting: Players can collect different virtual objects that enable them to improve their performance within the game (e.g. knowledge, competencies, gifts, etc.).

- Quick feedback: Players are informed how well they perform within the game. Instant gratification upon the completion of a task fulfils a natural human desire.

- Communal discovery: It engages a whole community within problem solving processes and it usually has a massive, positive influence on game adoption.

- Cooperation/Collaboration: Players need to work together for common or for individual goals.

- Infinite gameplay: This mechanic applies for example to casual games that can refresh their content and generate a new experience for the user.

The selection of the right game mechanics depends on the context, the content and the learning mechanics. The right choice is a precondition for achieving the learning goals. However, it is still unclear how different game mechanics influence the learning outcome. Thus, it is difficult to design the game properly from start. From a pedagogical perspective, it is difficult to dissociate game mechanics (GMs) from educational components at the implementation level [Suttie et.al 2012, p. 315; Arnab et al., 2014]. In order to overcome the gap between learning mechanics (LM) and GMs, Suttie et al introduced "Serious Game Mechanic (SGM) as a construct that defines the relationship between a learning mechanism and a set of GMs through which it is concretely realised" [Suttie, 2012, p 315], but this is still an area of research.

2.5.4 Frameworks for SG design and development

The aspects described above do all need to be considered in the design and development process. Thus, during the last couple of years, several frameworks for serious games [Marfisi-Schottman et al., 2010; Marfisi-Schottman et al. 2013] have been developed. The aim of these frameworks is to improve the game design process and to ensure the learning outcome, to reduce the time-to "market" and the use of resources. Nadolski et al [2008, p. 339] describes a "tailored methodology and generic toolkit for the efficient development and delivery of serious games for acquiring complex cognitive skills in higher education". The methodology helps to develop scenario-based SG and the toolkit offers the various elements needed for the game. Yusoff et al. [2009] propose a conceptual framework for game design, which includes learning and pedagogy theory in combination with gaming requirements. The framework aims to establish a conceptual model that will be used by the game designer or educational practitioner when designing serious games for effective learning. Fullerton et al. [2004] propose a framework for designing educational games that address both the educational and the ludic dimensions. The educational dimension employs Bloom's revised taxonomy (see section 2.3) to define learning objectives and applies the classroom multiplayer presential game pedagogical model while the ludic dimension determines the gaming elements subject to constraints imposed by the educational dimension.

The framework suggested by Westera et al. [2008] is based on a three level approach: at the conceptual level, they start out with a static modelling of the gaming environment, which is transferred later to a dynamic model, achieved by using events. The focus is on the game play, and the authors mention a typical problem:“games display many scenery objects that have aesthetic or atmospheric value as such, but which are irrelevant to the problem solving process” [p.424], therefore actually are more distracting than useful. Thus, only elements contributing should be included. In the second level, this framework describes the tool that is necessary for game development and implementation. Westera et al [2008] point out that it is better with width than depth and it should have shallow distracters. They also point out that the use of closures will reduce the complexity.

A different framework that has been recently developed is CISD [Duin et al. 2012; Fradinho et al. 2012]. The Contextualized Interactive Story Driven Development (CISD2) comprises two main parts: the first part is dealing with the competence that the players should develop, and the other care about elements like game mechanics, objects, interaction possibilities, i.e. scenario relevant elements [Duin et al. 2012]. The framework consists of a set of tables and documents that can be recombined so that the game can take different paths. Whereas Westera et al [2008] focus on decreasing the complexity of game design, by introducing a three layered model including tools supporting scenario generation, the CISD foresees a framework with two main components, but with several sub components.

Harteveld suggests the following approach for game design with three main components: Reality, Meaning, and Play (see Figure 6). These should be considered equally in the game design process in order to ensure a balanced game. World of reality and world of meaning are interdependent on each other. Hence, the criteria of two worlds are strongly related to each other, but they need to be reconciled with fun and engagement criteria from the world of play, where play represents how a game can be developed based on clear goals and rules so that learning involves dealing with engaging, immersive and fun elements.

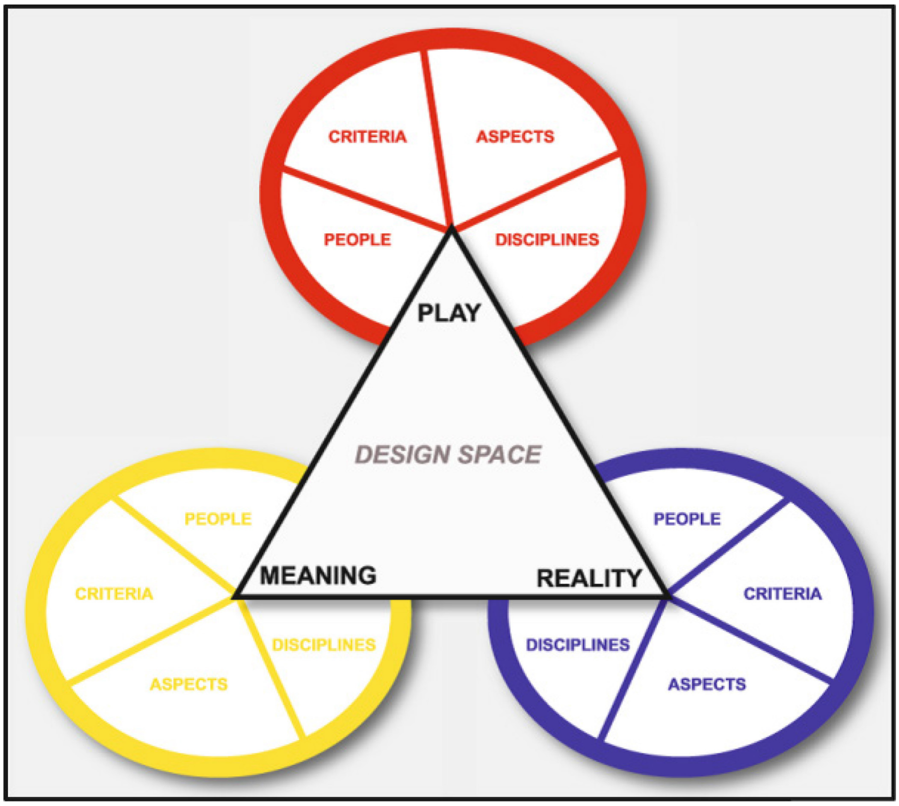

Figure 6: Triadic Game Design [Harteveld, 2011, p. 34]

The development process for games is often based on a spiral approach, derived from a typical software development process. The spiral approach foresees a rapid prototyping and then several loops of improvements until a final product has been delivered, and the game is put into operational use in a class. Most of these spiral approaches are based on agile software design methods. They are used for minimising the risks related to software development and allow flexibility with respect to requirements, technology and understanding of the situation [Cockburn, 2002, Barstad, 2002]. Due to the challenges in balancing the different elements in a game already at an early stage of the design and development of educational games for with high complexity, these games are often adjusted and improved over a quite long time based on the learning outcome of the users.

There are also different possibilities of reengineering games without starting from scratch. Two possibilities are either to use game engines or if less changes required using authoring tools. Games used for decision making in Supply Networks need to be adjustable for the dynamic environment. As described above, the design and development process mainly involves several different stakeholders, in which the teacher or the field expert is just one of few. For hard coded games, any change needs to be implemented by a software developer or a programmer. In many cases, a scenario just need to be adapted to fit the new requirements and thus thus an authoring tools could be used, at different levels and for different purposes. An authoring tool allows a field specialist or teacher in designing new scenarios. Bellotti et al. [2010b] describe different authoring support used in games for cultural heritage, and then present an authoring tool providing several tasks templates, using a layered approach, simplifying the authoring work. Another example is within the e-Adventure game platform, developed by the e-UCM e-learning research group at Universidad Complutense de Madrid [Moreno-Ger et al. 2008, Torres et al. 2010] within a project with the same name. Both Moreno et al. 2008 and Bellotti et al. [2010b] use a layered concept, i.e. content and game mechanics are divided. e-Adventure includes a game engine and uses XML Markup. The framework features a graphical editorial tool [Moreno-Ger, 2008], thus, it is not necessary that the author has any programming skills, in order to create a game. In the context of my thesis, two authoring tools have been developed in BIBA. One authoring tool is for the development of single user games focusing on the collaboration processes, and a second one is used for configuration of a game for strategic decision making. [Baalsrud Hauge et al., 2007a, Baalsrud Hauge and Rust 2012]. The first one uses a structured layered approach, which hardly requires any software skills, whereas the other is a toolkit, with a larger degree of freedom in configuration. However, this process requires that the author knows how to design a new learning scenario (i.e. need some pedagogical experience), in order to match the game scenario with the learning objective, and an understanding of what is possible and what is not.

Another, lower-level, approach concerns the direct use of game engines, such as Unity 3D. These provide often a framework and a development environment in which games can be developed. Direct programming on game engines allows the highest degree of freedom, flexibility and performance, but is time consuming and requires high technical skills [Anderson et al. 2008, Valente et al. 2005, Blow, 2004]. There is no single definition of what a game engine needs to comprise, but a thorough discussion can be found in Anderson et al. [2008]. be.mog developed in BIBA is an example of a game engine [Duin et al. 2009], however as this thesis started, it was not an engine, but a single game, namely Share [Schwesig, 2005], that had to be extended for this thesis and became a game engine.

2.6 Refinement of research question and research methodology

Based upon the previous state of the art analysis, this section first derive the emergence of the research question before it outline the research methodology to be used in order to answer the questions.

2.6.1 Emergence of research questions

Section 2.1 discusses what resilience is, the factors that affectit, and how resilience can be achieved. In summary, it can be said that resilient manufacturers must have the capability to adapt to a dynamic environment, continuously innovate, collaborate efficiently and identify and manage risks and opportunities (i.e. this research uses the managerial, symmetric, definition of risk). The key factors for increasing the resilience are related to the vulnerability and capabilities of a network. Furthermore, the dynamic and turbulent environment also requires that the organisation is prepared to handle unexpected events, which is one of the main challenges requiring a holistic risk management approach for the network. t [Jüttner, 2005; Peck, 2005; Sheffi, 2005; Pettit, 2010]. This is to a large extent a question of achieving a learning organisation, and much work has been carried out on understanding this issue during the last decades and suitable models, like Nonaka's SECI model has been developed. Furthermore, the different levels of learning, the need for organizational learning, but even more indvidulal learning in order to make the enterprise network agile and fit for operating in a dynamic environment were discussed. Thus, the first research question is related to competence development of the individual:

- RQ1: Which competences does a future employee need in order to contribute to the resilience of the Enterprise Network he/she will be working in?

Risk management is about making decisions considering different factors, and about the awareness that risks can be threats as well as opportunities. It requires the ability to analyse the situation and to develop different strategies on how to cope with the risks. Managing risks in a Supply Network is not only about reducing or avoidance, but also about identifying the different facets of a risk - sometimes, a risk is an opportunity, and sometimes the same risk in a different context or at a different time and place will be a threat, or at least have different impact, because the laws, the fitness of the company, the collaboration as such has a different risk tolerance. The question is therefore often related to if it is better to cooperate, collaborate or produce alone, since collaboration and cooperation will reduce the potential of some of these threats. However, also give rise to the emergence of some other types of risks related to the form of cooperation. For this, it is necessary to be able to make decisions and to solve problems in different contexts. Hence, the second research question is:

- RQ2: How can these competences be developed within the education in such a way that future employees can act as needed when a new situation arises?

Finally, section 2.2 and 2.3 discuss learning theories and the advances within the educational field during the last decades. It is discussed that in order to improve decision-making and problem–solving competences experiential learning methods have shown good results. However, it was also shown that most of the available games, in addition to conveying collaboration and communication competencies, are very specific [compare also Tan et al., 2010, and Lewis and Maylor, 2007]. Many games train decision-making and problem solving skills, but most games, even being collaborative, do look at the problems from a single company view, and therefore do not focus on the different facets needed for managing risks in Supply Network. In addition, very few of the decision-making games looks specifically into the uncertainties which may be high in dynamic environments. In fact, no existing game with the right target group (master students; production, system and industrial engineers) was found. There was also no similar game targeting master students from Supply Chain and operational management found focusing on risk management in Supply Network. Thus the final research question is therefore:

- RQ3: How to design a game-based course allowing the student to actively apply risk management and assessment methods and experience how different vulnerability and capability factors impact differently on an Enterprise Network and contribute to the arising risks in different contexts?

In order to address the research questions it is necessary to design a research methodology. The work is based on a mixed method approach and is described in more detail in the next section.

2.6.2 Research methodology

For the research design, a mixed method approach was used [Teddlie and Tashakkori, 2006], in combination with action research, involving teachers and students at an early stage. The reason for selecting this approach is that it gives the opportunity to analyse the research questions from different perspectives. Furthermore, it can be combined with the agile approach which was selected for the software development. The reason for the selection of an agile development approach was that this give an excellent opportunity to improve the software at an early stage, both by involving the users (the students) and also the teachers in the software development process. Through this, it was also possible to collect quantitative and qualitative data needed for a mixed approach [Creswell, 2009; Maxwell, 2002; Teddlie and Tashakkori, 2006].

The research methodology involves literature reviews, examination of games and courses, requirements gathering, tests (of knowledge, but also of the software) and evaluation and will be explained based on Figure 1, section Thesis Structure and Outline of the Chapter 1.6. This section discuss the methodology used in connection with the research questions. A more detailed description on how this methodology was used is in the corresponding chapter, e.g. in section 3.3, it is described how the questionnaires for requirements analysis and data collection are designed, whereas the evaluation methodology is described in chapter 6.

In order to answer research question 1, it was required to know the State of the Art of resilience, thus in a first step the challenges of resilient Supply Networks had to be analysed. This could have been done in different ways, but in order to get a broad perspective of what different people have written about the topic, a literature review searching for key words like resilience, supply chain management, supply chain risk management, enterprise risk management, risk assessment, was carried out. Not only is the research contribution of interest, but also entrepreneurial practice is very important. For this purpose, additional to the literature review, a web search on relevant news and blog contributions, speeches on trade fair were carried out.

Further, it was necessary to identify which competences could be relevant. During the last decades, much has been published on which competences are needed for engineers working in distributed production, so to get a holistic view a literature review was carried out. This answered in general which competences would be needed, but not specifically enough to exactly define the competences to be most relevant for resilience, risk and risk management in enterprise networks. Thus a questionnaire was developed and distributed at three large conference having attendees from the various relevant fields (engineering, product development, supply chains and logistics). This identified the needs.

In order to answer research question 2, it is necessary to know the state of the art, so a literature review assessing how such competences are most efficiently taught was carried out. In a second step, it was looked at how topics related to risk in enterprise networks are taught today and then compare with the findings on suitable learning methods. Also, a questionnaire was used in order to get a view of what practioneres and educators identify as relevant teaching methods. However, most of those answering the questionnaires where either lectures or high-level managers. In order to cover middle management and those carrying out the daily work in a collaboration, project managers working in large scale complex projects were interviewed and also asked to complete the questionnaire. In addition, in order to get more information from their daily work and need for risk management in collaboration, they were interviewed, using the questionnaire as a structure. These people had practical experience in collaborating within an enterprise network in a highly competitive, but complex field comprising several trades.

Finally, in order to answer research question 3, it was examined how games and courses are mostly designed and developed. Here, for the course development a literature review assessing common practice was carried out, but only focussing on approaches dealing with Game Based Learning. For the game design and development, it was different, since it was just investigated different approaches and then decided to use one for which we had good experience - an agile approach, which requires a good collaboration and regularly formative evaluations.

Evaluation of the developed software and the learning outcome is also very important. For this several methods are used, questionnaire, test, stealth –assessment, etc., which are described in detail in chapter 6. Based on the evaluation results the curriculum and game design were adapted and improved to produce a final curriculum with game integrated. However, the course and the game have been continuously evaluated during the last years, in order to systematically look for improvements.

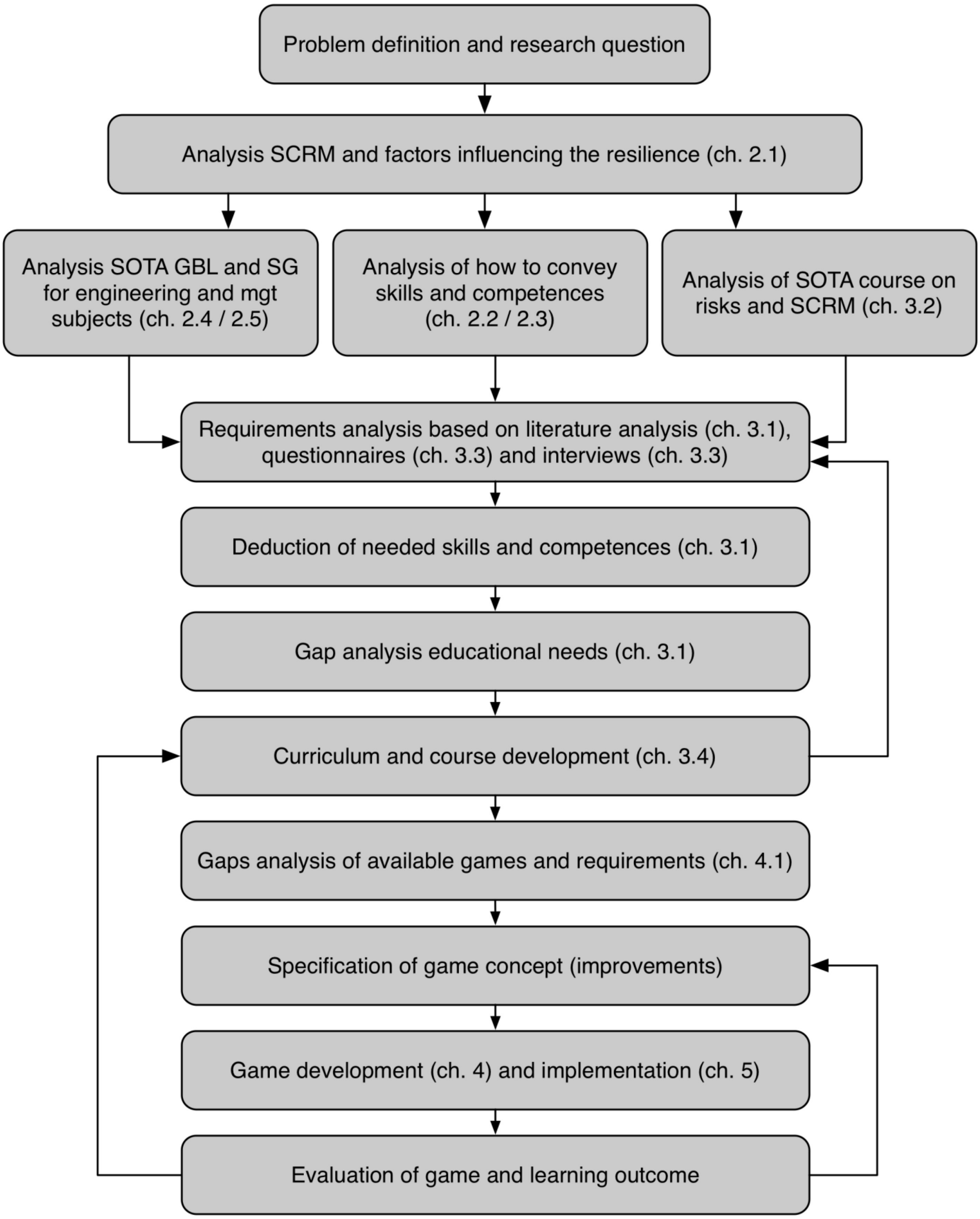

Figure 7: Research methodology

3 Requirements and Course module development

During the research parts of the text have been published in [3, 5-8, 11, 14, 15, 18, 22-24, 26, 30, 32, 33, 35-37, 40]. These are listed in chapter 12-Annex E.

The two main objectives of this chapter are to identify which competences employees need in order to contribute to resilience and the management of risks in Supply Network, and secondly, to develop a curriculum for how these skills can be mediated to engineering students. To meet the first objective the specific competences for managing resilience are analysed. For this purpose, a theoretical derivation based on the characteristics of resilient networks and their main challenges were carried out (compare section 2.1). This outlined some main competences in general. However, since it is a relatively new topic (as the thesis started), there was not so many publications on competences concerning resilience and risks in Supply Networks. In order to achieve more information, a survey of engineers as well as interviews with experienced project managers working in collaborative projects were carried out. To meet the second objective: SCRM and SCM are the related teaching topics, and thus in this chapter, an analysis of the current state of the art regarding mediation on risk management is presented. Based upon these findings, the specific learning goals were defined and a curriculum for SNRM was developed. As explained in section 1.4, competence development, like problem solving and decision-making competences needed in a dynamic environment require experience and training, and thus call for the use of experiential learning like GBL (compare sections 2.3 and 2.4), thus a game has been developed (see chapter 4, 5) and as an integrative part of the curriculum.

3.1 Qualification needs for engineers in Supply Networks

The objective of this chapter is to analyse the qualification needs for employees working in and contributing to resilient organisations as well as to identify what they need to know about risk management in Supply Networks.

According to Christopher and Peck [2004], as well as Pettit et al. [2010], the understanding of Supply Network risks is one key element for increasing resilience. As the employee is the person in an organisation that performs collaboration, the organisation’s success will mainly depend on his capability to learn and act in a dynamic environment [Windhoff, 2001]. Thus, research question one is, what competences does an employee need in order to be able to perform effectively in such environments? This can be divided into two parts: at the individual and at the group level. At the individual level it is about knowledge on risks, risk behaviour and risk management methods, as well as related to his competence on how to apply methods, to analyse, assess impact and draw conclusion for creating suitable strategies and create knew knowledge (i.e the three higher cognitive levels in Blooms revised taxonomy). As described in the previous sections, due to the complexity and the different perspective as well as risk appetite, it is not sufficiently if an individual in a single organisation carry out the SCRM-process. Consequently, this task should be carried out in cooperation and team work, leading to als requiring competences in information sharing, communica-tion, team work, and collaboration, cooperation abilities ensuring efficiently execution across the supply network. This part has to a large extent already been answered in previous works [Windhoff, 2001; Schwesig, 2005] and in the literature review in section 2.2.2, at a general level, so here only those aspects related to the specifics of risk and risk management in Supply Networks are elaborated in more details.

Figure 8 highlights the different elements for creating a resilient Supply Network. Being in line with the discussion in section 2.1, it seems plausible that to increasing an individual's understanding of Supply Networks by focussing on these aspects will lead to a more resilient Supply Network.

These factors must be managed in such a way that the vulnerability is reduced and the capability is increased, but still so that the outcome makes economic sense. In order to be able to operate in a global context, connectivity is a very important factor, since the higher the connectivity, the more interdependencies there are to different organisations. Consequently, the capabilities of collaboration, flexibility and visibility are relevant for resilience [Peck, 2003; Oosterhout, 2008] Poor capabilities in this area will lead to a vulnerable global network. The capabilities are context related i.e. the organisation ought to monitor and assess them continuously in order to identify changes. If the monitoring leads to the identification of an unexpected event, or a deviation from the overall strategy, then the organisation or the responsible management team has to develop and implement actions. Furthermore, a risk may be a threat for one organisation, but can be an opportunity for a different organisation in the network. It is also dependent on place and time. Thus, a supply network risks need to be seen from the managerial perspective, -i.e. as risks and opportunities [see section 2.1].

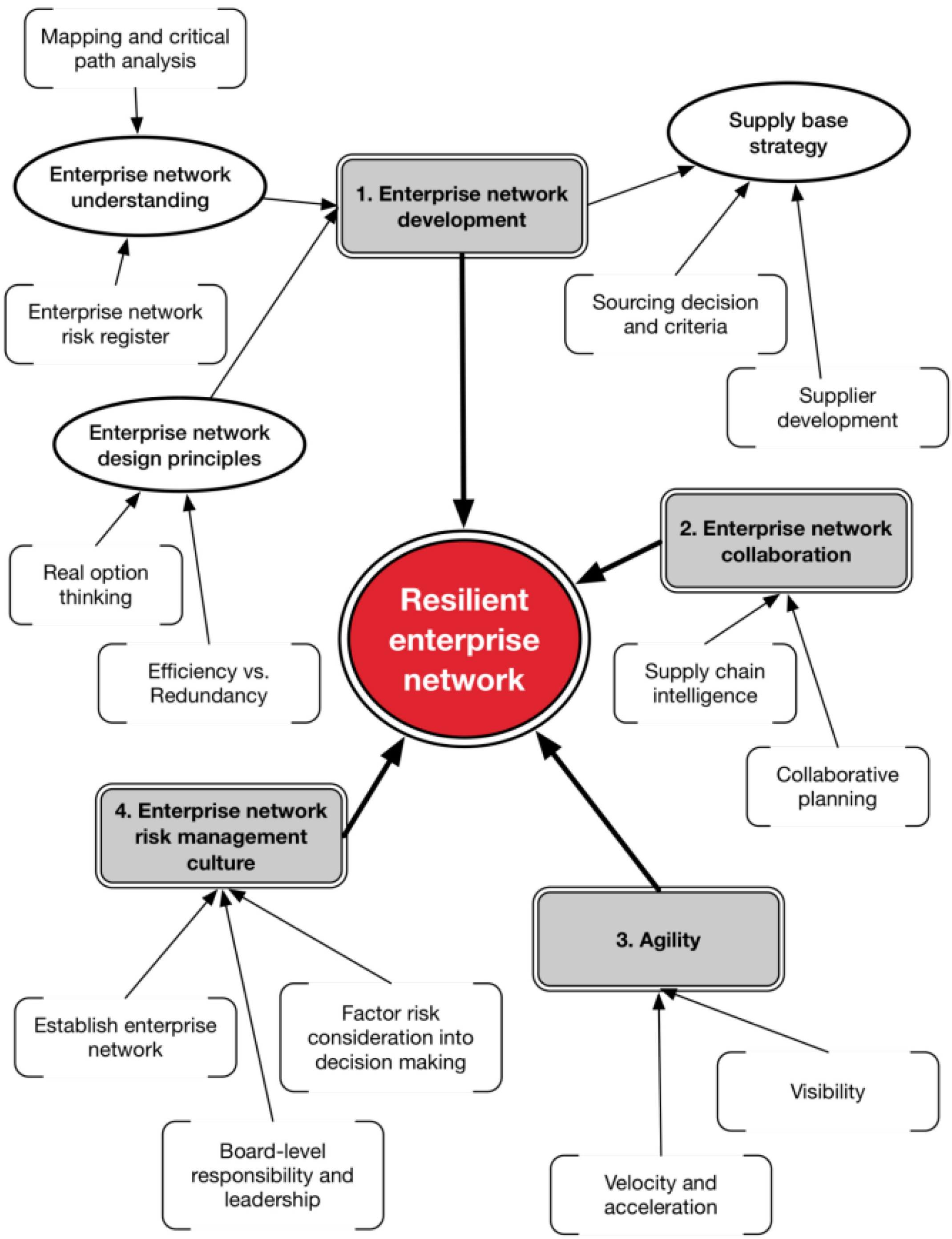

Figure 8: Creating a resilient Supply Chain [source: Peck, 2004]

Decision-making in dynamic systems is hard because it calls for dynamic decision making, which is a stream of decisions closely depending on one another[Manuj and Sahin, 2008; Jüttner, 2005; Peck, 2005]. As a starting point for deriving the educational needs, the quite comprehensive framework from Peck [2005] is used. Firstly, an analysis of Figure 8 shows that the resilience needs to be taken into account at the planning stage. Secondly, in order to create resilience, an employee needs to be able to understand and evaluate the risk perception at the supplier. Thirdly, it will only work if it is possible to achieve a common planning, which again requires trust, visibility and transparency. This requires fast reaction to changes. The agility of a Supply Network is also relevant. With agility this thesis means the ability to respond quickly to changes in demand in terms of both volume and variety [Christopher, 2000, 2005].

SNRM will contribute to a common understanding of the identified risks, and thus support the development of a common risk culture, i.e. a common understanding of how risks affect the Supply Network [Jüttner, 2005, Starr, 2003;].

The previous chapter explained that in order to deal with risks in dynamic systems, it necessary to know how to manage them (i.e. take the opportunities, but reduce the threats), and be able to act on unexpected events. This is still a challenge [Jüttner, 2005, Sørensen, 2005; Sheffi, 2005; Peck, 2005; Christopher and Lee 2003, Christopher and Peck, 2004; Fiksel, 2006; Pettit et al, 2010; Pfohl, 2002].

This requires both decision-making skills as well as knowledge on risks and risk management as well as the ability to continuously analyse changes in any of the vulnerability and capability factors and act on them. Jüttner [2005] points out that traditional risk management methods are not sufficient for this purpose, since it mostly looks at risk reduction, leaving out the opportunities and secondly, is developed for use within a single company. Therefore, the employee has to be able to evaluate the environment and draw conclusions as to which appropriate actions can be undertaken. This has been known for a while, and thus an analysis of the current courses on SCRM shows that there is an increasing interest. However, despite the above-mentioned abilities often being implemented in existing curricula, the need for risk management skills for Supply Networks is not so well documented, since most courses addresses the topic from a company instead of from a network view.

3.2 Analysis of state of the art for mediation of risk management

There is a large variety of educational offers (i.e. courses, workshops, seminars, presentations, etc.) on Supply Chain and SCRM related courses at universities and vocational training institutions. The offers range from one-day workshops to complete courses and master degrees. To get an overview of the existing educational offers, information on course content, target group and how the course/class is given were collected from several educational institutions. Table 3 shows a few examples, indicating the variety of offers. The information was partly collected through an internet search, by using a study carried out by Baumgarten and Hildebrand [2008] on the logistics and by writing to the administrations of the educational institutions. The faculties and departments of economics, law and engineering were addressed. In order to limit the number of courses to those relevant for this thesis, only courses and offers related to risks and/or Supply Chain/Supply Network, as well as collaborative production were selected. In addition to higher educational institutions, Supply Chain and risk related topics are offered by several consultancies and professional training organisations.

The identified courses and offers were investigated according to the criteria of topics (risks, risk management, supply network, supply chain, risks (mostly based on the module description), teaching method (lectures, lectures + tutorial, workshop, simulation and games, others), duration (long term, short term, no. days etc.) and level (undergraduate, postgraduate, executive, management, etc.). The intention of the analysis was to get an overview of the educational landscape in the field, as well as to identify the main foci for teaching and training in this area.

The analysis showed that lecturing is the primary teaching method for long-term courses at undergraduate and post-graduate level. The second most common method was lectures in combination with tutorials. Furthermore, the analysis showed that many institutions offer 1-2 day workshops, often based on case studies and problem based learning (cognitivism), or the use of business simulations (only a few) based on constructivism. These latter two involve active participation of the students. It also revealed that the more practice oriented the educational institution; the higer likelihood of active participation.

Most of the identified courses on risk management topics in the field of supply chain management were offered to post graduates.

Table 3 shows a few examples of the identified offers.

Table 3: Examples of risk management courses

Type of organisation (University/ Company)	Type of course/ event/ seminar	Short description of the course	Degree
Vienna University of Economics and Business Administration Institute for Risk Management and Insurance	Lecture "**Risk Management"**	Risk management in the enterprise policy; decisive-theoretical bases; confrontation Risk management / risk policy, tasks, purposes, methods of the Risk management, organisation of the Risk management; problems of the Risk management; practical use; psychological dimensions, application of the probability calculus; connection with assurance.	Post graduate
	Lecture "**Risk theory"**	Probability theory; concepts of the risk measurement and risk diversification; portfolio concepts and application to insurance supplies; use theory; instruments and strategies of the risk coping; risk transfer, risk transformation; models of the risk balance; (…)	Post-graduate.
University of Nottingham Business School	**Risk Management Decisions** Lecture and seminar….	This module will introduce the different aspects of corporate risk and examine how the risk of fortuitous loss may affect the various stakeholders in the operations of firm	Post graduate
University of Applied Sciences Osnabruck Faculty for economics and social sciences	Research project "**Risk management /-controlling"**	The research project Risk management /-controlling has the purpose to make the methods of the risk management and-controlling, which come partly from the bank company apprenticeship, applicable for the practice of medium-sized production enterprises. Besides, especially a process-oriented beginning is developed for the risk management and-controlling.	Post-graduate
ETH – Swiss Federal Institute of Technology Zurich	Lecture and tutorial "IT Security and Risk Management"	Systematic representation of technical, methodical, procedural and organizational aspects of the security and risk management in the IT sphere and imbedding in related areas like Compliance and Governance.	Post-graduate - Informatics
Institute for construction statics and construction (just examples of several courses)	Lecture and tutorial "Risk and security in the civil engineering"	Risk assessment of engineered components and systems is addressed from the perspective of supporting engineering decision-making on behalf of society. Both time invariant and time variant problems are considered.	Post-graduate
Humboldt University Berlin Professorship for Insurance- and Risk Management	**BBWL: Insurance management and risk management**	Bases of the insurance management, Asset and Liability management in the insurance enterprise, Risk Management.	Post graduate
	Lecture "**Risk Management"**	Subjects: Concept, being and rationality of the risk management; risk identification, risk measurement and risk assessment; risk use; well-chosen questions of the risk management.	Post-graduate
The education is aimed at an activity in the operational risk management also beyond the finance sector.	Practice to "**risk management, risk policy and accountancy of the insurance enterprise"**	The practice should be offered in every semester. In it practice tasks are calculated to the contents of the single lectures,.	Post-graduate
Züricher Hochschule ZHAW Weiterbildung	Certification seminar of **Integrated Risk management "Optimisation of the products, processes and management systems by means of integrated RM"**	The certificate course "Integrated risk management" is the base course of the Diploma of Advanced Studies in Integrated Risk management. The course provides important bases: The course gives a sound overview to the topical RM norms, with special consideration of those norms which have originated after 2000:	- Responsible person in the areas of Security, risk, quality

As mentioned before, the typical teaching form for postgraduate courses on risk management is lectures, whereas the courses targeting decision makers are more based on problem based learning or the use of business simulations. These latter courses require experience in the field. Regarding the content, several courses address IT risks, as well as Supply Chain risks. The offers from faculties and departments in the field of engineering are mostly related to safety and security, and thus only look at risks as a threat (compare discussion in section 2.1), whereas the more management related courses also look at the opportunities of risks. Based on this analysis, it can be concluded that most higher educational institutions, teaching global manufacturing or Supply Chain, have offers on topics related to risks, resilience (less available) and risk management in Supply Networks. Nevertheless, the literature still reports the difficulties in coping with unexpected events and risks in Supply Networks in a holistic way [Pettit et al., 2010; Jüttner, 2005]. In order to get more insight into the educational needs for Supply Networks a questionnaire was developed and distributed to professionals and lecturers at relevant conferences in 2006.

3.3 Results of Questionnaire on survey of experts

Section 3.1 outlines the qualification needs for engineers working in resilient Supply Networks in general, and the needed skills on decision-making in more detail. The analysis in the previous chapter also concluded that there is a demand for offers regarding SCRM. This section describes the last part of the requirements analysis. It comprises two parts- a descriptive survey based on a questionnaire that was distributed at three conferences in 2006 to industrialists and lecturers covering their perception of the needed skills and knowledge for risk management in enterprise networks as well as on how they see the different methods for conveying these competences. The second part is interviews with a small number of project managers working on large scale collaboration projects.

In order to get an indication on the needs and requirements on employees regarding competences on managing risks in Supply Networks in those areas identified as specifically relevant to resilience, a questionnaire was developed (Malhotra and Grover, 1998, Forza, 2002). A questionnaire can be a useful tool for gathering information if it is well-structured and asks the right questions. Since it is no follow-up questions possible, it is important that the questions cannot be misunderstood. The questionnaire was developed by the Dr.Ing. candidate with the help of the supervising professor. The questionnaire was tested before use on a small group of researchers. The questionnaire comprises 5 sections. Section A covers administrative information (position, number of employees in organisation, year of experience etc.). Section B (12 Questions) is related to risk management within his/her organisation and the personal experience of the respondent in dealing with risks in the company and in an enterprise network. Section C covers various aspects of risks in enterprise network related to the collaboration (cultural and communica-

tion (10Q), strategic risks(5Q), human resources (5Q) and innovation risks (5 Q). These areas were selected based on the theoretical analysis of risk in enterprise networks (see section 2.1). Section D deals with the educational needs for risk management for engineering students (12 Q). All together there were 51 questions. For each section there was one open question, the rest were mostly multiple choice using a Likert scale. The reason for the selection of multiple choice questions was the need to obtain quantitative answers, to make statements of the relevance of specific terms identified in the analysis of state of the art (see chapter 2, section 2.1 to 2.4). The advantage of multiple choice questions are that it is easy and quick to complete and analyse, and the answers can be converted into data (see Table 4, Table 5, Table 6,). The disadvantage is that the answers are not explained, not all questions can be answered with yes/no, or Likert scale. Thus, an open question was added to each section so that the person completing the questionnaire could add further information. Topics of high relevance for collaboration (like trust, information sharing, etc.) were looked at from different risk source perspectives.
The questionnaire was distributed at three international conferences in 2006: International Symposium on Logistics (ISL), PRO-VE (IFIP working conference on Virtual Enterprises), and International Conference on Engineering, Technology and Innovation (ICE). Only industrialists as well as lecturers were asked to fill in the questionnaire.

In total 56 questionnaires were completed; two-thirds were completed by industrial representatives and one-third were completed by educational representatives (lecturers and professors). The questionnaire also asked about the potential acceptance for using experiential learning methods, such as games. Due to the low rate of female participants at one of the conferences, no gender specific data was kept.

Table 4: Relevance of risks related to collaboration, trust and information flow (% (number in the cell), n=56)

Question	Not true				Very true
Lack of trust among the partner is a very relevant risk factor in collaboration	1,8	1,8	7,1	25,0	62,5
In collaboration, the optimum solution with minimum risks can only be achieved if all partners are aiming at finding the optimum solution for the collaboration as a whole	7,1	8,9	14,3	33,9	21,4
Each company, even in collaboration, mainly follows its own interests	3,6	5,4	23,2	42,9	23,2
Lack of information exchange is often a problem	1,8	3,6	1,8	32,1	58,9
Cultural differences often lead to misunderstandings	0,0	0,0	17,9	42,9	33,9
Collaborating with partners with a different mother tongue increases the risks for negative impact on the collaboration	8,9	16,1	25,0	25,0	19,6
Lack of openness and communication are detrimental to every collaboration	0,0	0,0	8,9	35,7	51,8
Information sharing is risky in an enterprise network, since you never know your who tomorrow`s competitors are	8,9	17,9	33,9	28,6	7,1
It is necessary to define a common strategy on information sharing before the collaboration starts	1,8	3,6	12,5	32,1	48,2
Seamless information flow between all collaboration partners is important for reducing the risks in enterprise networks	1,8	5,4	21,4	37,5	28,6

Table 4 provides an overview of the respondents' opinions on different aspects of trust, collaboration and information flow. Even though more than half of the respondents answered, "In collaboration, the optimum solution with minimum risks can only be achieved....", an even larger majority stated that "each company, even in collaboration, mainly follows its own interest" - i.e. even though it is known that an holistic approach is necessary, companies are still said to act at an individual level. This is one of the typical risks that Seiter [2006] describes as a collaboration risk. Furthermore, most of the respondents see information sharing and lack of information exchange as a source of risk, whereas issues like different languages or different organisational structure are seen as less relevant (Table 4). Table 4 also indicates that the respondents answer that employees do not share information, that their cultural knowledge is too low, and that trust is a prerequisite for successful collaboration. Furthermore, the respondents answer that most of the employees do not understand how their behaviour affects the collaboration.

Regarding more strategic components, it seems that the respondents find that support from the top management is important, and that both an insufficient IT infrastructure as well as the lack of a common understanding might influence negatively (Table 5).

Table 5: The relevance of the perception and knowledge of the employee (%, n=56)

Question	Strongly disagree				Fully Agree
Strategic					
The use of different technologies (e.g. different software) is a problem in performing the collaboration	5,4	12,5	23,2	32,1	25,0
Different organizational structures cause risks in the collaboration	10,7	17,9	25,0	33,9	7,1
Intra-organizational support by top management reduces risks in performing the collaboration	5,4	5,4	14,3	28,6	39,3
Different levels of management competences cause intra-organizational problems	5,4	8,9	25,0	48,2	7,1
Lack of common understanding is a problem	1,8	3,6	5,4	28,6	51,8
Human Ressources					
Employees do not have enough cultural knowledge of the collaboration partner	3,6	16,1	21,4	37,5	16,1
Employees do not share their knowledge with others	8,9	8,9	23,2	50,0	5,4
Employees are often not aware of the impact his/her behavior can have on the collaboration	0,0	8,9	8,9	55,4	21,4
An employee can only perform optimally, if he/she does not feel his/her position threatened	5,4	5,4	17,9	25,0	37,5
Trust between the collaboration partners (the persons working with each other) is vital for the success	1,8	1,8	5,4	25,0	62,5

The last part of the questionnaire asked about the expected knowledge on risk management and the mediation methods. The respondents expect that future employees should have skills on risk management (89,3%), on how to reduce risks as well as how to identify risks (73,2%) (Table 6).

The results of the questionnaire on mediation methods show that on average the respondents are sceptical of the sufficiency of only having theoretical classes (50%), but that they do expect that classes will give the students an understanding of risks in Supply Networks (28,6%, Table 6).

Table 6: Need of risk management skills and mediation forms (%, n=56)

All engineering candidates should get a basic knowledge of a standard riks management process				
Not at all				Very much so
0,0	0,0	5,4	37,5	51,8
It is important that engineering students learn about the different steps in the risk management process in more detail				
True				Not true
1,8	5,4	12,5	46,4	28,6
It is important that the candidate knows various methods of risk assessment				
Not at all				Very much so
1,8	10,7	23,2	35,7	23,2
The candidate should know different types of risks, how they may occur and how they can be detected				
Not at all				Very much so
0,0	1,8	19,6	41,1	32,1
It is important that the candidate knows how to reduce risks				
Not at all				very much
1,8	1,8	10,7	44,6	35,7
The candidates do not need to know anything about risk management, they will learn what they need while performing their				
Strongly disagree				Fully agree
41,1	32,1	12,5	3,6	3,6
Do you aggree upon that it is sufficient to read a book on risk management to understand how to apply risk management methods				
Strongly disagree				Fully agree
26,8	41,1	16,1	8,9	1,8
To what extent do you think it is possilbe to read a book on risk management to get and an understanding of risk management in enterprise network				
Not possible				Very well possible
5,4	32,1	39,3	12,5	5,4
Do you agree upon that it is sufficient to join a theoretical class on risk management to understand how to apply risk management				
Strongly disagree				Fully agree
12,5	37,5	23,2	21,4	0,0
To what extent do you think it is possible to join a theoretical class on risk management to get an understanding of risks in enterprise				
Not possible				Very well possible
5,4	17,9	35,7	26,8	1,8
According to your opinion, are simulation games a suitable way of mediating risk management methods?				
Strongly disagree				Fully agree
0,0	3,6	16,1	44,6	23,2
Do you agree upon that simulation games are a suitable way to mediate the understanding of risk behaviour in enterprise network?				
Strongly disagree				Fully agree
1,8	1,8	21,4	39,3	25,0

Based upon the results of this questionnaire with 56 participants, it can be concluded that issues related to trust, collaboration, lack of openness and communication (87, 5%), misunderstandings based on cultural differences (77,8), and information flow (91,0%) are seen as sources of risk within Supply Networks. Furthermore, even though most respondents stated that an optimal solution with minimum risks can only be achieved in collaboration (55,3%), they are also aware that most partners will follow their own interests (66,1) (all Table 4). In addition, more than 70% (agree and fully agree) of the respondents answered that employees are often not aware of how their behaviour affects collaboration. Regarding the need for education is this field, the respondents clearly see a need, and also see that theoretical classes and books are not so suitable for conveying the necessary methodological skills, but can contribute to improve the understanding of risks in Supply Networks. Around 70% are of the opinion that simulation games can be a suitable way of mediating risk management methods and for improving the understanding of risk behaviour in Supply Network.

In order to better understand the challenges risk assessment is facing in organisations, ten project managers, involved in large scale projects with several partners from different technical disciplines and engineering areas, were asked about their opinion and experience with risk management both from a company perspective and for the collaboration as such. These persons were selected, because they all had several years of experience in working in inter-organisational large scale projects with different types of stakeholders. The participants were either working in software development projects or construction projects. The interview used part B and C from the academics' questionnaire described above. Due to the interactive form it was possible to gather more specific information. All managers had a technical education, which might have had an impact on their answers. The project managers were interviewed about their experience of risk management in large scale collaboration projects. In addition they completed the same questionnaires on risk drivers, but did not receive the educational questions. The interviews revealed that most of the project managers carried out risk assessment and management tasks according to their respective companies' guidelines, but also uncovered that hardly any had received any supervision or training in applying risk management. Furthermore, typical for large projects, there is a team building component among those working with each other daily and especially if they need to rely on each other's work. The project managers worked on the same projects, but represented different companies with different goals. They confirmed that due to their internal risk management strategies, they paid more attention to the company interests than to the most suitable for the collaboration as such, however without putting the collaboration and the common goals at risk. However, the lack of an integrated and holistic risk management were reported to lead to more conflicts and stress, and this was not beneficial for the collaboration. Comparing the results of the questionnaire, their answers are mostly in line with the answers from the academics and industrialists, except for intra-organisational support by top management, as well as for the risk of information sharing and the need for a common information sharing strategy, the latter idetfied as more important.

Based upon the analysis of the interviews with the project managers and the evaluation of the questionnaire, it can be concluded that engineering students need skills and competences on risk management and of how risks arise and behave in Supply Networks. Furthermore, such a course should focus on letting the students apply risk management methods, experience how risks related to cooperation and collaboration in a Supply Network arise, and how these can be managed. Next section describes the derived learning goals and the curriculum.

3.4 Curriculum development

This section describes the conceptual development of a curriculum to foster the competences an engineering student needs for working in dynamic and continuously changing systems regarding management of risks in Supply Network (Compare section 0, 2.3 and 2.4).

"A curriculum is a closed concept for the realisation of a measure of the professional and continuing education in which the purposes, contents, methods, organisation forms and the forms of the achievement control as well as the available time are expelled explicitly and obligingly" [Buggenhagen in 2000, p. 74].

Learning processes are dependent on different parameters. Individual personality qualities, intellectual conditions, specific competence and learning experiences generate an internal learning setting. This learning setting faces again to an external learning climate that is generated by individuals and different factors of influence (among other things by the simulation game). The internal learning setting and the external learning climate influence each other mutually and determine the quality of the appropriation and the mediation.

According to common human resource HR] development strategies, the abilities needed above can be related to one of the four competences area [Bea, Dichtel and Schwitzer, 2006; Wöhe, 2008; Windhoff, 2001].

In HR, competence comprises the area skills, knowledge and behaviour and these competences can be divided in four sub groups:

Professional competence: Ability to solve technical problems based on expertise and specialist skills. In the own field, these should be advanced, whereas basic knowledge in related domains seems to be sufficient.

Methodical competence: Ability to apply methods and approaches for solving a given task independently. This requires the knowledge of different methods and approaches, like project management, presenting, presenting etc. and in this specific case the application of different risk assessment and management methods and approaches.

Social competence: Ability to work and collaborate in teams aiming at solving specific tasks. This includes intercultural competence also counts beside abilities like communication ability, negotiations talent, integration ability, team ability.

Self-learning and self-reflecting competence: Ability to own learning objectives, to identify learning resources, to select adequate learning strategies, to assess own learning results. Furthermore, the ability to reflect on personnel behaviour and underlying reasons as well as the difference in own and foreign perception. Abilities like flexibility, creativity, initiative, self-criticism etc. counts here.

According to common human resource development strategies, the abilities needed above can be related to one of the four competences area [Bea, Dichtel and Schwitzer, 2006; Wöhe, 2008; Windhoff, 2001].

3.4.1 Development process of the course

Previous sections presents different learning paradigms as well as outlines how the different paradigms will be used for different conveying different type of skills. Risk management is a process following specific rules and using specific methods. These are typically skills that can be conveyed in a congnitivistic way [Baumgartner and Payr, 1994] focussing on the right application and selection of risk assessment and management methods. However, as discussed in section 2.3 and also mirrored in the identified competences, constructivistic approaches are more suitable in cases where the learner has to interpret multiple realities though abstraction and reflection. I.e., in order to train the problem solving skills for problems arising in dynamic systems, a constructivistic learning approach sseems to be preferable.

Based upon the theory of constructivism (see section 2.3), an additional requirement is that each learner has to be able to construct his/her knowledge individually. This is a main part of the game to be developed.

The curriculum has been regularly evaluated and due to structural changes in the transformation from diploma to master studies also merged with a different game based course specifically looking into strategic management of complex production networks. Thus, today these two courses form a three ECTS lab course. The continuously evaluation has also led to changes in the curriculum, since the evaluation of the game and the workshop setting in the first version showed that the students were overloaded and thus, the principles of flow were not fulfilled. The overload leads to frustration, stress, lack of motivation and engagement. The merge with the other course using a different game (a description of this course can be found in [Baalsrud Hauge et al., 2012, 2013 a,b]) has led to a better cognitive workload. The first part of the course focus now on methods for strategic decision-making both at an individual as well as on team level for the distributed, collaborative or cooperative production, mostly within an Supply Network. The second part of the course, which is described in this thesis focus on risks and risk management as well as managing unexpected events. The games are complementary regarding the competences needed for working in distributed productions. The reduction of workload for less skilled students and the higher flexibility within the competence level of the game did lead to a better balance and better learning outcomes.

3.4.2 Curriculum

3.4.2.1 Aim of the course

The objective is to improve the competences needed for resilience focussing on the management of risks in Supply Networks. The designed course is based on an experiential learning approach and game based. The curriculum will emphasize on mediating competences explained in section 3.1 and focuses specifically on risk and opportunity management in Supply Networks, since the need of such capabilities have been mentioned in the literature [Jüttner, 2005; Sheffi, 2005; Peck, 2005; Pettit et al., 2010]. It comprises professional, social and methodological competences. The course is one of several courses comprising different, but related topics within FB 4 at the university. Thus, in order to avoid overloading the course, elements that are already covered in other experiential learning environments will be paid less attention to. Based upon the identification of topics carried out in section, identification, assessment and risk management methods as well as to support the ability of the participants to understand the occurrence, interrelationship and impact of risks in Supply Network will be given highest priority.

3.4.2.2 Rationale of the course

Compare this section with chapter two. This is the summary, which is needed in order to use the curriculum without the thesis as such. The rationale of the curriculum can be found in detail in chapter 1.1, 1.2 and 2.1 and is therefore not repeated here completely.

3.4.2.3 Goals and objectives

Mediation on risk management skills includes different aspects. The main goal is to increase the awareness of factors (both vulnerability and capability factors) that influence the resilience. Secondly, how these factors can be managed and how the impact can be reduced or fostered. Of specific interest are risks related to communication, collaboration, organisational and enterprise risks (i.e. those connected directly to the vulnerability and capabilities of the Supply Network). How these occur and how they may affect a complex network regarding its vulnerability. Furthermore, the ability to solve problems, to collaborate, and communicate and to make decision will be improved. For this, the students will learn to develop strategies to overcome challenges and to solve problems. In the development of these strategies, it will be focussed on creation of knowledge and application of methods.

The course will support the general curriculum for production, system and economical engineers at master level at the University of Bremen. The second part of the course focuses on strategic decision-making in Supply Networks. It is a part of a three ECTS course, but can also be used as a standalone course. It will then use a different introduction to the topic. The game and the group tasks will remain the same. Main objective: Increase the awareness of cooperation and communication risks

Professional competence:

This area is often related to knowledge development, both procedural and declarative. Often this are facts and basics an employee just have to know. Thus, many of these will be internalised. Especially for declarative knowledge, a behaviour learning paradigm is still suitable. This is also holds for procedural knowledge if it is knowledge the person also need to be able to carry out without thinking, f.ex. in a crisis or emergency situation. This is in many contexts also a part of risk management strategies in companies, but for the risks being most interesting here, it is not needed.

- Identification of potential risks and chances in Supply Chain networks
- Acquire and improve risk management skills
- Know R.A and R.M methods, their boundaries and their advantages. Most methods are not developed for Supply Network, thus it is important that the student learn how he can assess if he can apply one method for a given risk in a given situation or not. This has also much to do with his experience, which has to be gained during gameplay.
- Know and understand different types of risks occurring in Supply Networks.
- Table 7 shows risks that can occur during gameplay. It is important that students experience as many of these as possible during gameplay, so that the students can familiarised with the type and being able to identify such later.
- Learn to develop strategies reducing the negative impact and supporting the positive impact of an occurring event.
- Learn to assess a decision’s impact on the other partner prior to the decision
- Develop risk mitigation and contingency plans
- Learn ways of information sharing and to exchange data
- Learn to express thoughts and ideas

Table 7: Risk overview own overview based on literature review)

Level	Source	Risk kinds according to functional areas	Risk kinds in Supply Chains	Main risk causes	Examples	Level of process	Result divergence	Decisive level	Category
Enterprise	Organisational risks	Research and developing risks		Different causes	Research and developing risks		Unilateral	Operational disturbance	General risk
		Production risks			Weaknesses in the production planning		Unilateral	Operational disturbance	General risk
		Quality risks			Product quality		Unilateral	Operational disturbance	General risk
		Management risks			Leadership risks		Unilateral	Strategically insecurity	General risk
		Personnel-economic risks			Risks of the employee's qualification		Unilateral	Strategically insecurity	General risk
Network (Interorganisational)	Interorganisational risks	Procurement and logistic risks	Interruption of logistics	Lack of possession (unclear responsibility areas, camp posture costs) chaos/ nervousness (Bullwhip effect) sluggishness (lacking flexibility)	flow of goods, e.g., disregard of dates of delivery	Physical process	Unilateral	Operational disturbance	Supply Chain risk
			Prize escalation		Inadequate cost transparency, wrong investments	Financial process	Unilateral	Operational disturbance	Supply Chain risk
			Continuance and expiry risks		Different information software	Informational process	Unilateral	Operational disturbance	Supply Chain risk
		Distribution and demand risks	Technological access		Involved partners	Relational process	Unilateral	Operational disturbance	Supply Chain risk
			Quality		Market entry of products	Innovative process	Unilateral	Operational disturbance	Supply Chain risk
			Collaboration risks	Different goals of coll. Lack of trust and mutual understanding,	Sharing incomplete information	The whole collaboration process	unilateral	Strategic	Supply Chain risks
			Opportunism		Disregard of engagements		Unilateral	Operational disturbance	Supply Chain risk
Environment	External risks	Political risks		Juridical and political changes	Risks with regard to the political stability		Bilateral	Operational catastrophe	General risk
		Social risks		Cultural changes	Job market risks		Bilateral	Operational catastrophe	General risk
		Market risks		Market price fluctuations	Exchange rate risks		Bilateral	Strategically insecurity	General risk

Methodical competence:

The focus is on applying metods correctly. In SN, it is important that these are applied with care (see above). This is to some extent a questions of training their procedural knowledge on how to carry out a process or a task, but related to skills as defined by Proctor and Dutta [1995]. It is here mainly perceptual and problem solving skills that is trained. The learning improvements should mostly be at the cognitive level according to Blooms revised taxonomy [Kratwohl, 2001], applying, analysing , evaluating and through reflection they should be able to apply what they learned in a new context. Typical learning paradigms are related to cognitivistic, but also for the highest level constructivistic approaches.

- Apply methods for solving problems and conflicts
- Application of standardised risk management approaches
- Apply classical risk management, identification, assessment and treatment methods
- Apply decision-making methods at different level
- Methods for assessing the environment in which the Supply Network is operating (technology assessment, SWOTs, FMEA, ETA; FTA, etc. Even though not always suitable for RA in Supply Network)
- Apply methods for improving and analysing communication and collaboration forms
- Apply change management methods

Social competence:

These competences will only be trained within the course using a constructivistic learning approach.

- Experience group and team work and knowledge exchange
- Experience communication and collaboration problems in a distributed working environment and strategies for coping with the problems
- Acquire and improve
  - communication skills
  - collaborative skills (including interpersonal skills, conflict, negotiation, problems solving strategies)

Self-reflecting skills

Also for these skills only constructivistic learning approaches will be used.

- Learn to take decision under uncertainties
- Learn to reflect on own behaviour,

Audience and pre-requisites

The target groups are master students in the field of production, system or economical engineering at master level.

3.4.2.4 Pre-requisites

- It is necessary that the participants have theoretical knowledge of concurrent engineering.
- Good command of English
- They do not need any risk management skills, but a pre-test (compulsory) will decide upon the level of introduction
- The course is based on an active role of the participants. It is therefore important that the participant do have an intrinsic motivation to learn something
- Open minded and collaborative in the discussion

Based upon the defined learning objectives a GBL approach was selected.

3.4.2.5 Description of subject matter

Many of the students will later work in Supply Networks, which are collaboratively developing and producing products. Challenges of such Supply Networks are as described in section 2.1 related to the dynamics (the risk and the impact changes according to time, place and context), the occurrence of unexpected events, and the cooperation as such. Risks are arising because different companies are cooperating and collaborating in order to achieve a common goal, but actually basing their decision-making on finding an optimum solution for their own company. Due to the time and place relevance for risks and their impact and also because the risk tolerance is also depending on time, place and company conditions, there is not a standard way of identifying and assessing the impact of risks in Supply Network. For such risks, since the impact changes so often, there are not so much statistical data available, or if they are available, they might not be correct for a specific case. Far more is it a matter of being able to analyse the relevant factors, put them in context and then draw conclusion on what to do. Furthermore, risks related to the collaboration do often increase by time if not identified. Collaboration is not an easy task, and it is influenced by several factors. The focus is on information, collaboration and network related risks. The participants will therefore produce a product collaboratively and thereby discover the impact distributed information may have on the collaboration. Each participant will experience risks arising from the communication and collaboration. The risks occur from the behaviour and interaction in the game but are also depending on the distributed information, the different character roles as well as the inexperience of the participants.

3.4.2.6 Instructional plan

Before this part of the course starts, the students have had an introduction to game based learning, teamwork, problem based work and change management. In addition, they have had six classes on production in distributed environment and decision-making using a different game. They have applied at least six different methods from strategic management and carried out tasks in cooperation and collaboration. The course is weekly, 5,5 h/session. The concept foresees that the participants will receive the theoretical material on the risk management process as well as on different types of risks and risk management methods, and they will carry out some of the same analysis they did for the decision-making, but only focussing on the related risks.

1. Unit 7 of the course: The first class of this course starts with a discussion on the previous game and the first group task is to reflect upon what happened and identify risks related to the decision they took and to the collaboration. The students carry out a SWOT analysis for some of the risks, focussing on both identify the opportunities as well as the threats they experienced. Based upon this task, an introduction to the risk management process and risk in Supply Networks as well as on conflict management is given by the lecturer. A short introduction to different approaches for risk identification and assessment is given. More detailed information on the methods can be found in the given literature and an in-game description. The level of the introduction depends on the knowledge of the students, which is known beforehand based on a pre-test. The last part of this class is a tutorial for introducing the students to the gaming environment in order to reduce the complexity during the game session.

2. Unit 8 of the course: One week later, the participants play the first level of the game. This game is scenario-based, and contains different tasks both on producing a simple product collaboratively as well as on different risk management aspects. It starts with a short introduction and repetition of the risk management process. The first game scenario takes around 3,5 hours. Due to the role description and the non-collaboratively behaviour of some roles,

some conflicts will arise during game play. The impact of these conflicts depends on how the students managed the conflicts. The students learn how to develop solutions collaboratively and to carry out risk assessment and risk management processes both at the individual level as well as through team tasks. The intention is to improve their awareness for risks as well as their communication, collaboration and risk management skills. During this first phase, the focus is on understanding, analysing and evaluating the environment regarding to different types of risk and to apply risk management methods. Furthermore, the students will develop risk mitigation strategies as well as look at how to take advantages of opportunities. Directly after completing the game the participants meet for debriefing and reflexion on what they experienced in the game. This is facilitated (lecturer). The students reflect upon aspects of the communication, information sharing and collaboration during gameplay and on the events that occurred. Within this debriefing phase, they identify and discuss problems, opportunities and initiating events that occurred in the areas of communication, collaboration, and trust. During the debriefing session, the focus is on lesson learned and which new knowledge they can create based on the experiences they had in the game.

In some cases there is a need for additional work, either because the group did not solve the conflicts during gameplay or because there are still some students not being sure on how to apply different methods or a new chanllenged emerged during the debriefing phase. In such cases relevant additional tasks will be used for group work (PBL). If this is identified during gameplay, the tasks is inserted in the gameplay by the factilitator. If first in the debriefing phase, it is given as a PBL group task. The challenges will also be discussed in the debriefing session in order to support the development of suitable strategies to cope with the challenge. The lecturer has also the possibility to go in more detail on topics like trust, cultural awareness, communication and collaboration strategies, and conflict management if that should be necessary. Note: The use of additional tasks was more needed during the first years of the course. During the last courses, they were neither requested nor needed.

3. Unit 9 of the course: A week later the second round of the game is played. The session starts with a discussion of what they experienced last time and what they learned, and on what they have to pay attention. The scenario is now inter-organisational and more complex. The game objective is to produce an extended product in a distributed environment. The players do only have an overview of processes within their company and department, not of the others. The players will again have to deal with unexpected events, experience different risks and need to apply different risk management methods etc. Since the information flow is intransparent they need to take decision on the basis of incomplete information. As during first level, there is a debrief-

ing session directly after the gameplay, where the players come together physically in order to reflect on what has happened and why certain events took place. It is the intention of the game to focus on specific situations.

4. Unit 10 of the course: In order to internalise the knowledge acquired during the class, and since not all students apply the same methods for risk identification, assessment and management, the students present group and individual tasks in the class the week after. The material they need for the presentation is developed as a part of the tasks within the game and can be exported. The intention of this is firstly to increases the level of knowledge since the students have to explain the different methods and how these are applied to the others. Secondly, this part is used of a more detailed discussion on the difficulties in applying the methods, especially those on identification in dynamic systems and to make sure that the methods are applied correctly. The observation of how the other participants solved their tasks and applied the methods leads to a reflection on the method and thereby to improving the understanding among the participants.

5. The last step for the participants is to prepare a report in which they reflect on the problems experienced and to assess the strategies they did develop at the beginning in order to reduce them.

As described above, the reflection phase is very important for the success of an experiential learning process. During a game play, participants glean information from a realm of parameters such as emotions, strategies, data, graphs and discussions. After these experiences had happened, they are recollected and reconstituted through a process known as debriefing [Lederman, 1992]. Debriefing can be seen as a process aiming at improving the learning.

Overall, it is expected that the facilitator supports the individuals, concentrates on procedures instead of contents, adopts a helping attitude, demonstrates authenticity and integrity, engages into an attitude of inquiry and especially abstains from voicing opinions. In addition to that, the primary concern of a facilitator is that individuals reflect on their experiences. Striving to achieve this goal, the facilitator should not try to direct or dominate the individuals. Moreover, a typical debriefing session comprises three phases: description, analogy/analysis, and application [Steinwachs, 1992]. Therefore, the debriefing phase (applied three times in this game) can be described in more detail:

1. Description Phase: the participants are asked to tell about their feelings: how they find the simulation game, whether it is fun and useful, if they learned something, etc. Usually, the ideas of the participants are not always organized in this phase, but quite spontaneous and authentic because this stage is the first outlet for their expressions after some significant time spent in

simulating and gaming. The timing of this phase depends on the reactions of the participants and how much they have to tell.

2. Analogy/Analysis Phase: The participants are supposed to draw parallels with real-life situations according to the problems identified in this phase. The participants to are asked to determine the decisions that they took, explain why such strategies were chosen, and detail what they learned from the simulation game. This stage of the debriefing process lasts around one hour.

3. Application Phase: The participants consider which learning gained during gaming is relevant enough to be transferred to the real world. Indeed, a good facilitator will highlight the lessons learned so that they can be applied to other areas [Prensky, 2001]. In this case, debriefing supplied the participants with a competitive advantage. Also pre-, mid and post tests are used for some assessing the learning and the students experience.

It is important to recognize the influence of each type of feedback used on the debriefing, and hence, on the results obtained.

3.4.2.7 Materials

This list the materials needed and which has been developed.

- Introduction to the course and the objective of the game
- Material for hands on (partly in game)
- Slides on risk and quality management and risk assessment processes and methods
- Introduction to risks in Supply Network
- Pre-, mid-, and post-test questionnaires
- The Beware game
- Introduction to risk management compendium including the web links, also available in the game, but given before hand
- Risk management process (in game)
- Conflict management, cultural awareness slides
- QM process (in game)
- Prepared worksheets on risks (in game)
- Computers with collaboration software (in different rooms with access to internet and communication devices)

3.4.2.8 Plans for assessment and evaluation

In order to evaluate the professional skills, questionnaire and tests are in use. These are completed three times- before the course starts in order to find the right level, after the introduction to enterprise risks and risk management and finally by the end of the course. Furthermore feedback is collected in the reflexion and discussion phase, by assessing the report and the presentation as well as by tracking the communication level and the changes of the indicators in the different processes (only costs, time, quality) using the facilitator's tool. It will also be assessed at which cognitive level the learning was achieved, since the different topics need different cognitive level.

The participants do also answer question about their subjective improvements (results in chapter 7).

4 Game concept

During the research parts of the text have been published in [9, 10, 16-20, 24, 25, 28, 29, 31-34, 40]. These are listed in chapter 12-Annex E.

This chapter describes the transition of the learning goals into a game concept. Build upon the basis of the course described in section 3.4, it aims at supporting the development of the competences described in section 3.1, taking into consideration how to design and develop good games discussed in section 2.5.

In section 2.3, different learning theories were discussed and in section 2.4 it was discussed on which principles game based learning is mostly based. This chapter will first outline the requirements on the game, so that it can be used in the context and thereafter revisit existing games, in order to see if parts can be reused, before the actually game design is presented.

4.1 Requirements

Strategic planning and strategic decision-making is crucial for enterprises in order to cope with the complexity and dynamic of global Supply Network, while maintaining their competitive position, but is faced with problems like incomplete knowledge about the exact situation in the market or time pressure for reacting on competitive challenges. The use of a serious game can help to gather experience in decision-making and learn how to cope with risks in a risk-free environment. Based upon the principles of constructivism, the players will construct their own knowledge through the experience. As described in section 2.4 and 2.5, in order to ensure the development of specific competences, a game can be integrated in a learning context. Kerres et al. [2009] specifically address the need of debriefing and communication for management games, so that the simulation model behind the game does not need to fully mirror the exact processes. Bellotti et al. [2010a, p.24] point out that in order to "be effective, serious games need incorporate sound cognitive, learning and pedagogical principles into their structure and design".

Furthermore, due to the situated cognition, it is essential that the learner learns in a real and authentic context [Jonassen, 1991a,b,c; Schwesig, 2005; van Eck, 2006], and this environment has to be similar to where they will apply the knowledge [Brown, 1989]. In order to deal with the complexity of some tasks and to get a deeper understanding, the players will need to deal with it over time as well as to revisit the challenge from different perspective [Bransford, et al. 1990; Savery and Duffy 1996; Schwesig, 2005; Kerres et al. 2009; Honebein 1996].

Section 3.4 describes the learning objectives for the whole course, including tasks that will be a part of the debriefing process, the construction of knowledge based on both the debriefing process. Also, a repetition is foreseen by letting the students present and explain what they did within the game to the other students and by producing lab reports.

The game a part of a course and aims at preparing engineers to deal with risks and the management of risks in dynamic Supply Networks, by supporting the players' understanding of which factors influencing the resilience and supporting his competence on assessing how changes in these factors affect the workplace, organisation and the network. This requires in addition to a procedural knowledge on risk management and to apply specific methods depending on the given context, also that the students improve their communication and collaboration skills, and strengthen their understanding of transparency and visibility regarding the information flow and sharing. For training procedural skills, cognitive methods will be used; for learning how to construct new knowledge, constructivistic approaches will be used. Thus, the procedural knowledge will only be trained within the game, whereas the construction of new knowledge will be achieved both within the game and within the debriefing and explanatory phase.

Section 2.4 discusses different existing games within related fields, and section 2.4 explains that even though educational games developed by multi-disciplinary teams are mostly better matching the curricula, COTS are often also usable. Thus, before starting to develop the game, different games were compared with the learning goals and target groups of the course (see Table 2). The Marga games and TOPSIM do deal with risks and risk management, but here the target group is different and a more detailed analysis (compare van Eck's suggestions of analysing COTS games), showed that these are focussing much more on the financial aspects and less on risks arising from collaboration. Spiko is also addressing risk management, but this is a single user game, not able to show any effect of collaboration and is therefore not usable. Matching the target group, the games Cosiga, MINT and Share seem to convey several of the related skills, but do not touch the topic of risk management. A more detailed comparison of these three (section 2.4) showed that MINT and Share would be most suitable. Since Share was developed in-house, this game was selected as a basis. A detailed description of Share can be found in Schwesig [2005].

4.2 Design and development process

The Beware game is an extension of a game engine, which is developed and used at BIBA [Duin et al. 2009]. Schwesig developed the basic game, dealing with the communication barriers in 2005 [Schwesig, 2005]. In addition to changes in the processes [see chapter 5] and roles, it was also necessary to introduce new functionalities. The management of risks in a dynamic Supply Network is to large extent a matter of dealing with unexpected events. Thus, it was required to create a function allowing the facilitator to set events. These can be set if there are deviations from specific values or in order to simulate events occurring in the Supply Network. In addition, the risks are considered to be a deviation from plan. Consequently, it is important that not only the facilitator can check the deviation, but that also the players get immediate feedback. For this purpose, measures on quality (depending on deviation from expected value) were introduced. Correspondingly, also quality enhancement measures were developed, in order to give the student a tool to deal with it.

SHARE mediates skills on inter-organisational and intra-organisational collaboration. It is a cooperative game, where the players have to communicate and cooperate for carrying out their tasks, as well as to share information. Thus, in a first step, only the curriculum and a few tasks within the game were changed. The evaluation of the learning outcome showed that the role description had to be changed in order to ensure that the collaboration and enterprise risks would arise. Also the tasks to be carried out had to be replaced with tasks more focussing on the network and collaboration risks. Furthermore, in the old game, it was possible to carry out the tasks without real collaboration. This mirror what often happens in reality, since people work in parallel, and not always with sufficient communication and information change and also (at level 2) carry out tasks needing input from a partner, before this partner had completed his tasks. However, it gives rise to several risks, which were important to capture. However, this required re-engineering, since it had to be connected to a risk management process. Secondly, it also increases the complexity, and thus the new related part now allows the facilitator to use this as a way of adapting the level of complexity on the fly for different players (in order to keep them engaged and in flow). There are now process steps that can only be completed in collaboration, and there a process steps, that needs to be completed before another can start. In addition, it was also required to add tasks on applying risk management methods within the game [compare Klimmt, 2005; Kerres et al. 2009 on explicit and implicit learning in games]. As discussed in section 2.3 and also mirrored in the identified competences, constructivistic approaches are more suitable in cases where the learner has to interpret multiple realities though abstraction and reflection. I.e., in order to train the problem solving skills for problems arising in dynamic systems, a constructivistic learning approach sseems to be preferable. Thus, the game comprises both types of elements. In section 2.5 the challenge with the cognitive overload was mentioned [Kiili et al. 2012, Sweller, 1988, 1994]. The learning objectives and the topics described in the curriculum are challenging, require handling of unexpected events and taking decisions under uncertainties. These are all aspects that contribute to a high cognitive load and emotional stress, as soon as the players have the feeling of not controlling the game. Thus, in order to reduce the risk for overloading, the game is integrated in a blended learning concept, first repeating the methods and explaining the tasks as well as having access to a facilitator during game play [compare Bellotti et al. 2010a]. The game will also need to make use of scaffolding principles, so that the different tasks can be adapted to the individual competence level, first defined through the pre-tests, and then monitored during game play.

Based on the test results and previous experience with the development of educational games [Baalsrud Hauge, et al. 2007a, Baalsrud Hauge et al., 2007b, Hunecker, 2007, Duin et al. 2009], a user-centred development approach was taken, using principles from the Agile Programming Community after [Beck et al 2006] and the spiral development approach (see [Boehm 1988]). The methodology is illustrated in Figure 9. The user requirements are not a well-defined stage in the methodology, so the end-users provide input into the design and implementation process from the very beginning until the beta stage milestone, this is in this case the students and teachers observation and feedback, see section 7.2 and 7.3 for the required changes.

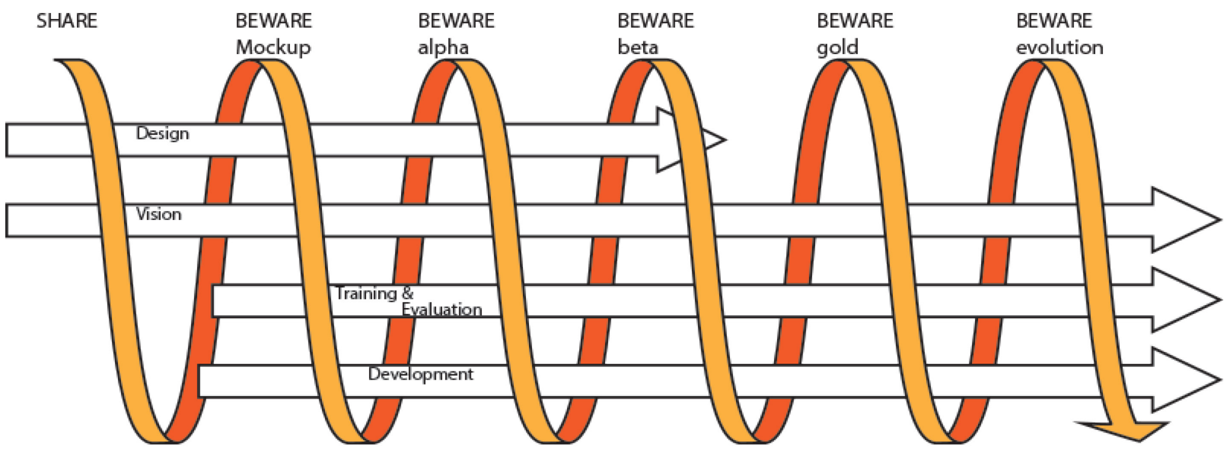

Figure 9: beware development process

For a long time, user involvement was limited to observation and not active participation (Sanders & Stappers, 2008). However, as mentioned in the previous sections, for developing games all stakeholders need to be included, in order to both collect their specific knowledge, and also for getting fast feedback from the potential users regarding usability and also user acceptance [Bødker, 1996, Bellotti et al. 2013a]). The user is in this case the teacher, who has made the curriculum and the game concept, but has no skills in programming, as well as the students. Hence, it was necessary to work closely with an experienced developer also taking care of the actual coding.

The first test with SHARE also showed that some students were bored and other overloaded. In both cases, the flow was disturbed and the learning outcome was reduced. Thus, a monitoring tool was built, which allows the facilitator to monitor the process, the communication and the play, and based on her observation set events, change the cognitive load (by taking out or adding tasks) and also give individual instructions. Elements like the one of completing tasks requiring input from partners or more complex/simple events are now used to offer the players tasks more related to the level of their competences (an indication for what the facilitator can expect for each player comes from a pre-test all students have to complete when signing into the course).

4.3 Gaming engine

The main objective of developing a gaming engine is to create a tool, which allows for the generation of different game scenarios without having the need of re-programming. This is the reason for separating the simulation engine from the underlying model. The engine reads and executes game models providing an advanced user interface for the players.

It uses a layered concept separating content and game mechanics (See section 2.5). The architecture of the simulation game consists of an underlying business model, a simulation engine and a user interface, which allows to examine the model elements and to apply game specific actions. These parts are described below:

- Business Model: The underlying business model provides all modelled entities as a formal basis for the implementation of the simulation game. I.e. comparable to a simulation model, but also includes the game mechanics. From the conceptual point of view, this is the most important part, because only elements described here can be used in the game.

- Simulation Engine: The engine works on the underlying model and simulates time and costs, which are the main variables influenced by the players in taking specific actions, events occurred, the time or quality enhancement measures used. The simulation engine can be seen as the central control unit of the game.

- User Interface: The user interface allows to browse the overall and personal information in the game and to apply game specific actions.

The business model enables the definition of the simulation engine. The user interface allows data input from players as well as displaying game relevant information as illustrated in Figure 10.

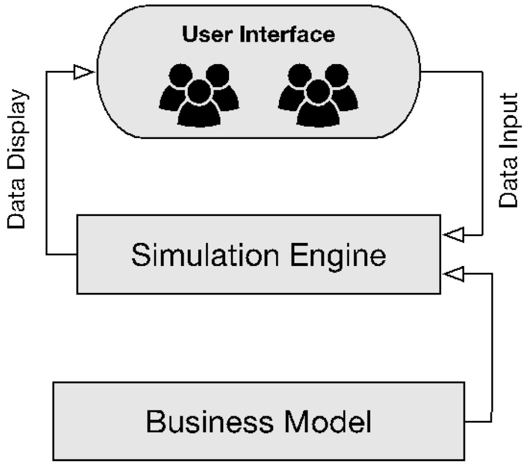

Figure 10: Relation between User Interface, Simulation Engine and Business Model

4.4 Simulation Model

The underlying simulation model is the most important part of the game. From the developer's point of view, the structure of the model defines the database structures and the information as well as the activities players can use. Thus, a new scenario is actually just a change of the content of and the relation between these elements. The two implemented scenarios are described in chapter 5.

The following sub-chapters describe the new model elements. The names of the single model elements are given in italics style in order to differentiate between real world entities (which are modelled) and the corresponding model elements (representing the real world entities).

Beware is based upon SHARE, thus the model remains similar,extended by new elements. Some elements often used in the SHARE game are hardly used for Beware, but are kept if used at all, also in order to be able to adapt to individual users' needs (specifically the communication tasks). A detailed description of the complete business model can be found in [Schwesig, 2005; Duin et al., 2009; Baalsrud Hauge et al., 2008a]. Figure 11 shows the relations between the different entities of the business model.

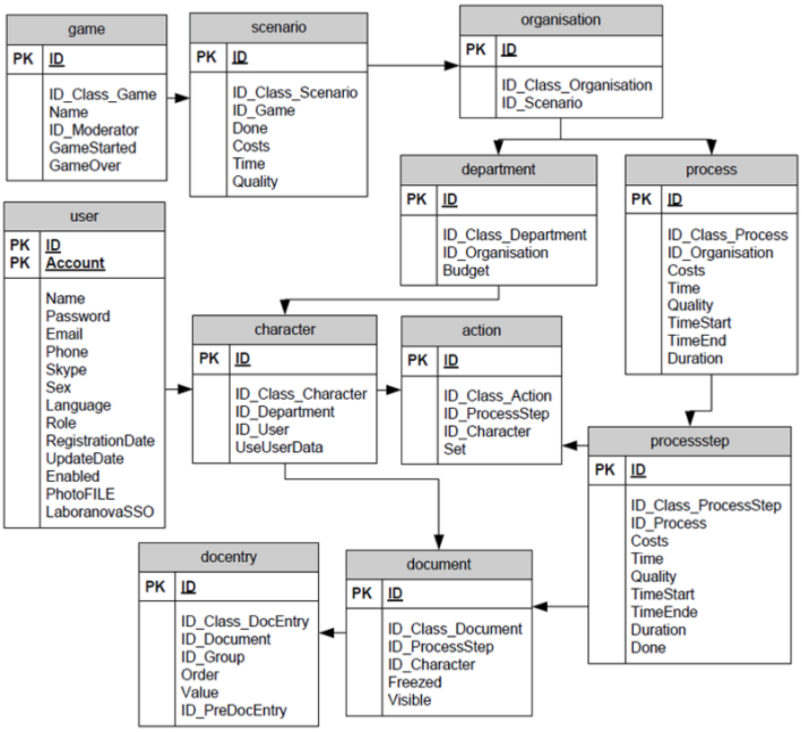

Figure 11: Class diagram be.mog

Model Elements *Events* and *quality enhance measure*

An event is a game element, which the facilitator uses in order to control the game or to make the game more engraining. It can be predefined or be set during the game. The costs associated with events can be positive and negative. An *Event* can either simulate typical events occurring in reality or can be set by the facilitator in order to help the players. It can be automatically set by the system if, for instance, the quality level is too low, or the time they use are too long, or by the facilitator. An event will always have an impact on the game, actually on at least one of the KPI's, which are cost, time and quality. It can reset or take the game scenario back to a certain level.

Table 8: The Main Attributes of the *Event* Element

Name	The name of event.
Description	A description of the event.
Costs	The costs of the event.
Time	The time of the event.
Quality	The amount of change in the overall quality.
Result	The result, which is displayed to the player after the event has been applied
Role	The owner of an event is defined by the facilitator, who will set the events depending on the progress in the game scenario but also depending on how the player performs. An event can be pre-defined or defined by the facilitator during the game. An event can be defined as single or multi-mode use
ProcessStep	The process step, where the event belongs to.

The quality enhancing measure is a game element, which can be applied in order to improve the quality of the processes step. The use of this game element will always increase the costs. The players decide upon the usage of this element. The decision should be made based on existing fincial ressources, the level of quality of their processes, the company strategy, goal and target values. Some of the quality enhance measurments can be applied several time, some only once.

Table 9 : The Main Attributes of the *Quality Enhancing measure* Element

Name	The name of Quality enhancing measure.
Description	A description of the Quality enhancing measure.
Costs	The costs of the Quality enhancing measure.
Time	The time of the Quality enhancing measure.
Quality	The amount of change in the overall quality.
Result	The result, which is displayed to the player after the Quality enhancing measure, has been used.
Role	The owner of a Quality enhancing measure is defined by a specific role. A player, who is in this role, is the owner of the instantiated Quality enhancing measure. A QEM can be defined as single or multi-mode use.
ProcessStep	The process step, where the QEM belongs to.

Figure 12 shows the overall be.mog concept.

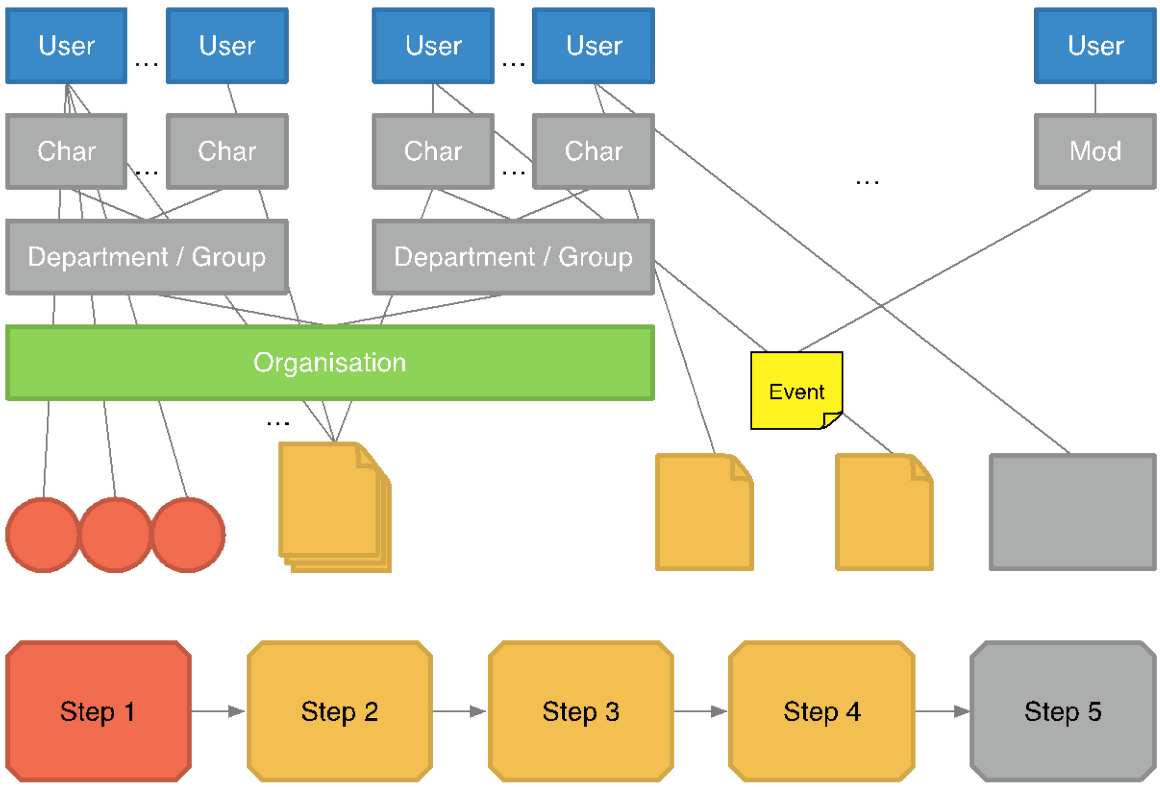

Figure 12: be.mog concept

The current version of the engine, be.mog2.0, uses a LAMP/WAMP (Linux or Windows, Apache-web server, MySQL; PHP). It comprises the operating system, the web-server, the database, as well as the script interpreter on the server side. be.mog 20 works on Windows 2000 Server systems with Apache 2.2 as web server. The libraries are libapache2-mod-php5 and php5-mysql. The database is MySQL.

4.4.1 Performance indicators

At the moment, only three performing indicators are used: Cost, time and quality. The idea is that the player can use these indicators as a motivating competing element, and they are always shown for every single process, for the company and the department, as well as the overall performance. The objective is to produce with a quality of 98 % with minimum cost and time. Additionally, since the players need to find hidden information and base their specifications on this information, each document entry has a target value. This value and the deviation are also measured and have an effect on both, events arising, as well as on the performance.

4.4.2 Facilitator tool

The game is played in a distributed setting, i.e. all players are not in the same room. Thus it is difficult for the facilitator to support the gameplay. Since risks are partly event driven and their impact depends on both the treatment and on the performance of the players, this requires that the facilitator monitor the game play, and also that based upon the observation, events with the right level of difficulty is selected. It was first the intention to automate this part, but this require a better learning analytics than could be implemented as a part of the thesis. Thus, this is a manual process, requiring quite much experience. In the first versions of the game, it was not possible to rework processes with high risk or low performance. This is now changed to better mirror the reality. Since reality however, the loss of a supplier or too low quality in a processes/product may lead to additional work, both in order to develop contingency plans, as well as to redo the work. Thus a function for this in the facilitator tool was developed.

Figure 13 shows how the facilitator can set, change, delete and make an event, as well as monitor which already have been set where and when. It also shows the GUI for the facilitator for unset events (if it is set by mistake or similar).

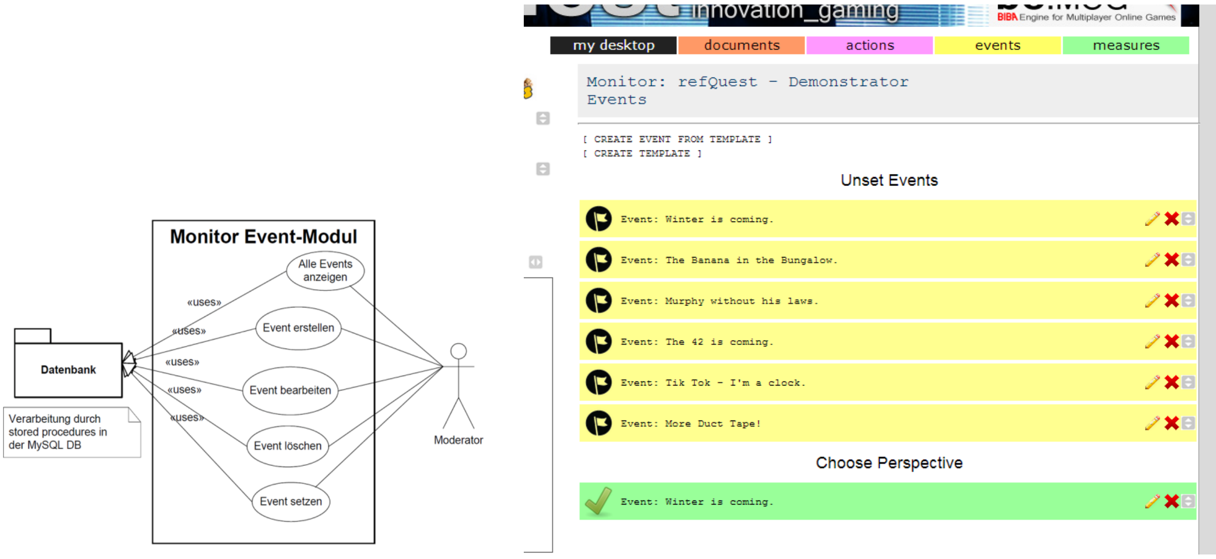

Figure 13: Monitor Event Module and GUI facilitator for unset Event

With this tool, the facilitator can either just watch the game and trace the communication and collaboration activities, or he/she can reset processes, set predefined events or generate new events on the fly. The intention is not to use the resetting function if there is only a small deviation. In some cases, events are occurring which requires that the player will carry out a task once more. An example is if a supplier is not able to deliver. The player will have to select a new supplier and go through the selection process once more. In this case the process will be reset. It is important the player does understand why it is necessary to carry out a task once more. The facilitator's tool gives the opportunity to support and control or even stop/delay the game and the GUI is shown in Figure 14 .

Figure 14: Facilitator's GUI

The next chapter will describe the concrete implementation of the two existing scenarios.

5 Implementation

During the research parts of the text have been published in [14, 18, 20, 22-24, 30, 40]. These are listed in chapter 12.

Chapter three describes the pedagogical concept, defines the learning objectives, whereas chapter four outlines the requirements on the game as well as describes the agile development process and the game engine.

This chapter describes the implementation of the two scenarios in use. These scenarios can be changed and extended according to specific needs, so that the game is adaptable to changing user groups and requirements. This has to be changed in the database. The starting points the scenarios are the scenarios given in the SHARE game by Schwesig (2005). The original game needed to be substantially changed in order to fit the purpose of the new curriculum. This required, as explained in chapter 4, that functionalities were added, but also that the original scenarios were re-purposed and re-engineered. In order to increase the usability for further changes, a game engine was developed, allowing a game designer to re-engineer.

Beware is a role based multi–player game, process driven and event triggered. It is facilitated and to be used with additional instruction and debriefing. The facilitator has a monitoring tool, which allows the facilitator to monitor the game without being an active part in the game. However, the facilitator can intervene and interact both directly, via using the chat function for advices or by setting specific events, or indirectly with asking questions. The intervention can be resetting some processes or setting events. The game is embedded in a workshop setting as a part of a 3 ECTS course. The game supports an interaction between the players and the game at different levels as illustrated in the figure below.

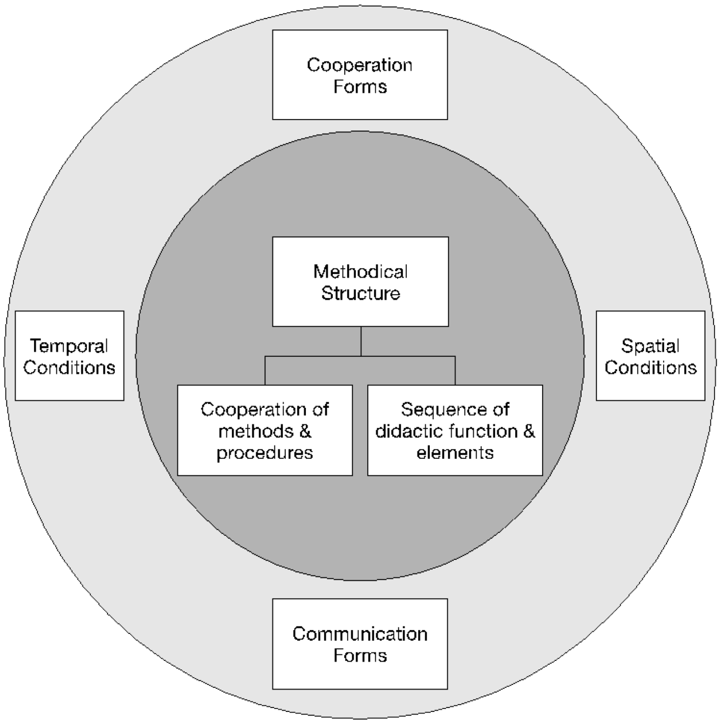

Figure 15: Relation between game and participants

In order to simulate a realistic, but not too complex environment, only important processes are simulated. Many risks are not process driven, but event triggered. Thus the game needs to be able to simulate both event triggered and process driven risks. In order to ensure that specific conflictual situations will arise, each player is assigned to a role with a specific behaviour and tasks to carry out in collaboration. Information is partly incomplete or hidden in order to simulate real situations and to train the students to make decisions under uncertainties and to assess the related risks. This provides a safe environment for the players, as their behaviour is related to the role description and not to their real personality. The simulated working environment is distributed, i.e. the player will be in different locations, and needs to communicate via chat, or phone and in a foreign language, in this case in English in order to simulate the challenge of communicating with people having a different understanding. The challenges in communication in a foregin language does not only increase risks related to semantic misunderstandings, but shall also simulate the challenges of working in multi-disciplinary teams using a specific taxonomy and semantic. This is needed, since most of the students are from the same program, and mostly know each other for years.

During the gameplay, the players need to carry out different tasks. These tasks are actions that mean they will have the possibility to choose between different options, completition of documents or to perform analysis and applying methods. In some cases, it is related to solving specific challenges related to problems in collaboration and communication. The latter type is always event triggered, where as the others can be process or event triggered.

Many of the risks occurring in a network will also occur in a single enterprise. This is used to reduce the complexity of decision making and risks in Supply Network. , In a first step, the players only deal with risks within an organisation. In a second level, they will operate in an inter-organisational collaboration. The reason for this is that the students hardly have any theoretical nor practical knowledge of risk management before they join the lab, and not very much experience in collaborating. In order to reduce the complexity until they know the methods, it is easier to just deal with organisational risks.

Figure 16 shows the starting graphical user interface. The game intends to foster implicit learning. The player finds all information needed within the game environment [Klimmt, 2005]. The player can find information related to his task and role description in his interface. The GUI also provides information on processes, actions as well as on the organizational setting. He will also find a description of events that have occurred as well as an overview of measures he can use or have selected. In addition, the GUI gives an overview of the most relevant indicators, both for overall as well as for each single process. Based on these he can take actions and make his decisions.

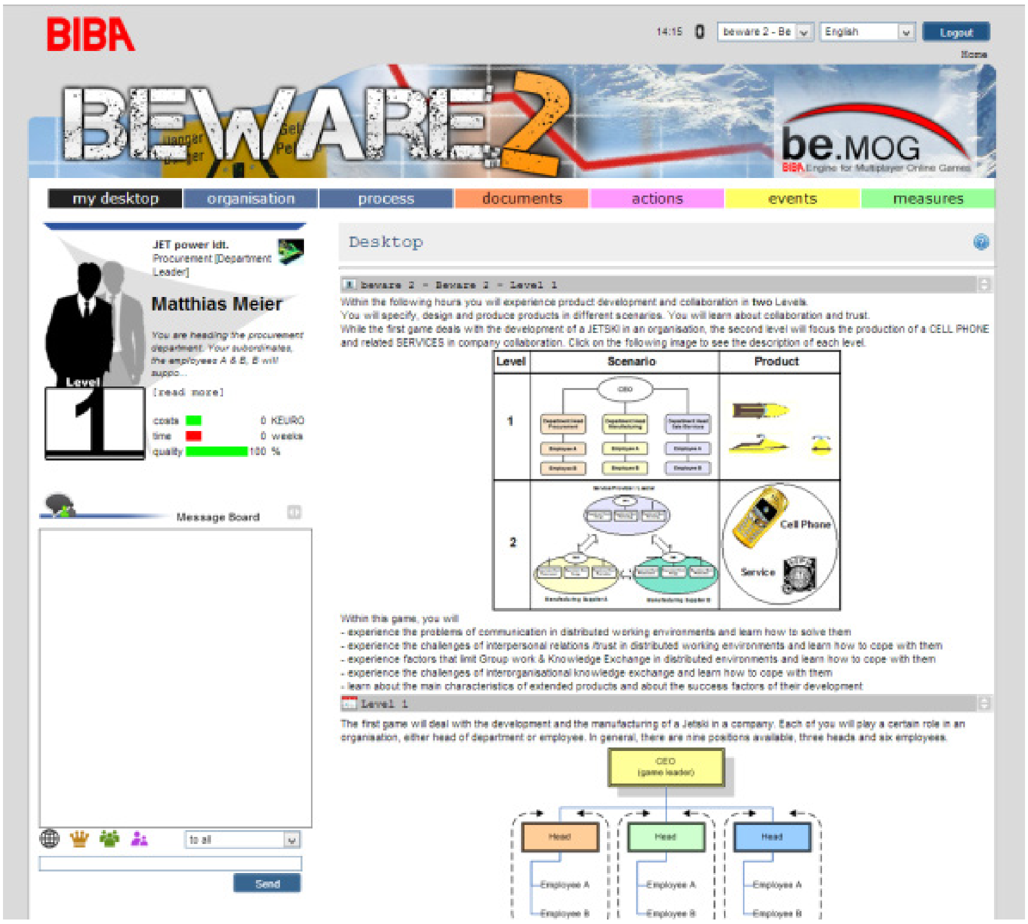

Figure 16: Starting user interface for beware

5.1 Game Scenario Level 1 – Intra-organisational Level

In the first level, the players have to specify, design and produce a quite simple product within one company. They act as employees of an organisation that covers the basic economical functions procurement, manufacturing and sales/services. They have to order from the supplier and deliver to the customer. They have to co-operate and to communicate, as well as to analyse hidden risks to be successful. The players need to specify, design and develop the product, and plan the orders. While playing, different events occur related to what is happening in the game, mostly including a specific task related to the application of risk management methods or risk assessment methods. The exchange of information between different departments enables the players to improve their communication skills in distributed environments. Following their role descriptions, some players act non-collaborative to simulate "people barriers" affecting the overall result. The players experience the destructive effect of such behaviour and have to develop contingency plans for reducing the negative impact. During gameplay, the students will alos experience late deliveries or missing parts and low quality, as in some cases a supplier might get bankrupt or cannot deliver for several reasons and due to incomplete information, the transparency variets. This shall simulate a real environment.

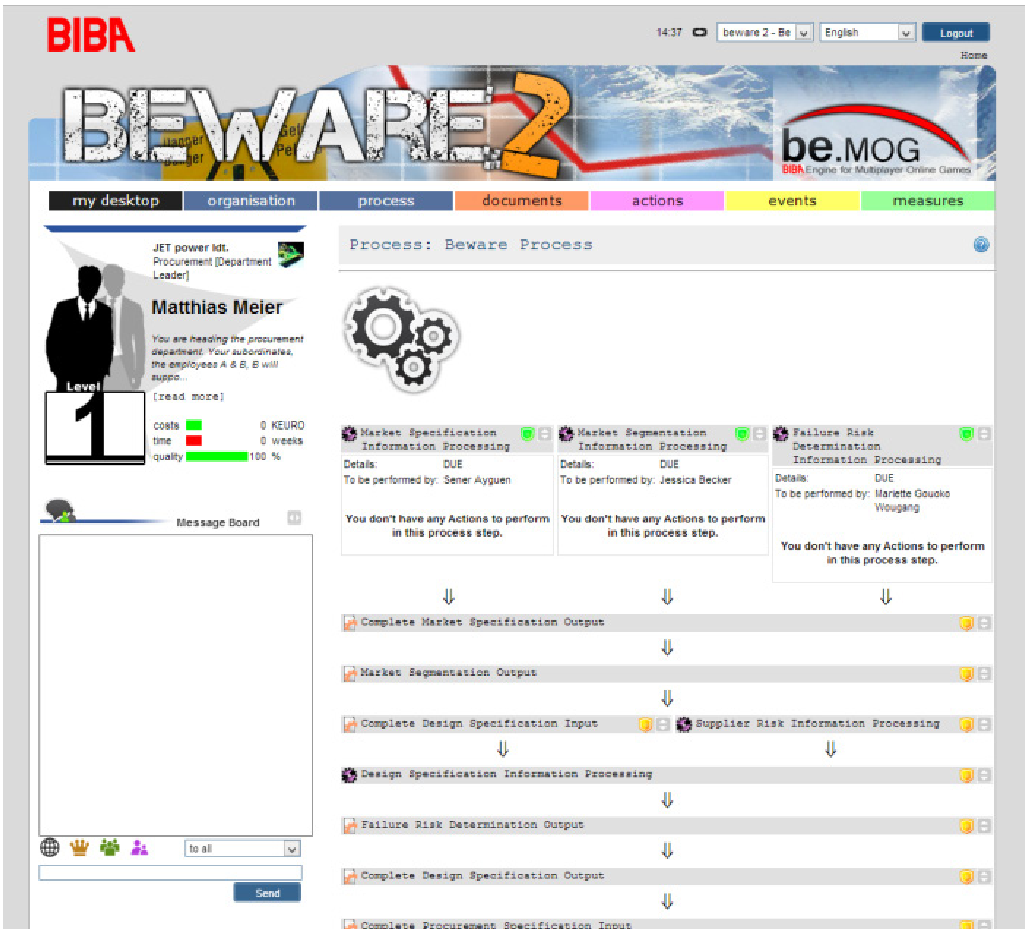

Figure 17: Beware process view user interface

The organizational structure is simple- there are three departments with one head and two employees in each department. Each department has its own working space (i.e. different lab rooms). The rooms are equipped with standard working materials like computers, internet and phones. The head of the department takes the lead at this level and gets support from his/her employees. The employees are also responsible for their own tasks. Consequently, there will be a problem for them to carry out their own task and simultaneously respond to the head's requirement. The employees then need to prioritise and to make decisions. This situation is the origin of several risks and usually leads to some disputes between the team members in which they have to act according to the role description (i.e. collaborative or not, different skills etc.). The challenge for the player is that he does not know who he can trust, who is collaborative, or have a non-collaborative attitude, keeping the information or giving wrong or too much information away.

They have to cooperate and to communicate, as well as to analyse hidden risks to be successful. The players can schedule physical meetings to discuss relevant issues. The exchange of information between different departments enables the players to improve their communication skills in distributed environments. The pre-tests (see section 7.1) shows regularly that the students have hardly any knowledge and skills in this area, and the experience from the gameplay has shown, that it gets too complicated if they have to deal with communication risks, applying methods and caring about risks arising within the collaboration at the same time. In the first tests they were regularly overwhelmed and did not manage to prioritise and carry out the tasks. Thus, the first level of the game is kept on enterprise internal level. The reason for this is that number of risks is more limited and easier for the player to deal with, but even at this level the production processes are complex enough to simulate a real production environment and related risks. At this level, the processes are transparent to all players, which also is important for their experience at the second level. This difference helps in understanding the relevance of transparency and information sharing. Figure 17 shows the process flow for the first step. In each process, one of the players needs to choose an action or complete a document, for which he needs information. In order to keep the other players in flow and motivated and engaged, it is important that all players have tasks to work on as a part of the scenario, even though only one player is responsible for a process. This part has been one of the most difficult one to balance, since how to keep them in flow is dependent on their skills and their motivation, and thus the tasks they carry out needs to be adaptable and scaleable, depending on the time the process owner needs. However, the tasks need to be designed in such way that they feel actively involved in the processes and take part in the communication. In order to simulate a real environment, and increase the probability of making mistakes (as in the real world), the players also have to be put under pressure with so much to do that they cannot handle the request or experience difficulties in prioritising. This is according to the theory of flow and cognitive load normally not wanted in gameplay, since it puts the player out of flow. However, it is very important for simulating a whole range of risks. Thus, in order to make sure that the time they are under stress is not too long, it is important that the facilitator monitors the play and assess if a student is overwhelmed. The main problem is that this has to be done on the fly by observing the group. The players shall experience that it is possible to do mistakes, and that it is necessary to deal with decisions made and figure out how best to reduce unintended impacts or how to take advantage of new opportunities.

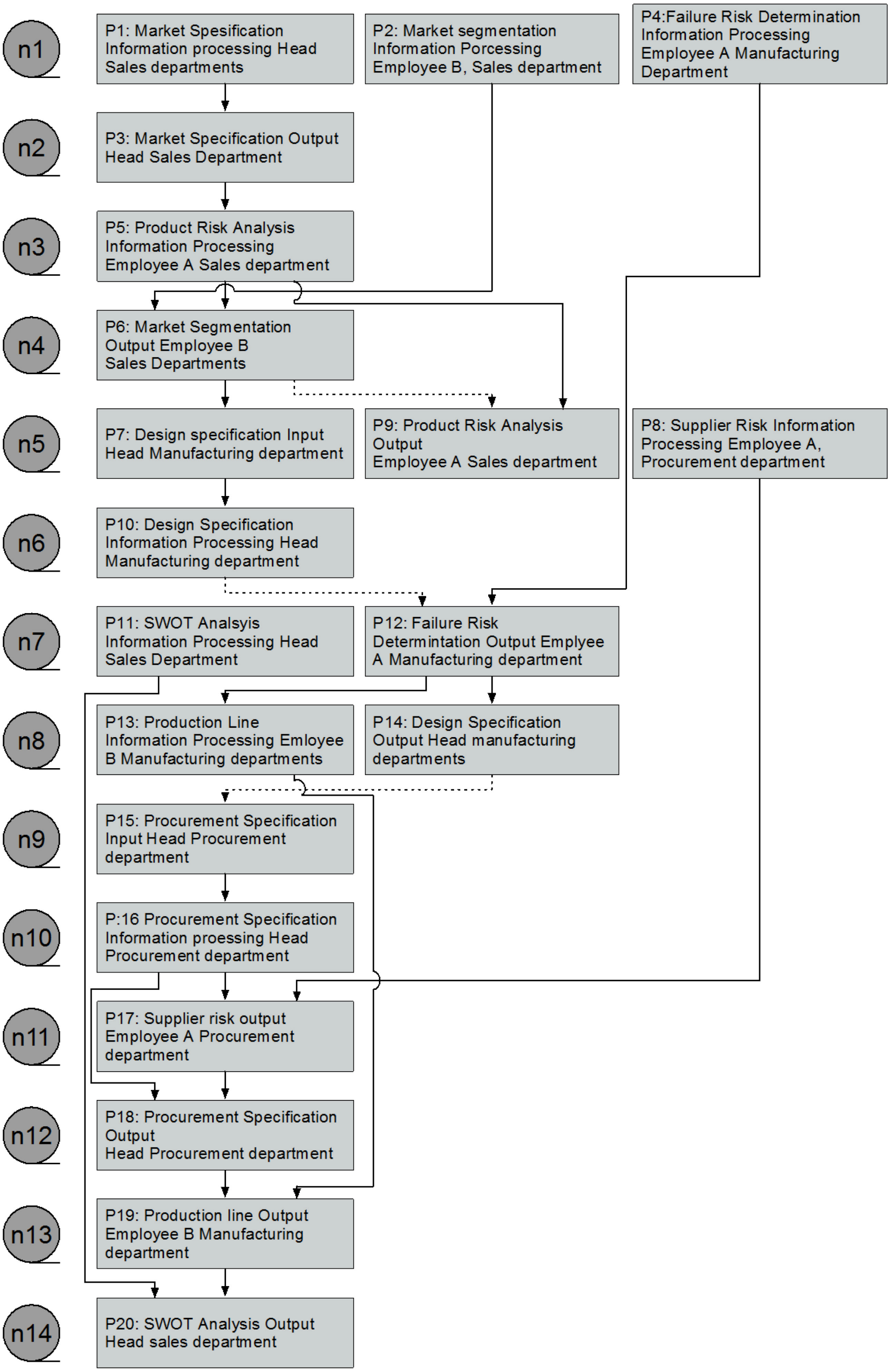

Figure 18: Process flow diagram first level

In addition to completing the documents and take action, each player will apply different risk management and risk assessment methods. This is procedural knowledge, and therefore the process will be repeated at different levels, but the task will be slightly different, so that the students do not get bored. These tasks are aiming at supporting the cognitive levels applying, analysing and evaluating in Blooms revised taxonomy, whereas the level creating is supported both in the debriefing phase as well as in some tasks during the gameplay. The rewarding mechanism is in this case related to the reduction of risks and improved KPIs. Table 10 shows some of the tasks different players have to carry out.

Table 10: Example of tasks to be carried out

Scenario 1	**Task level 1**
Manufacturing Head	• Event Tree Analysis with the risks of suppliers.
Manufacturing Employee A	• Failure risk determination output (looking for possible failures leading to a not-working product). Complete a R.M process for some of listed risks. Use the FERMA Standard
Manufacturing Employee B	• Determine the number of assembly lines. • Identify information, communication and collaboration risks which might lead to a production delay
Procurement Head	• Company mission statement. • Create a scenario analysis on the impact of a delay in delivery. Develop contingency plans for the different scenarios
Procurement Employee A	• Supplier risks output using swot- Add a complete RM using FERMA
Procurement Employee B	• Support employee A, and additionally react fire the supplier use an ETA for the analysis of possible impact
Sales Head	• You were assigned to a special project that has been triggered off by your most important client: Please prepare a requirement analysis for a future Jetski model that will be manufactured in 2015. The diligent preparation of these analyses will have major impact on the future of your company, as you might be able to acquire this project. Please identify the risks of not being able to introduce the product to the market, and look at how you may reduce the probability
Sales Employee A	• Support the head of sales with the completion of the market specifications • Carry out a SWOT-Analysis with the help of three others • Risk Management based on the FERMA standard • Marketing concept (probably given as a group task)
Sales Employee B	• SWOT analysis on company weaknesses and strengths • R.I. External changes, • Support marketing concept • Market segmentation • Apply the FERMA RM standard

However, in order to be able to scaffold and adapt the gameplay to the level of the players, the facilitator can change and assign tasks to a different player depending on their prior knowledge level and how they play the game, as well as the workload in the other tasks. In addition, different events will occur with other tasks. Below some possible events are listed, but these are only meant to illustrate the possibilities and are not complete.

Example one (for every player):

During the last month you have noticed that your character does not always fit into the company philosophy and communication strategy. Reflect on risks arising because of your character (role) and the impact this has on the collaboration within the department and between the departments. You will all carry out this task, but on an individual level. The Heads use the ETA for risks identification, the employee ‘a’ uses the FTA and the employee ‘b’ will use brainstorming. Do also reflect on the limitation of the identification method. Find a short strategy for how you could reduce any negative risks and strengthen any positive risks.

Example two for the manufacturing department:

There are some problems in the process flow. The manufacturing department does not carry out the tasks inline with the process scheme. Carry out a complete R.M looking for risks caused by the changes in the process flow. Carry our each step according to the FERMA standard.

Example three- used when the collaboration does not work:

There seem to be some communications problems in the manufacturing department. Please make sure that you carry out the tasks in the right order. The manufacturing department needs to carry out a complete risk analysis regarding the impact caused by not following the given workflow. Carry out a complete Risk management process according to the FERMA standard. Use the FTA for the risk analysis. Focus on the communication and collaboration risks.

Or

The department responsible for the design has already delivered suggestions for the new design, but it does not seem to fit with the market specification output. This seems to be a communication issue. The manufacturing department needs to develop a communication strategy in order to reduce the risks, the additional costs they have caused with this behaviour. When you have finished the Communication strategy, please distribute it to everybody for discussions.

Example four: problems in their internal project management

For the development of the new jet ski, JetPower Ltd has hired a new engineer in the manufacturing department. He is responsible for the collaboration project. Even though he has been hard working, he has not managed to coordinate the tasks and forgotten several things, which he should not have, so you are 3 month behind schedule. Due to the lack of experience, he has not been able to recognise this delay at an early stage, and he did not plan so much time for the delays. This is mainly due to the lack of experience in development projects, and there are hardly any possibilities to recover. The problem is that a three months delay would lead to launching the new jetski in the middle of the season, and actually you can't afford that, since you competitors never sleep. Manufacturing department: Please make a contingency plan, in order to fix the delay. This work should be coordinated by employee 'B'. Please identify at least five risks, describe and treat them. Use the FERMA process in order to develop the strategy to follow

In reality, it is possible to take some actions, which improve the performance. In the game, these are simulated by the quality enhancement measurements. The player can decide upon the usage, but they cost and take time, and each department has limited resources, they carefully have to assess if the quality enhance measures should be used or not. The effectiveness of them depends on the specific measure.

5.2 Game Scenario Level 2 – Inter-organisational Level

Within the second level, the players use the acquired knowledge and skills in the inter-organisational contract negotiations in order to specify, design and produce a complex product inter-organisationally.

The second level is based on an aggregated process model of different enterprises. At this level, the focus is on inter-organisational activities and on the risks occurring due to the collaboration between at least three independent companies (according to the definition from Seiter introduced in chapter 2). It is the intention that the players shall experience the impact of having different objectives in the collaboration, as well as how difficult it is to understand the situation of the other companies due to the lack of information.

While the simulated service company takes consortia leadership and develops services, the two simulated manufacturing companies develop and produce generic cell phone parts. As necessary information will be distributed unequally, the partners have to cooperate to enable the flow of information that will lead to a right flow of material. Also, here different events and risks are included, and the player needs to carry out some risk management tasks. In order to develop and produce this extended product, the overall success depends on every partner's contribution. Inter-organisational related challenges are realistically simulated, and the flow of information is affected by the simulated organisational boundaries space, time and diversity. The players are required to find appropriate solutions in order to overcome the barriers.

There are three different companies, with three departments each. I.e. at this level, each player plays a department leader and is allowed to make more decision independently than in the first level. His decisions influence the other departments and the collaboration as such, so in order to achieve the best result, the players need to develop a common strategy for the product. The player should afterwards have this common strategy into mind for his decision-making process and also information exchange. Again, the game is role based, so that there will be some conflicts arising. As an example, there are different payment agreements, so that the head would profit from only looking on his department. If he does, the overall performance is decreasing etc. The roles are also designed in such a way that the collaboration will not lead to any suitable result if the players do not communicate with each other.

The three different companies are in different parts of the world, i.e. they hardly have the possibility to meet physically and they also need to deal with time zones and different cultural behaviour. This challenge requires intense communication and collaboration among the organisations. Additionally, two of the companies receive cooperate role descriptions to simulate diverse cultures. This do not only simulate typical barriers, but are also the source of a variety of risks, which the players need to identify, evaluate and treat.

The product they produce in collaboration is a complex extended product, thus they need to start with negotiating a consortia agreement, in which they need to decide upon risk sharing, communication and collaboration rules etc. Furthermore, in order to design and produce the product, the different companies need to collaborate. The performance of the different companies is measured in a function of the time they use in a process step, as well as a function of the percentage deviation of target value of each entry in specific documents. The owner of the document does not have the needed information himself, but can retrieve it from other players by communicating with them. However, since the parts are produced in different enterprises, the internal company processes are not visible for the other companies. This actually leads to an increased need of information, but as in real life, the partners do not have access to the internal information flow, so they need to deal with information and collaboration risk at a much more advanced level than in level one. Figure 19 shows the processes for the second level of Beware for the three different companies.

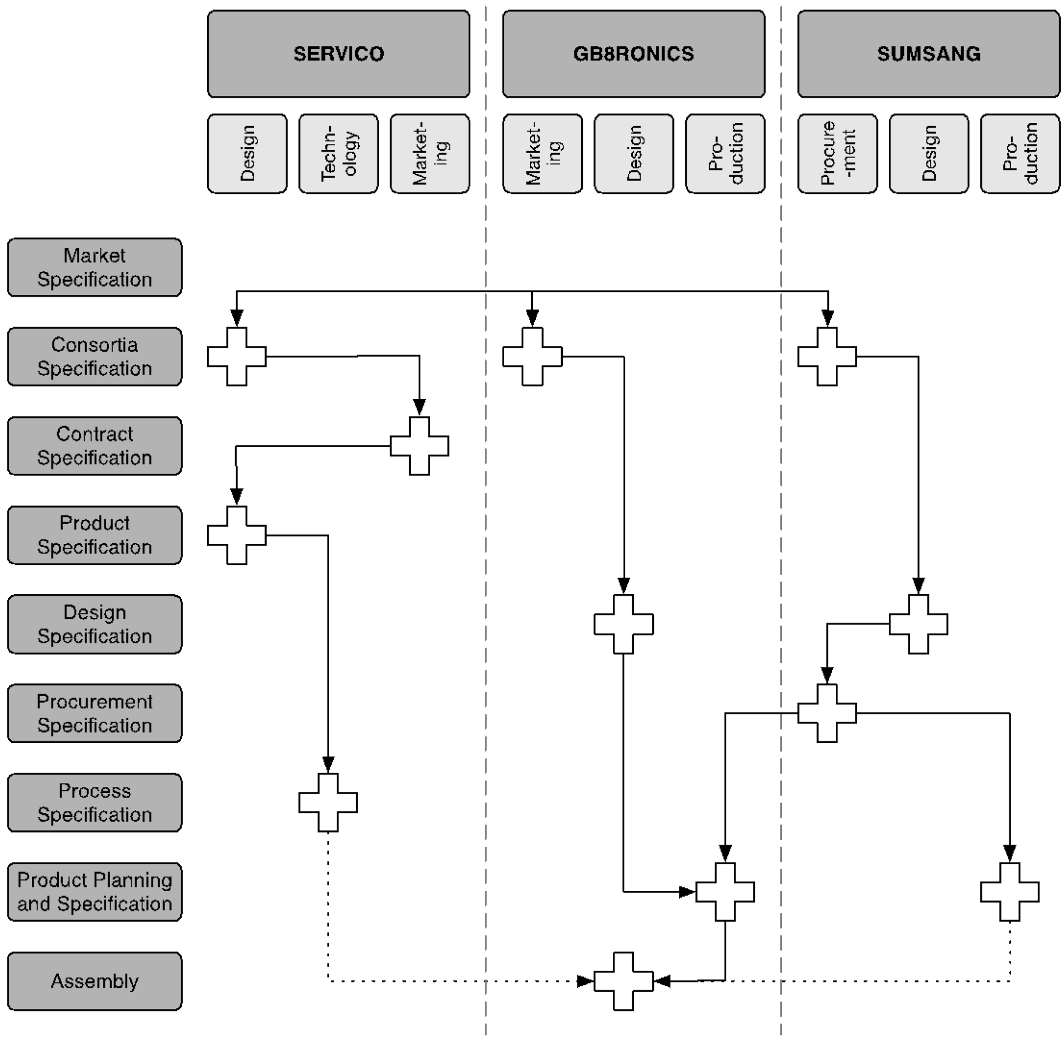

Figure 19: Overview of processes level 2, inter-organisational product development

Also, here each participant needs to complete processes, deal with additional tasks and events. The intention is the same as in level one, but this time they are all dealing with risks and barriers at the inter organizational level. Hence, the players need to apply different risk management methods by solving their tasks as well as to develop strategies which will help them in reducing the negative impact of a risk or the likelihood of that risk on one hand side, but on the other side, still look for business opportunities and to strengthen the collaboration. At the second level, the focus is moved towards quality management and integrated risk management. Each player has to carry out some analysis and also to evaluate the impact of different risks both on the own enterprise as well as on the collaboration and the partners.

6 Evaluation methodology

During the research parts of the text have been published in [2, 5, 6, 11, 16, 19, 28]. These are listed in chapter 12.

This chapter describes the evaluation methodologies. The objects of evaluation have carefully being selected in order to be able to answer the research question on how to convey the competence necessary in order to manage risks in enterprise network as well as how a game supporting this objective has to be designed. Thus, within the frame of this research four different objects are subjects of evaluation:

- The curriculum
- The game's learning outcomes
- The learning outcome of the whole course
- The game as software in terms of usability

The evaluation of the learning outcome of the game and the course will contribute to answering research question 2. A comparison of the outcome of section F (compare section 3.3) on the students perception of skills improvement with the outcome of the experts survey used for requirements collection will contribute to answering research question 1, whereas the analysis of learning outcome within the game and the software evaluation will contribute to research question 3. However, the evaluation of games is complex and multi-dimensional, since it involves evaluation of learning outcomes both within the game as well as for the course as a whole, as well as the evaluation of the usability and the appropriateness of the game in terms of being software. This requires multiple evaluation approaches. The possible evaluation methods are reviewed and the rationale for selecting the appropriate evaluation methods discussed.

In order to improve the curriculum and the game in terms of achieving the desired learning outcome, a phased approach has been used for continuously improvements and hence the evaluation has been carried out continually over several years. The results of the evaluations have been used to improve the curriculum and the game.

This chapter first discusses the nature of evaluation.

6.1 Evaluation definition

Evaluation is always done for a specific purpose. The purpose of an evaluation may differ since evaluations focus on various aspects (see DeGEval 2003). Therefore, it is necessary to evaluate and assess the evaluation object against some criteria. In order to ensure an objective evaluation, it is an advantage to use quantitative measures, since these are mostly objective. However, there are still challenges to overcome in the evaluation of learning outcome, both of a game and of a course. This is especially a challenge if the learning outcome is measured in terms of increased understanding, awareness or soft skills i.e. not only a question of reproduction of knowledge [Gibson, 2002]. This section looks more into different research designs for evaluation of the learning outcome as well as on software evaluation.

Formative and summative evaluations are both important in developing and testing games [Bellotti et al. 2013a]. In this work formative evaluation has been carried out in order to improve the game and the curriculum, whereas summative evaluation has been used for the evaluation of each single course and also for comparison of different groups in order to better understand the influence of the group on the learning outcome.

"Evaluation is the systematic investigation of an evaluand's worth or merit. Evaluands include programmes, studies, products, schemes, services, organisations, policies, technologies and research projects. The results, conclusions and recommendations shall derive from comprehensible, empirical qualitative and/or quantitative data." [DeGEval 2003, p. 5]

Frank and Kromrey define evaluation as "the assessment of an object by applying certain methods in order to derive an extent of concordance of the specific object with a certain set of goals" [Kromrey, 2001 in Fettke and Loos, 2004c]. An evaluation approach consists of four components:

- **Evaluation object (Evaluand)**: the specific artefact that needs to be evaluated as well as its environment and its effects. In this work there are three evaluation objects: the games as a product, the training courses and the games in terms of learning outcomes. These will be evaluated individually and different evaluation methods and criteria will be applied, because they all have different evaluation objectives
- **Evaluation objectives**: A set of objectives determines the goal of the evaluation project in question. Examples here are that the objective of the evaluation of the training courses is to evaluate the learning outcome as well as the suitability (i.e. if the course trains the user on the right subject and level). The evaluation objective of the quality in use of the game is quite different. Here it is the objective to evaluate if the game has the features needed in order to be supportive in the training on resilient enterprise network.
- **Evaluation criteria**: A set of evaluation criteria needs to be determined as it is not possible to evaluate all available aspects of an artefact. Such criteria can be reduced costs, increased speed, learning outcome, etc.
- **Evaluation method**: This determines the process and phases of an evaluation project. In this work, different methods are applied depending on the evaluation object.

An evaluation has to contain the four basic attributes: Utility, Feasibility, Propriety and Accuracy. In the following section, those attributes will be described (see DeGEval Standards).

- **Standards of Utility**: Those standards are supposed to make sure that the evaluation is aligned with the clarified purpose of the evaluation and the information needs of the intended user.
- **Standards of Feasibility**: The planning and conducting of an evaluation has to be realistic, thoughtful, diplomatic and cost-effective.
- **Standards of Propriety**: Those standards are supposed to ensure that those people and/or groups affected by the evaluation are treated with respect and fairness.
- **Standards of accuracy**: The evaluation should only produce and pass on valid information and results for the specific evaluation object and evaluation formulation of question.

6.2 Methods for evaluation of the curriculum

This section describes possible evaluation methods for curriculum evaluation as well as how these are applied for the developed curriculum.

There are some different approaches for the evaluation of learning outcomes in games. Kirkpatrick's model is a four level process used to determine the effectiveness of training. Kirkpatrick [1996] has defined the four levels of evaluation as follows: 1) Reaction, involves measuring how participants react to or feel about a training program. 2) Learning, measures the extent to which participants' knowledge, skills, and attitudes change as a result of training. 3) Behaviour, examines the extent to which a change in behaviour has occurred as a result of attending a training program. 4) Results can be defined as the final results that occurred due to students attending a training program. Results may be related to, for instance, changes in his skills and competences, in this case on risks and risk management.

Furthermore, as described in chapter two, also Bloom's taxonomy as well as the revised taxonomy are used for assessing the learning outcome. Within the field of management, we mostly look at the cognitive aspects.

Within the field of business and engineering games, both the original and the revised are used, depending on the main focus of the game. Bloom's original taxonomy is more suitable if the main purpose is to evaluate hard skills [Romero et al., 2011, Usart et al. 2011]. However, as seen in 1.4, and discussed in 2.4 the use of Serious Games in management and engineering education is often in the context of understanding the complexity of distributed production and collaboration across the Supply Network, aiming at improving the soft skills, and understanding the complexity and the influence of own decisions. In these situations, the learning objective is not primarily connected to right or wrong, but to improving the ability to make context-based decisions, mostly as a part of a collaborative process. In such cases, the objective is more to create new knowledge, and thus the revised version is used.

Table 11: Original and revised Bloom taxonomies

Cognitive competences in Bloom taxonomy (Bloom, 1956)	**Structure oft he cognitive process dimension** **Revised Bloom taxonomy (Anderson and Krathwhol, 2001)**
Knowledge	Remembering
Comprehension	Understanding
Application	Applying
Analysis	Analysing
Synthesis	Evaluating
Evaluation	Creating

6.2.1.1 Justification for selected evaluation method for the curriculum

The curriculum is designed to support the students in developing the competences they later will need in order to deal with risks in enterprise network and also in order to give them an opportunity to apply methods and observe the outcome of their decisions in a safe environment. Chapter 3 and section 0 discussed which competences (comprising skills, abilities and knowledge) they need for this purpose, and it was stated that both procedural as well as declarative knowledge [Collins, 1999] is necessary as well as perceptual and problem solving skills [after Procter and Dutta, 1995].

The learning outcome, in term of cognitive skills can be measured according to Blooms taxonomy as described in section 6.2.1.1. When the content evaluation does not deliver the expected results (i.e. the learning goals are not satisfactorily achieved for the students seen as a group), it is always a question of how the course structure can be improved- Should the introduction be changed, do they need different material, is the scenario too complex or too simple (compare the flow theory) is the length of the session the right one, etc.

In chapter 2.1 the complexity and dynamics of enterprise networks were discussed and different influencing factors were identified. Taking the right decisions in such complex, dynamic systems is related to the managers' ability to assess the environment. Thus, in this research the revised version is used. This evaluation is carried out after the course is finished.

As input serves:

- The survey based on questionnaires (i.e. the overall evaluation of the learning outcome for all students)
- The analysis of the lab reports
- The analysis of the students presentations
- Feedback from the student (all students are asked to give suggestions for improvements, and based on the overall feedback changes in course and game are proved.

By using Bloom's revised taxonomy in this analysis, it is possible to find out at which cognitive level the learning is good and not so good. By comparing this with the learning objectives and the cognitive levels for them, it can be identified where the structure needs to be changed.

The cohort in these lab courses is quite small- it is between 8 and 18. This is a very small number, and thus before large adjustments are done it is necessary to collect data from more than one year, in order to see if it was a problem caused by the group dynamic or if it is a structural problem.

6.3 Methods for evaluation of the learning outcome

It describes different research designs for the evaluation of learning outcome and explains the differences.

This section first describes appropriate methods that can be used both for the evaluation of the learning outcome of the whole course and of the game. This is followed by sections showing how these can be applied for SG evaluation as well as with examples from the literature on SG evaluation.

6.3.1 Methods usable for evaluation of learning outcome of the course and of the game

The introduction of a serious game into the curriculum raises similar issues to any other educational intervention since the aim is to improve students' performance on a specific leaning outcome. Woolfson [2011] proposes a hierarchy of evidence for evaluating educational interventions:

(1) Meta-analyses

(2) Randomised controlled trials (RCT)

(3) Quasi-experimental designs

(4) Single case experimental designs – pre & post test

(5) Non experimental designs – surveys, correlational studies, and qualitative studies

Evaluation of learning results requires that an individual has been exposed to the situation where learning was intended to take place. However, it has to be made clear that learning has occurred during the game [Michael and Chen, 2005; Bente and Breuer, 2009].

At the top of the hierarchy of evidence for the effectiveness of interventions are meta-analyses. There are no reports of meta-studies for higher education in the field of management and engineering subjects, so it is not considered further. Thus, the next section will explain and discuss different other evaluation approaches, their advantages and limitations and how these can be applied for the research carried out here.

6.3.1.1 Randomised control trials (RCT)

The Randomised Control Trial (RCT) is increasingly considered the gold standard for evaluating educational interventions. In an RCT participants are randomly allocated to an experimental (game) group or a control (non-game) group and their performance on the target skill/behaviour before and after the game intervention is tested. Ideally pre-testing should confirm no existing difference between the groups, while post-testing should show that the experimental group performs better than the control group. Improvements in the target skill/behaviour for the experimental compared with the control group in a follow-up study would allow further confirmation that the intervention was successful. Examples of RCTs can be found in Papastergiou [2009], Habgood and Ainsworth [2011], Beale et al. [2007] and Baalsrud Hauge et al. [2013]. Due to the conception of the curriculum, only one RCT has been carried out for Beware. This was done only with two groups of 9 persons, all research assistants in BIBA; from different studies (computer science, engineering, industrial engineering and logistics), in 2009, and not a part of a course. The results of the RCT were interesting and contributed to the improvement of the game. However, the results are not comparable to the other evaluations carried out and it is therefore not included in this thesis.

6.3.1.2 Quasi-experimental designs

While a RCT requires the random assignment of participants to experimental or control groups, in educational interventions this is not always possible. In that case a quasi-experimental design would have to be used [Field and Hole, 2003]. This kind of design is also used to refer to a one group post-test design where participants' behaviours are measured following an intervention and to a one group pre-post-test design where participants' performance is measured before and after the intervention. In group comparison designs, the performance of two (or more) groups is measured after the intervention. These designs are all of lower quality than a RCT, but for pragmatic reasons may have to be used in real world research.

6.3.1.3 Surveys

Survey research typically uses a questionnaire methodology to ask many respondents about their attitudes to, perceptions of, or use of games generally, or of a specific game. The results are typically reported in terms of descriptive statistics reporting for example what percentage of people play games, intend to play games, enjoyed a game or felt that the game had helped them achieve the intended skills. Some studies, such as Connolly et al. [2007] and Karakus et al. [2008] examined game playing generally, while others, such as Lindh et al. [2008], studied students' use of a specific game. Surveys can also be used as part of a formative evaluation or user requirements analysis to assess whether potential players of a game would perceive a particular kind of game as useful.

Rather than just reporting descriptive data, it is possible to carry out more sophisticated analysis with survey data looking at links between variables and this would typically be done where a theoretical model is being tested. Weibel et al. [2008] for example used regression analysis to examine the relationship between engagement variables, presence, flow and enjoyment, in an online game. They found that flow mediated the relationship between presence and enjoyment.

In terms of the hierarchy of evidence, qualitative research is regarded as lower quality than quantitative research. Qualitative research is more subjective than quantitative since it is more interpretative, but it can provide a much broader approach to examining the skills that playing games can support.

6.3.2 Methods suitable for evaluation of the learning outcome within the game

This section describes the selected methods and why they were selected. The measurement of learning outcome is a challenging task and section 6.2 describes different approaches. The main objective in the designed/developed/observed course is to improve different competences related to the management of risks in enterprise networks. To some extent, this is done by improving knowledge and for this pre- and post-test can be used. The advantage is that such tests provide quantitative data. However, for answering the research question 2, it is not enough to only evaluate the improvement of knowledge. In addition, their skills and abilities need to be evaluated. This is quite difficult, since not quantitative measureable and depends on several other factors. Thus, using different methods like feedback forms completed by the students combined with in-game observation and measurements (teacher assessment) it is possible to gain an impression of the improvements of the students' skills and abilities. In sum, this evaluation will indicate if the learning goals were achieved or not.

6.3.2.1 Stealth assessment

Key Performance Indicators define a set of values used to measure against. These raw sets of values fed to systems to summarize information against are called indicators. Indicators can describe both ratios (like percentage of orders delivered on time or costs per unit) as well as absolute numbers like lead-time, time spent on a task or number of users. Performance indicators and performance indicator systems give the information for the planning the controlling of the enterprise [Webber, 2002], but they can also be used for evaluating employees, internal departments or products. Their main function is to give information and to serve as a help in decision-making at one hand, and to be used in the operative business for controlling on the other hand. They may be used as benchmarking, comparing enterprises or products, to raise the information transparency of a company or a product or they may be used internally. Bellotti et.al [2013b] and Mayer et al. [2013] discuss evaluation based on performance within the game, often called stealth assessment. The advantage of this method is that the game provide immediate feedback to the players, and that learning in the game is implicit (compare [Kerres et.al., 2009] on implicit and explicit learning), and in addition, it can also contribute to more detailed and reliable information [Bellotti et al., 2013b], depending on what was measured in the game.

The development of appropriate indicators and the availability of statistics are necessary. Thus, for the players, three KPI were selected: cost, time, quality performance as indicators to give feedback to the students. These are some of the most typical indicators to be looked at [Albert et al. 2004]. In addition, the facilitator tracks the communication among the players as well as deviation from given standard value within the game. Furthermore, for each process step of type *document* there are target values that can be compared by the facilitator. The indicators are intended to provide an orientation to the player for how he/she plays as well as for triggering some events. They are also important for the assessment of different risks within the game.

The mission will also measure some In-Process Assessment [Chen and Michael, 2005; Bellotti et al., 2013b], however restricted to what will be available through the computer log and the facilitator's assessment. By any deviation from what is normal in this course, these results are also compared with the other evaluation results in the post evaluation of course and game (i.e. for the curriculum improvements).

6.3.2.2 Observation

Observation can be used as an evaluation method during game play. Observation can be carried out at different levels. If only declarative knowledge gain is measured it will not say much about skill improvement. The teacher could observe if the student answered right or wrong, or how many correct answers he has. This corresponds to Kirkpatrick's level two, "learning". The player is requested to play twice, at different level and in different context (intra- and inter-organisational levels, complex and simple products). Observing and analysing the changes in how the player solves his tasks and how he behaves gives some indication on the learning outcome regarding soft skills and increasing awareness on how risks arise and behave. This corresponds to Kirkpatrick's level three. At the end of the training session, the player is asked to present and explain her/his tasks/missions – a written task with challenges to be solved in the game. The mission will be followed up to get information about how the mission was accomplished. Information of interest will be: Did the player complete the task? What choices did he make? This supports the reflection phase in Kolb's learning cycle as well as Kirkpatrick s level four. The mission element measures whether or not the player completes the lesson, and thereby covers what Chen and Michael [2005] refer to as Completion Assessment.

6.3.3 Review of evaluation methods in different studies

The following table summarises the types of evaluation methods that can be used and when they can be used for evaluating Serious Games. It is followed by some examples of studies using some of the methods.

Table 12: What to measure, how and when

How		What?	Pre-game	In game	Post-game
Self-reported	Qual.	Personality, player experiences, context, etc.	Interviews, focus group, logbook.	Logbook, interviews or small assignments as part of the game.	Interviews focus group, after-action review.
	Quant.	Soc-dem., opinions, motivations, attitudes, engagement, game-quality learning, power, influence, reputation, network centrality, learning satisfaction, etc.	Survey, quest., individual or expert panel	In-game questionnaires	Survey, quest., individual or expert panel
Tested	Qual.	Behaviour, skills, etc.	E.g. actor role-play, case-analysis, assessment, mental models.	Game-based behavioural assessment.	Game-based behavioural assessment.
	Quant.	Values, knowledge, attitudes, skills, personality, power.	Psychometric, socio-metric tests: e.g. personality, leadership, team roles, IQ.	Game-based behavioural performance analysis.	Game-based behavioural performance analysis.
Observed	Qual.	Behavioural performance of student, professionals, player and/or facilitator, others; decisions, strategies, policies, emotions, conflicts, etc.	Participatory observation, ethnographic methods	Video, audio personal observation, ethnography, Maps, figures, drawings, pictures, etc.	Participatory observation, ethnographic methods.
	Quant.	Biophysical–psychological responses, like stress (heart freq., perspiration).	Part. observation, network analysis, Biophysical–psychological observation.	In-game tracking and logging, network analysis, data mining, biometric observation.	In-game log file analysis, network analysis.

Evaluation data can be gathered through mixed methods, mostly combining pre-game and post-game questionnaires of the players, live or video observations, transcripts of after-action reviews and game results. In a few cases, methods are applied more rigorously with in-game knowledge tests or network and communication analyses from logging tools or video observations. Table 12gives an overview of how to mix the various methods in pre-game, in-game and post-game stages.

As described above, the use of pre and post tests for evaluating learning outcomes remains one of the most popular used methods [Bellotti et al. 2013b], even though RCT is seen as the gold standard for evaluating educational interventions. However, often it cannot be applied in practice, both due to the difficulties in having randomly selected control groups, and the arising ethical issues and practical concerns (it cannot be implemented during a course due to the unfairness of having different groups experiencing different educational methods (game/non-game). Consequently other methods which are less "valuable", or rigorous, but more usable are usually applied in combination. The next section describes the evaluation methods used in this research.

6.3.4 Selected evaluation methods learning outcome

This section describes the selected methods and why they were selected. The main objective in the course is to improve different competences related to the management of risks in Supply Network. To some extent this is done by improving knowledge, and for this pre- and post-test can be used. The advantage is that such tests provides quantitative data. However, for answering the research question 2, it is not enough to only evaluate the improvement of knowledge. Also their skills and abilities need to be evaluated. This is quite difficult, since it is not quantitative measureable and depends on several other factors. Thus, using different methods like feedback forms completed by the students combined with in-game observation and measurements (teacher assessment) it is possible to gain an impression of the improvements of the students' skills and abilities. In sum, these evaluation will indicate if the learning goals were achieved or not.

6.3.4.1 Justification for the selected evaluation method for the overall learning outcome of the course

In order to evaluate the learning outcome of a quantitative method in the form of pre and post questionnaires is used. This method was selected, because it is well approved. The comparison of pre- and post- questionnaire helps in evaluating the learning outcome in terms of improved declarative and procedural knowledge, but not much on skills, which is as knowledge improvement, a main part for competence improvements. The students' presentations of how they applied different methods for risk assessment and risk management serves as input for and additional evaluation of the improvements of the procedural knowledge) correctly. This is observed and assessed by the teacher and is a qualitative analysis.

For evaluation of the learning outcome in terms of improvements of the skills, a qualitative analysis of the learning outcome of the course has been used. It consist of three parts: analysis of the lab reports, the presentations and a post questionnaire. This is self reported by the students, and is compared with the teachers analysis of the lab reports and the presentation. The learning outcome at this level cannot be measured in right or wrong answer, but more by analysing if the students was able to draw conclusions, take different factors into account and apply his knowledge, only qualitative methods were selected.

The questionnaires were also used in a formative way, and the outcome of the analysis used to improve the curriculum.

6.3.4.2 Justification for selected evaluation methods for the Beware serious games

It is important that the game support implicit learning [Kerres et al., 2009; Mayer et al. 2013 b]. This is done by using different evaluation methods as described below.

The preferable method for the evaluation of the game would have been to use RCT over longer time, letting one group play the game and the other only getting the same knowledge presented in a traditional class. This is however not possible, since it would require two different types of courses. Thus, I looked at other, well used possibilities to evaluate the game, and made a mix of different methods.

Chen and Michael [2005] claim that there are three main types of assessment used in Serious Games:

- Completion Assessment - Did the player complete the lesson or pass the test?
- In-Process Assessment - How did the player choose his or her actions? Did he or she change their mind? If so, at what point?
- Teacher Evaluation - Based on observations of the student, does the teacher think the student now knows/understands the material?

For the completion assessment the facilitator tool is suitable. With this tool the facilitator sees when the player has completed a task by a notification in the system. In the Beware game it is not a matter of passing any test, but the facilitator also measure how long time it took to complete, and how the performance indicators were related i.e. it is a quantitative evaluation based. This assessment is mainly done based on information delivered by the game, and thus quite objective. These results can be compared with the results in the group playing in parallel, or in the previous years for more detailed analysis.

Beware is played in a distributed environment. I.e. the facilitator/teacher is not in the same room. The In-Process Assessment is also based on using the facilitator tool and stealth-assessment. In this case it is the matter on how the player decided, and of specific importance for the learning outcome (compare learning goals chapter 3.4), is the communication. Thus, in this case the communication threads is measured or observed, and combined with how the three main KPIs for the corresponding process are (time, cost, and quality) regarding actual/targeted. In addition, for processes of type *document,* the communication threads are combined with the entries in the documents and its deviation from expected value. For this sort of evaluation, it would also be preferable to either get more feedback from the system (by measuring brain activities etc.) or using video cameras for tracking emotions and discussion. However, even if this might be desirable in order to get better feedback, it is quite a big intrusion to the students' privacy, and need for ethical reasons a specific consideration. So far, I never considered such additional results as so relevant for the learning outcome that it could be justified, and therefore not taken into consideration.

For the teacher evaluation two different methods are used. The main method for doing this while playing is observation. Monitoring how the player completes the task, the level of communication gives a first indicator of if the player did understand the task and how to apply the method. Secondly, also the number of requests for explanation or help indicates that. However, only based on this tool, it is not possible to assess the level of understanding, so it is combined with the observation done and the impression arising during the debriefing phase and the presentation at the end of the course (for the R.M. methods), and with a comparison of the mid and post-questionnaires (however after the game completion). The observation based on the in-game measurement is qualitative.

6.4 Evaluation process for quality in use of the software

This section describes the Beware game as a software product that can be evaluated and the utilised evaluation methods.

6.4.1 Methods and standards for software evaluation

In addition to the evaluation of the learning outcome, also the usability of the software has to be assessed. If the usability is not good, then the students will use time on getting along with the software and the user interfaces, and thus focus less on what is happening in the game.

Given the complexity and expense of developing Serious Games, it is important to carry out formative evaluation early in the development of the game. Thus, for the development of the beware game an agile development approach was used, and thus evaluation was carried out during both development and testing phases. In addition, after each course, the game is evaluated and also the degree of achievement of the learning objective is assessed. The outcome of this serves as input for improvement both of the game as well as for the course, so that both have been continuously improved over time. The benefits of early evaluation of games have been reported in Shrimpton and Hurworth [2005].

Quality of a product or service is not an absolute measure. It is a measure comprising different components and describes roughly how good a product meets specific requirements and expectation. Quality may be described with the help of different characteristics. These characteristics can again be measured and described with the help of key indicators/attributes [Balzert, 1998]. The quality of a product is dependent of the environment, therefore the quality of a product, may be high in one environment whereas exactly the same product may have low quality in a different environment. Quality is often described in different terms- we often speak of quality of the product in a more technical sense looking at the fulfilment of functionalities and its usability where as we also speak about the quality of a product actually meaning how the product is in use. The first two can be evaluated according to the ISO 9126 standard, while the third depends strongly on the human factor. It is possible that a software product performs a good quality in technical sense, but it might be too difficult to use. In such a case, it will probably not be considered successful. Therefore, software products should be evaluated regarding to their quality in use, too. The corresponding applicable ISO is ISO 25040:2011[1] [2] (ergonomics).

Below the main criteria for the formative evaluation of the software are listed:

- Functionality is the existence of a function with specific characteristics. The function has to fulfil the defined requirements.
- System reliability is the ability of a system to keep its level of proficiency under predefined conditions for a certain time period.
- Maintainability tells about what kind and amount of effort has to be applied in order to make changes in the software or the system. Changes can be corrections, improvements or adaptions.
- Efficiency tells about the relationship between the level of proficiency of the software and the extent of the engaged resources/equipment under determined conditions.
- Portability describes the effort required to transfer the program from one hardware and/or software system environment to another.
- Usability tells about the amount of effort that has to be applied in order to operate the system. This is very dependent on human factors.

[1] http://www.iso.org/iso/catalogue_detail.htm?csnumber=24902
[2] http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=35765

The first five criteria are important for the evaluation of the software and was used during the development phase, and still for monitoring issues measured, but they do not so relevant for the learning outcome.

Usability attributes outline the features and characteristics of the product that influence the learnability, effectiveness, efficiency and satisfaction with which users can achieve specified goals in a particular environment (Broad version).

Sub characteristics:

- Understandability: Attributes of software that bear on the users' effort for recognizing the logical concept and its applicability.
- Learnability: Attributes of software that bear on the users' effort for learning its application (for example, operation control, input, and output).
- Operability: Attributes of software that bear on the users' effort for operation and operation control.

Quality in use may be influenced by any of the quality characteristics, and is thus broader than usability, understandability, learn ability and operability, which are the main sub characteristics of usability. Quality of a product in use is very dependent on the user. Quality in use can be measured in terms of user performance and satisfaction.

The capability of the software product to be understood learned, used and attractive to the user, when used under specified conditions is of major concern for games used for learning [International Standard Organisation, 1998, 1999, Holzinger, 2005].

Most evaluation criteria are preferable objective, but this does not hold for user usability, because this will always be an individual perception of the user. However, analysing enough users will give an indication on how the software is perceived and accepted. Within the usability studies of the Beware game, the following main factors have been taken into account:

- Good overview of available functions
- Easy to understand (in the sense of well explained, using well known terms etc.)
- Delivers enough information about required input
- Help functions available

Understandability: the capability of the software product to enable the user to understand whether the software is suitable, and how it can be used for particular tasks and conditions of use. How easy it is to understand the structure of the software for those operating it.

Learnability: the capability of the software product to enable the user to learn the platform.

Operability: the capability of the software product to enable the user to operate and control it.

Satisfaction: measures the freedom from discomfort, and positive attitudes towards the use of the product. Satisfaction is composed of comfort and acceptability of use.

- Comfort refers to overall physiological or emotional responses to use of the system. Cognitive workload is closely related to comfort: even if a system is apparently acceptable for use, it may be low in comfort if it demands too little or too much mental effort. A task demanding too little mental effort may result in a lowered efficiency because it leads to boredom and lack of vigilance, which directly lowers effectiveness. Excessive cognitive workload may also result in lowered effectiveness.
- Acceptability of use may measure overall attitude towards the system, or the user's perception of specific aspects such as whether the user feels that the system supports the way they carry out their tasks, do they feel in command of the system, is the system helpful and easy to learn. Measures of satisfaction can provide a useful indication of the user's perception of usability, even if it is not possible to obtain measures of effectiveness and efficiency.

Understand and specify the context of use

The characteristics of the users, tasks and the organisational and physical environment define the context in which the product is used. If there are extensive results from user feedback, help desk reports and other data, these provide a basis for prioritising user requirements for system modifications and changes.

Measuring User Performance

Measuring user performance gives reliable measures of the effectiveness and efficiency of system use. By evaluating to which extent specific goals are achieved, and how long it took to achieve task goals, it is possible to draw conclusion on how good the software is. It can also give measures of time spent unproductively (for example, overcoming problems and seeking help), plus diagnostic data about the location of such difficulties. The diagnostic information helps identify where specific problems are encountered and where improvements need to be made. These measures are important in order to identify the degree of difficulty in operating/use the software.

Measures of **effectiveness** relate the goals or sub-goals of using the system to the accuracy and completeness with which these goals can be achieved.

6.4.2 Selected evaluation approach for Beware software

For Beware, an agile development approach has been used. This requires formative evaluation during the development process and in operation of the product [Bellotti et al. 2013b, Seager et al. 2012]. For Beware, this has been carried out according to the standards and by using the criteria as described below. It has resulted in changes in the software, as mentioned in chapter 4, a more detailed overview of the implemented changes are in section 7.

The product, i.e. the Beware game is evaluated according to the following main criteria:

1. Evaluation of the software/product according to its functionality, usability (technical), maintainability, reliability, efficiency and portability.
2. A description of the components of the context of use including users, equipment, environments, and tasks.
3. Quality in use measures consisting of target or actual values of effectiveness, efficiency, and satisfaction for the intended contexts.
4. Evaluation of product's learning outcome based upon subjective feedback, assessment of communication between the players, the given presentations, questionnaire and the written report.

The table below lists the evaluation objects, the evaluation objectives, the evaluation criteria-main group and the method.

Table 13: List of evaluation objects and the applied main criteria

Evaluation object:	Game and supplemental material	Game quality in use
Evaluation objectives	Learning outcome	Learning outcome of the game it self Quality-in-use
Evaluation Criteria	Evaluation Criteria for Human Factors Performance indicators Learning outcome	Evaluation Criteria for Human Factors Ergonomics (quality in use) Performance indicators Technical criteria
Method	Quantitative: measuring performance indicators, the communication and collaboration level Qualitative: questionnaire (user feedback), presentations, written feedback in report form, oral feedback in debriefing part.	Quantitative: measuring performance indicators Qualitative: questionnaire (user feedback)

The next chapter discusses the results of the Beware evaluation, as well as the impact these had on the game design, the development of new functionalities and the curriculum.

7 Results of the evaluation

During the research parts of the text have been published in [2, 6, 12, 14, 40, 41]. These are listed in chapter 12.

The focus for the evaluation is to evaluate the Beware game regarding its learning outcomes and quality in use. The second aspect is the purposes of the evaluation. There are different purposes and uses of evaluation of learning programmes [Phillips, 1997]. According to the evaluation methodology presented in chapter 6, there are four object to be evaluated. Section 7.1 comprises the different evaluations carried out in order on the learning outcome both of the course and the game. This evaluation approach uses five sorts of input data:

1. The observation and the exchange of information between the facilitator and the students,
2. The performance indicators from the game,
3. Questionnaires comprising questions on the functionalities, the utility, the usability of the software, and on the individual learning outcome,
4. Individual and group presentations,
5. Feedback collected in the debriefing phase and the completion by students of extensive laboratory report comprising information on the involvement in the game, skills gained and past experience, with additional information on how the participants applied the learned methods in the game as well as on the developed game scenarios, including their own goals and the fulfilment of these goals.

Section 7.2 concentrate on evaluation of the curriculum. The outcome of the formative evaluation will address research question 2 and 3. The last evaluation is the evaluation of the software. This is addressed in section 7.3, and will mainly contribute to answering research question 3.

Research question 1 is evaluated by comparing the competences derived on a literature review with the evaluation results of the surveys and interviews described in section 3.3. This was used for the requirements analysis and therefore not a part of this chapter.

7.1 Analysis of the questionnaire learning outcome of course and game

This section provides a discussion on the results related to learning outcome based on the questionnaire

This section discusses some of the main outcome from the questionnaires regarding learning outcome as well as a discussion based on an analysis of the lab reports and the observation during game play.

Table 14: Improvements of abilities regarding collaboration

3. I was able to identify the challenges within interpersonal relations/trust in distr. environments

	strongly disagree	disagree	agree	strongly agree	no opinion	Sum
Communication Lab SS 06	0	1	7	0	0	8
Communication Lab WS 06/07	0	1	11	3	0	15
Communication Lab SS 07	1	1	11	1	1	15
Communication Lab SS 08	3	3	20	7	2	35
Communication Lab WS 08/09	2	2	10	4	1	19
Communication Lab SS 09	1	0	3	5	0	9
Communication lab WS 09	0	0	9	8		17
Communication lab WS 10	0	0	8	9		17
Communication lab WS 11	0	0	3	6		9
Communication lab WS 12	0	0	2	6		8
Communication lab WS 13	0	0	2	15		17
Total	**8**	**11**	**115**	**68**	**5**	**207**

5. My ability to understand the perspective and motivation of others improved during the game

	strongly disagree	disagree	agree	strongly agree	no opinion	Sum
Communication Lab SS 06	1	1	4	1	1	8
Communication Lab WS 06/07	0	2	7	3	3	15
Communication Lab SS 07	2	3	7	1	2	15
Communication Lab SS 08	1	5	17	6	6	35
Communication Lab WS 08/09	1	3	6	2	1	13
Communication Lab SS 09	1	1	5	2	0	9
Communication lab WS 09	2	0	8	7		17
Communication lab WS 10	0	0	8	9		17
Communication lab WS 11	0	0	4	5		9
Communication lab WS 12	0	0	3	5		8
Communication lab WS 13	0	0	2	15		17
Total	**11**	**21**	**89**	**61**	**19**	**201**

A main objective with the course as such, but in specific the use of the developed game is to improve the ability to collaborate in distributed environment. Trust is an essential factor for collaboration. Table 14 shows how the students assess their ability regarding trust and developing personal relations within the gaming environment.

It shows that the ability of the students to identify challenges related to collaboration and trust was good already in the first game play. This is as expected since the game used as a starting point was designed for this purpose, and therefore very suitable. However, in order to be able to deal with risks related to communication, it is not enough only to identify these challenges, it is also important that the students are able to develop strategies that are adaptable to the dynamic environment..

Table 15 is about the knowledge-sharing attitude based on the experience in the game. It shows how the students assess the relevance of knowledge sharing in relation to the success of the collaboration. Again, it can be concluded that already from the beginning, it was obvious for the students that information sharing is important. The results show that there were some challenges in developing the relevant strategies at the beginning. This leads to letting the students experience during the first level looking at the same information from different perspective-partly by setting events, and partly by slightly changing the context to be a little more diffuse, so that it was possible to revisit the same information and to interpret it differently.

Table 15: Improvements of abilities regarding information sharing and group work

8. Exchanging knowledge with other colleagues is significant fort he company's success

	strongly disagree	**disagree**	**agree**	**strongly agree**	**no opinion**	**Sum**
Communication Lab SS 06	0	0	0	5	3	8
Communication Lab WS 06/07	0	0	3	11	1	15
Communication Lab SS 07	0	0	4	9	2	15
Communication Lab SS 08	4	2	15	8	6	35
Communication Lab WS 08/09	1	0	1	11	0	13
Communication Lab SS 09	0	0	3	6	0	9
Communication lab WS 09	0	0	3	14		17
Communication lab WS 10	0	0	2	15		17
Communication lab WS 11	0	0	0	9		9
Communication lab WS 12	0	0	0	8		8
Communication lab WS 13	0	0	1	16		17
Total	**5**	**2**	**39**	**137**	**18**	**201**

9. My ability to understand the perspective and motivation of others improved during the game

	strongly disagree	disagree	agree	strongly agree	no opinion	Sum
Communication Lab SS 06	0	1	4	0	3	8
Communication Lab WS 06/07	1	4	7	2	1	15
Communication Lab SS 07	0	4	5	4	2	15
Communication Lab SS 08	2	4	11	13	5	35
Communication Lab WS 08/09	0	3	7	3	0	13
Communication Lab SS 09	0	1	5	3	0	9
Communication lab WS 09	0	1	9	7		17
Communication lab WS 10	0	0	9	8		17
Communication lab WS 11	0	1	3	5		9
Communication lab WS 12	0	0	3	5		8
Communication lab WS 13	0	0	4	13		17
Total	**4**	**28**	**83**	**69**	**17**	**201**

The game in its earliest version comprised much distributed information, hidden by people the players did not expect. This leads to frustration and time consuming search for information that they could get from somewhere else. The feedback from the students also showed that hiding information in roles or organisational units that normally would never have them, was only confusing and did neither increase their ability to share and exchange information or to collaborate, but lead to much waste of time and lack of concentration. This had been working well in the SHARE game [See results, Schwesig, 2005], but was not working in a more complex situation, and actually confirms the relevance of building realistic environments, and only mirror what is necessary and not more [Bellotti et al,. 2010a, Westra, 2008]. Thus, this setting was changed, so that the students have to deal with incomplete information, leading to several uncertainties which they had to cope with, and which has a different impact in each role. The outcome of this new setting is a better understanding of the relevance of sharing information and made it easier for the students to developed risk mitigation strategies as well as to see opportunities.

The results described above are based on their assessment of what they learned within the game. The debriefing session did also have an effect on their perception. The next part of the evaluation deals with comparing the pre-, mid and post-test, in order to identify if the game supports the understanding and the ability to apply different methods. The change with using incomplete instead of hidden information had the advantage that the students got more focussed on their tasks- i.e. to develop the product within the timeframe in a specific quality, which is only possible if they collaborate and cope with the induced (from the role descriptions and the events) challenges. Thus, they paid more attention to the collaboration, and were aware of problems in the communication earlier. In addition, regarding applying risk assessment and risk management methods, this has to be carried out according to a specific process, and they need specific information, which they had time to look for. Table 16 gives an overview of how well the students are familiar with a standard risk management process. As the table shows, their knowledge is quite limited before they join the class. In the earlier version, it remains, even though slightly improved, limited also after the game. Thus, the facilitator tool and events connected with specific tasks for which they had to carry out risk management processes were introduced. It is interesting to see that in the first years, without doing many changes in the game, but the introductory was changed quite much, their knowledgeimproved. An instructional approach is used, so the teacher always introduce the methods beforehand. In order to verify if the game or the introduction is most helpful, a mid-test was introduced in the winter term 2008/2009. Comparing the results again, shows that the level increases more after the game play (post-test) than after the introduction (mid-test). Even if the restructuring helped, the regularly changes has shown that in order for the student to internalise the process steps and understanding what he need to look for, a few similar, but slightly different analysis have to be carried out.

Table 16: Results for internal and external risk drivers within a Supply Network

	61. There are many different ways to describe risks. Please list the external and internal driven risks you know in an enterprise network.					
	classification of answers					
	excellent	**well**	**satisfy-ing**	**ade-quate**	**inadequate**	***no. participants***
Communication Lab WS 07/08 (Pre-Test)	1	2	6	4	23	36
Communication Lab WS 07/08 (Post-Test)	0	9	6	2	13	30
Communication Lab SS 08 (Pre-Test)	0	2	5	7	23	37
Communication Lab SS 08 (Post-Test)	1	7	12	3	12	35
Communication Lab WS 08/09 (Pre-Test)	0	5	2	0	12	19
Communication Lab WS 08/09 (Test after Intro)	0	1	10	2	6	19
Communication Lab WS 08/09 (Post-Test)	1	6	8	2	2	19
Communication Lab SS09(Pre-Test)	0	0	2	2	5	9
Communication Lab SS 09(Test after Intro)	0	2	2	2	3	9
Communication Lab ss 09	5	3	1	0	0	9

08/09 (Post-Test)						
Communication Lab WS 09 (Pre-Test)	0	0	3	3	11	17
Communication Lab WS 09 (mid)	0	3	10	4	0	17
Communication Lab WS09 (Post-Test)	4	9	3	1	0	17
Communication Lab WS 10 (Pre-Test)	0	0	3	3	11	17
Communication Lab WS 10 (mid)	0	5	6	6	0	17
Communication Lab WS10 (Post-Test)	2	11	3	1	0	17
Communication Lab WS 11 (Pre-Test)	0	1	2	2	4	9
Communication Lab WS 11 (mid)	0	1	4	4	0	9
Communication Lab WS11 (Post-Test)	2	3	3	1	0	9
Communication Lab WS 12 (Pre-Test)	0	0	2	1	5	8
Communication Lab WS 12 (mid)	0	4	1	2	1	8
Communication Lab WS12 (Post-Test)	5	1	2	0	0	8
Communication Lab WS 13 (Pre-Test)	0	1	1	2	13	17
Communication Lab WS 13 (mid)	1	8	7	1	0	17
Communication Lab WS13 (Post-Test)	12	3	2	0	0	17
Total	**1**	**11**	**26**	**24**	**107**	**169**

Table 16 shows that in the first year of using the Beware game for risk awareness, it was not successful. Even thoug it can be seen that in the first two terms, the number of participants not being able to list the internal and external risks was reduced by 50% between the pre and the post test, but it was still very high, since more than 30 % still answered inadequately. The second interesting observation was that there was not a large increase in the number of those answering better after rather than before the game. After discussing these results with the participants and also looking for the reasons, some changes were introduced. The participants mentioned two main causes; first, they lost the overview and did not manage to deal with the user interface and what was happening. Secondly, they found it difficult to identify risks, which were not clearly addressed. In real life, these risks are not clearly addressed either, but in the game play students have to have the opportunity to discover them and to learn what to look for. Thus, the complexity in the first level was reduced and additional tasks focusing on specific risks (like supplier risks) were added. Furthermore, the overall duration was increased, so that it was possible to increase the period between the games and also between the introduction and the game. Thirdly, the facilitator's tool as well as the use of events had a positive effect. The results for the following period shows that it has been possible to decrease the inadequate answers after the game. The first changes helped, but the outcome was still not satisfactorily, so further analysis and experimentation with the events were carried out.

Table 17: Relevance of finding a holistic optimum solution for risk reduction in collaborations

14. In collaboration, the optimum solution with minimum risks can only be achieved if all partners are aiming at finding the optimum solution for the collaboration as a whole						
	Not true				**True**	**Sum**
Communication Lab WS 06/07	1	0	1	8	5	15
Communication Lab SS 07	0	0	3	7	5	15
Communication Lab WS 07/08	0	3	7	7	12	29
Communication Lab SS 08	0	6	3	15	9	33
Communication Lab WS 08/09	0	0	4	6	3	13
Communication Lab SS09	0	0	3	4	2	9
Communication lab WS 09	0	0	3	6	8	17
Communication lab WS 10	0	1	4	4	8	17
Communication lab WS 11	0	0	1	4	4	9
Communication lab WS 12	0	0	0	3	5	8
Communication lab WS 13	0	0	0	8	9	17
Total	**1**	**10**	**29**	**72**	**70**	**182**
project managers	0	0	1	6	3	10

In chapter 1.2 and in chapter 2.1 it is discussed that to look at the Supply Network from a holistic perspective and to ensure seamless information flow are important factors for improving the resilience and reducing the risks. Both aspects improve also the transparency and visibility within a network. During the gameplay the students experience the concequences both of lack of information as well as the lack of transparency (level 2) and also that if the communication is not good, it is difficult to achieve the best possible solution in a given context.

Table 18: Awareness of how behaviour can influence the collaboration

30. Employees are often not aware of the impact his/her behavior can have on the collaboration						
	Not true				**True**	**Sum**
Communication Lab WS 06/07	1	0	3	7	4	15
Communication Lab SS 07	0	0	3	6	4	13
Communication Lab WS 07/08	0	0	4	17	7	28
Communication Lab SS 08	0	3	8	19	2	32
Communication Lab WS 08/09	1	0	1	7	3	12
Communication Lab SS 09	0	0	0	5	4	9
Communication lab WS 09	0	0	2	6	9	17
Communication lab WS 10	0	0	1	7	9	17
Communication lab WS 11	0	0	1	2	6	9
Communication lab WS 12	0	0	0	3	5	8
Communication lab WS 13	0	0	0	8	9	17
Total	**2**	**3**	**23**	**87**	**62**	**177**
Project mangers	0	1	0	5	4	10

Table 18 describes how the students and the practitioners assess the understanding of how the behaviour can influence the collaboration and thus have an impact both on the resilience as well as on how risks arise as well as which impact they get. The intention with this question to the students is that based on their experience in the game, and the relevance their role driven behaviour had on the collaboration and the resulted conflict, they will be more aware in the future. The answers to this question are not changing so much over the time, and is more or less the same as for the practitioners.

7.1.1 Evaluation of the learning outcome in the game using stealth evaluation and observation

As mentioned in the previous section, the learning outcome of beware is also measured by using pre-, and post-questionnaires. These actually just compare what the student knew before and what he knows afterwards, i.e. factual knowledge. In addition, it is important to know if the student also is able to develop strategies to handle what he experiences- i.e. he needs to be able to understand, analyse and evaluate what he observed and based on that is able to abstractulate. This is at one hand evaluated through the monitoring done by the facilitator (compare Michael and Chen’s [2005], Teachers’ assessment) and also by asking the students for their subjective experience. In combination, this gives information on how the students have been able to improve.

The performance in each game is dependent on the players and the communication level. The introduced facilitator tool offers the possibility to track the communication flow against performance in the game, and this information is used both in the debriefing phase as well as in order to identify problems in the communication at an early stage. The communication carried out by using the chat function is stored in the database and can be analysed after game session, in addition to the observation and analysis done during the games. The level of communication is normally also matched to the performance in the different processes (regarding time it took to carry out the tasks, the quality delivered and the costs). This information is used in the debriefing phase in order to nurture the reflection on why different events happened or why the goal was achieved/not achieved. This has had a very positive impact of the overall learning outcome, since it helps the students to improve the understanding of the complex relations. A second measure that was introduced was the three indicators related to each process step. This motivates the students to perform as best they can, and also give immediate feedback on how they perform. Debriefing is a central part of the two stage game, and time is set aside for the players to analyse the communication and collaboration problems identified during the game in this phase. The trend in these discussions supports the impression of the facilitator, that the communication level has an important impact both on the KPIs as well as on the risks that need to be dealt with.

7.1.2 Evaluation of the learning outcome of the course based on the reports and the presentations

As part of the game each participant needs to prepare his tasks as a presentation, which is presented after the game. The intention is that he will then gain more knowledge and be more aware of what and why he acts as he acts during the game, because he knows that he must explain this later. Since the output is a presentation of the identified risks and how to treat them, it does not have objective criteria, which can be compared every time the game is played, but it shows if the participant understood the task and if he was able to identify risks. Since the presentation is explained to the other participants, they are also telling their impressions. The presentation sometimes shows some misunderstandings of how to apply the methods, but they have the possibility to discuss that in the group and to improve the tasks in the written report. The students report that they find the presentation and explanation of the other participants, as well as the additional written reports, helps them to deepen their understanding of risks and also of the application of useful methods.

7.2 Evaluation of the Beware Curriculum

The aim of the course and the game that has been designed is to support the competences and skill development among engineering students in the field of working in complex, dynamic systems. It specifically intends to convey skills related to management and identification of risks in dynamic systems, like in Supply Networks, as well as increase the ability of the student to be aware and understand how different factors contribute or reduce the resilience. Thus, it is aiming at improving the understanding on how risks occurs, to analyse and evaluate the context before making decision on how to reduce threats or take opportunities, both arising out of the same risks. Thus, the game and the course is based on a managerial, symmetric risk definition. The formative evaluation of the curriculum has led to structural changes over time, so that the results have been improving.

7.2.1 Support for Bloom's cognitive learning goals

As described in section 6.2.1.1 it essential that the learning outcome can be evaluated and there are methods for doing so, as described in section 6.1. However, this has to be seen in context of the learning objectives. The developed game based course is aiming at supporting the students in applying procedural knowledge and, at the same time to construct new knowledge based on what they experience and observe and based on that abstract and apply in a new context, taking any changes into account. Thus, it is to a large extent not the matter of just solving a problem, but to foster the ability of strategic thinking.

In the first design phase of Beware, Blooms taxonomy was hardly considered, but in the later changes it has been considered, both in the changes done in the curriculum as well as in the changes for the game. However, the game is designed mainly aiming at supporting the higher levels. Consequently, only the higher levels are supported. This is typical for management games [Kerres et al. 2009]; it emphasizes on the two highest levels of evaluating and creating.

Table 19: Bloom's cognitive learning goals covered by Beware

Learning goal	Modality/mechanics
Remembering	The first version *Beware* did not support remembering, but based on the feedback from the students, all information needed accessible during gameplay and also it provides some key points so that the students better remember what talked about in the debriefing and in the introduction part.
Understanding	Understanding is supported by Beware in the newer versions. The system delivers the information needed. The tasks carried out help in understanding how the same risk influence the collaboration, the resilience of the system and thereby also the output depending on the context in which they make their decision. It supports the player to understand the decision-making process and to help to develop strategies for how to deal with risks, both for understanding how they arise and also for understanding how to best in the given context, manage the risks. The understanding arises partly within the game environment, but it is additional supported in the debriefing sessions, which is outside the game. Thus, in order to support the understanding, it is important that the students play both levels, so that they can reflect upon the experience in the first game, take the outcome of the debriefing into account and then try out once more. Far more important is the role of the facilitation process in the debriefing phases. This phase is outside the game, but essential for the success of the game play and for reaching the learning goals.
Applying	Beware is designed to support the users in applying different risk assessment and management methods in context based situations. It also allows the students to apply the strategies they develop for dealing with the risks and the collaboration.
Analysing	With the information delivered within the game, the players are able to analyse and compare how different factors identified during game play influence both on the collaboration and results. Furthermore the player is able to analyse the context/environment, and thus being able to make context-specific decisions.
Evaluating	The game supports the students in evaluating the influence different factors have on the risk as well as on the resilience by delivering the relevant information. Furthermore, the game also delivers enough information to evaluate the learning outcome. However, this is additionally deepened within the debriefing session.
Creating	The game supports creation of new content, because it helps the player to identify specific structures and pattern. It encourages the players to combine different information and to construct new knowledge based on these experiences. However, creating of new knowledge is more supported in the debriefing session, than in the game itself.

7.2.2 Support for Kolb's learning cycle

The use of Beware uses an extension of Kolb's learning cycle: it uses the BIG (beyond the information given) defined by Perkin's [1991, p. 20] BIG constructivism.

Following the BIG approach, a facilitator directly introduces the concepts, provides examples to the students with concrete experience in activities that challenge them to apply, generalise and refine their initial understanding in multiple activities. This approach presents information to the learners but stresses the need to go beyond the information given.

Table 20: Support of Kolb's learning cycle due to the BIG approach

Learning stage	Modality/mechanics
Concrete experience (feeling)	The concept for Beware foresees the use of BIG constructivism, so the students receive a starting scenario and a role for which they must choose a strategy to follow and to apply the suitable methods for dealing with the risks throughout the game play. For every time the students decide to either solve a problem or act in a specific way, they will again make their feeling-based decision based, but as the game proceeds, these are more and more related to what has happened in the game in the past. However, a challenge for working in dynamic systems is to deal with unexpected event. Thus, the student will regularly experience something unexpected. As the time pass, it is intended that the student will make his choices based on understanding, analysing and evaluating the situation, and not only on his intuition.
Reflective observation (watching)	As the game play succeed, the student can observe both how their own processes evolves depending on his/her own choices and how they handled risks and unexpected events, but also how this affect the collaboration with the other players. Based upon this information as well as the indicators delivered by the game; he can observe how close the overall target of the collaboration is being met and the game performance is.
Abstract conceptualization (thinking)	In Beware this is supported in two ways- during game play, the student can draw his conclusion based on how his indicators (quality, cost and time) emerge. The players are encouraged to use the left hand elicitation method during the game for this process in combination with the introduced methods for strategic decision-making; however, this is a challenge for several students, so that they often do only apply the methods. This process is strongly supported in the common debriefing session and by the facilitation of the game.
Active experimentation (doing)	Based upon the outcome of the previous phase, the player changes the scenario according to the analysis and observation carried out so far.

7.2.3 Implemented changes

Based on the formative evaluation of the course, several changes have been introduced. The ones affecting the game design and its functionalities are described in more detail chapter 4, but outlined for the overall evaluation again here. For the structure of the course, the following changes have been implemented and lead to improvements:

- The course used to be given at two following days, as full day courses. This was exhausting for the students, and they reported that they did not have time enough to reflect and internalise the methods they should use. Since they had introduction, game play and debriefing on one and the same day. The first action was to have more time between the two days. That helped, but not enough so that it is now divided in four half-day parts, with one week in between. The first day is for introduction and hands-on. The second and third days is for playing level one, two and debriefings. The fourth day is used for presentations of the tasks of the game, group discussions and reflection. So far the results and the feedback from the students are positive.

- The second major change regarding the structure was to increase the time for introducing relevant methods and processes for risk assessment and risk management and also for explaining how risks can occur and behave and how this affects the resilience. This is actually a normal lecture, and teacher centric. The effect has been that the students have a better level of knowledge on this topic before playing the game, and thus can concentrate more on the actually task in the game- i.e. to identify, asses and manage risks in enterprise network and to apply different methods, observing how it impacts the resilience.

- As described previously in chapter 4, based on the evaluation the game has got a facilitator tool, the functions events and quality enhance measure have been implemented, the roles, the tasks and the processes have been redesigned.

7.3 Changes in the software based on evaluation

The first usability studies showed that the students had difficulties in finding the right information and used too much time on getting along with the GUI. In addition, information on their tasks and their role was still paper-based, which distracted the players while playing. In a first step, a hands on, instead of a manual was introduced. This helped the student to concentrate on the game play instead of the interface. Still it is room for improvement, but a new GUI is under development. This is based on the analysis of using be.mog for different gaming scenarios.

The second large change done, based on the evaluation of the usability of the game was that the information lacking is included so that the students find everything in the game. In addition, the introduction of the facilitator tool ensures that the students can get help as soon as they need. Furthermore, the implementation of the events helps to simulate a real working situation. It helps the facilitator to adapt the learning content to the individual level of the players (i.e. if a student has a lot of experience in working in networks or specialised in project management, he can get different tasks than a different player having less experience and knowledge). The possibility of having a sort of personal adaption helps to keep all students engaged and to reduce the risk of feeling overwhelmed or bored.

The third main change that arise from the usability studies were the inclusion of the indicators as a feedback tool for the students to see how they performed during gameplay. It also improved the possibilities of analysing the relevance of communication to the results for the facilitator and is a useful help for the debriefing section. However, the used requires much experience.

7.4 Evaluation of the use of evaluation methods

Tracking the communication as well as all the actions taken by the participants is very helpful, but requires a lot of experience of the facilitator. This information is also supporting the debriefing sessions.

Using pre, mid and post questionnaires as well as collecting communication data and using in-built performance measures is time consuming. The experiments shows, that the students are motivated and reach the learning goals. However, the evaluation process is complex (especially the part based on interaction and communication), gives good results, but is time consuming and does not support immediate feedback.

Validation of the learning goals-The results show that for students without any, or with a little knowledge of risk management, it is important to make their task more visible in the first game level. Furthermore, it was seen that the process of playing one game, debriefing it, and then playing another game level as expected helped to increase the performance in the second gameplay, most likely due to the transfer of knowledge. The participants identified the risks, as well as developed strategies for reducing the collaboration risks to a much higher degree. The continuous evaluation of the learning effect demonstrates that the time required to transfer information into knowledge does not only depends on the essential debriefing phase, but also relies on the experience that the participant already has. This needs to be taken into consideration at an early stage of the experimental set up, so that the students can be supplied with the necessary information on methods and approaches in advance.

8 Summary and Outlook

8.1 Summary

Contemporary Supply Chains are becoming longer, leaner and more brittle, involving more cooperation and collaboration and thus transforming into global Supply Networks. The goal of the Supply Network is to deliver the right numbers of goods at the right time and quality to the customer. The complex interrelations in supply networks also increasing the number of risks occurring, which might lead not only to higher costs, but also to reducing the quality of on-time deliveries, or in the worst case, no delivery at all. Risk is driven by trends like the rapid growth in global sourcing and offshore manufacturing, due to costs and efficiency focus. Supply Network risk is therefore an evolving issue. One reason for companies entering collaboration is therefore to share not only rewards, but also risks, reducing the risk of failure. The objective is to secure a higher performance and reduce the risk compared to what it would be by operating individually. Companies are aiming at being able to operate in a dynamic environment in such a way that they can use the opportunities and reduce the threats. Hence, during the last decade the concept of resilient Supply Chains has increased in importance.

This thesis is analysing aspects of resilience related to the requirements an organisation will have on an employee regarding competences within this field. In order to contribute to this area, three research questions were defined:

- Q1: Which competences does an employee need in order to contribute to the resilience of the Supply Network he/she is working in?

In order to answer this question, a detailed study of risks in enterprise networks, a literature review and then verification through a survey and interviews were carried out. Based on this analysis, the risks related to collaboration, communication, decision-making, and information sharing across the Supply Network were identified as specifically relevant for enterprise network resilience, and in addition also the inability of the Supply Network to cope with unexpected events. The relevance of these risks was confirmed by a survey among industrialists and lecturers and with interviews with industry project managers. Based upon these findings, the competences required of employees were derived. The main competences: communication and collaboration, problems solving and decision making, as well as the ability to cope with changes were identified. In detail, a future employee needs to know methods on risk assessment and management, how risks occur and behave in an enterprise network. Furthermore, the employee needs to understand the dynamics and be able to make decisions based on incomplete information and to cope with the fact that the impact of a risk varies with time and place. Furthermore, he must be able to develop strategies, both for maximising opportunities and minimising any possible threats. Therefore, the next research question was:

- Q2: How can these competences be developed during engineering education in such a way that future employees can act as needed when a new situation arises?

Competences like communication and collaboration, as well as problem-solving skills, have already been stated as necessary in engineering education, and there are results that GBL can contribute to overcoming the separation of theory and practice. Thus, after analysing different learning paradigms, and an examination of previous experiences with GBL for the mediation of complex competences, a course based on the principles of experiential learning, using cognitivist and constructivist learning methods has been identified as a suitable approach. A course was therefore developed to provide a learning environment in which the required knowledge, skills and abilities could be conveyed in different ways. The course follows a typical approach based on Kolb's learning cycle. Thus, the last research question to be answered was:

- Q3: How to design a game-based course allowing the student to actively apply methods and experience how different vulnerability and capability factors impact differently on a Supply Network in different contexts.

The game "Beware" has been developed for use in a blended learning environment. The objectives of the Beware game were defined in order to be in line with the derived learning objectives to increase the understanding and awareness of risks in Supply Networks. Two further objectives were to improve the players' skills in risk management in a Supply Network and to apply common risk management methods to gain some experience in a risk free environment. The focus of the game design was to have as much as possible implicit learning, according to the recommended approach in GBL.

The different elements had to be evaluated, in order to prove if the game and the course would produce the expected learning outcome, and that the research questions could be positively answered. Thus, the following objects were evaluated in every course with the following methods, see Table 21 below.

An agile development approach was used, i.e. each course evaluation contributed to a formative evaluation of the curriculum, the course content and the game.

Table 21: Evaluation objects and respective evaluation methods

Evaluation object:	**Game**	**Course**	**Game quality in use**	**Curriculum**
Evaluation objectives	Learning outcome within the game	Learning	Quality-in-use	Structure
Methods	Quantitative: Measuring performance indicators, the communication and collaboration level Comparison mid- and post-test on knowledge Self-evaluation using post questionnaire Qualitative: Observation during game play Feedback during debriefing and in report	Quantitative: Comparison of pre- and post-test on knowledge improvements Self-evaluation using post-questionnaire Qualitative: Oral feedback, presentations, written feedback in report form, facilitators' observation in debriefing phase Lab reports	Quantitative: Measuring performance indicators Usability questionnaire Qualitative: Open questionnaire Oral and written feedback Observation	Comparison of learning evaluation results with Bloom's revised taxonomy and Kolb's learning cycle

In the developed game two forms of evaluation were used every year. The first was formative - the facilitator monitors the gaming process, collects information on how the different players are playing and on the communication and collaboration between them. A set of indicators (communication thread, costs, time, quality per process and overall) is continuously collected by the game. The players to evaluate how they played during the game can also use these indicators. This information is used in the debriefing stage in order to analyse and evaluate what happened in the game and thus to help the students construct new knowledge on RM.

The second part of the evaluation is the use of pre-game, mid-term and post-game questionnaires, completed by the players to find out to what extent the players have gained knowledge from playing the game. It is only on declarative and procedural knowledge, so it does not deliver enough information concerning if the player has improved his/her skills on resilience. Over the years of running the course with the game, the outcome of these evaluations was used for improving the game.

In the first years, the game and the course setting did not produce satisfactory results, even though they were promising. Thus, the game has been continuously improved, new functionalities have been added, and the course has been restructured. The participants mentioned two main challenges (provoked by the game). Firstly, they lost the overview and did not manage to deal with the user interface and what was happening. Secondly, they found it difficult to identify hidden risks. Additionally, the distribution of information in the first version was not so good. Much information was assigned to roles that normally do not have such information. Thus the students never found it, and this had a negative impact on the motivation and results. This led to an improvement of in-game information, better structuring of the GUI. It also lead to consider the development of the monitoring tool for facilitators. It was also observed that the students did not often deal with unexpected events. This is a major issue for management of risks in Supply Networks. Consequently, this new functionality was developed. It also requires that the facilitator can monitor, and thus analyse the play in a better way. The facilitator's monitoring tool delivers information on game play and helps the facilitator in giving advice and moderating the debriefing session in a better way.

The facilitator's tool offers a possibility to track the communication flow against the performance in the game. The performance of each game is very dependent on the players. The learning outcome improved after introducing the facilitator's tool. This was expected, since it improved the teachers' possibility for stealth assessment and her/ his possibility to give feedback and identify learning problems among the players. Some other reasons are that the monitoring tool helps the facilitator adapt the game, play more to the competence level of the players by observing problems, setting events according to the game play and trigger the communication, as well as the awareness of the players. The fact that their communication is monitored leads to a higher communication level. Also the linkage of KPIs and generated events helps the students obtain immediate feedback, and thus better understand what is happening in the game. Regarding the functionality of resetting processes, triggered by events, it is reported and seen in the observation that this is important for the learning outcome. However, the reason for resetting must be understandable for the players, so that they can appreciate why they need to improve, or rework, and this has an impact on their performance; they find it challenging and motivating. If not, they get quite quickly demotivated.

The introduction of the new game functionalities "events" and "quality enhancing measures" (QEM) improved the students' perception of the realistic Supply Chain scenario. In, addition, both functionalities were reported to be motivating. Firstly, because the events were unpredictable but related to the task. Secondly, the students reported that the QEMs were motivating because they were usable in order to improve the quality, and thereby achieve the goal. Never the less they produced costs, and the students had to pay attention to their impact. The improvements introduced by the two new functionalities are both observed by the teacher as well as reported in the lab reports. A restructure of roles and processes as well as new role description were done in order to solve the information problem. This helped the students in finding the right information.

It was found that the learning outcome depends on whether they find the game fascinating/challenging and whether they have the expected level of knowledge of the topics mediated by the game. Therefore, the success of a game is based upon its adaptability and usability to other environments, so that the game always fits the requirements (level of knowledge and skills, but also working context) of the target group. The evaluation results clearly showed that especially for students without, or with little, knowledge of a specific topic, it is important to make their task more visible in the first game level. Thus, an introduction time explaining methods, theory of enterprise networks risks, game play, tasks and objectives, before game play, the time between game plays, as well as the debriefing time were increased. Consequently, students have more time to reflect and think and this improved the results.

Comparing the findings from the analysis of the cognitive level of learning outcome with the learning levels of Bloom's revised taxonomy that was intended to let the learning take place, confirmed that an adaption was necessary. These adjustments have contributed to better learning outcomes, according to the evaluation of the questionnaires as well as according to the student's perception of competence improvements.

The process of playing one game, debriefing it, and then playing a different game level helped to increase the performance on the second game, because of the transfer of knowledge from one game to another through debriefing. In the second game the participants identified the risks, as well as developed strategies for reducing the collaboration risks to a much higher degree, than with the short time between gameplay.

Important for further use of the concept in different settings, or with different games are the following:

1. The continuous evaluation of the learning effect demonstrates that the time required to transfer information into knowledge not only depends on the essential debriefing phase, but also relies on the experience of working in collaboration, as well as knowledge that the participant already has. These factors need to be taken into consideration at an early stage of game development.
2. The use of stealth assessment helps the teacher in supporting the learning in the debriefing phase and to adapt the content to the different competence level of the students. Secondly, the students benefit from the immediate feedback, and it helps them in training decision making with uncertain information.

3. Regarding the usefulness of the game/course for increasing competences that help to manage risks, based on the formative evaluation, it can be extracted that it is necessary to set enough events within a dynamic, but not too complex environment The combination of instruction, game-play, debriefing and presentation seems to give good learning outcomes, both based on the evaluation of the questionnaires as well as based on the students self-report. The presentations show that they are able, in the current setting, to apply methods in a suitable way and to understand the impact of their decisions.

8.2 Conclusion

The research reported in this thesis sought to develop a curriculum and serious game for Masters level engineering students. The process to derive the educational needs and the required competences to mediate was described. This included literature reviews and surveys of industrial experts and lecturers/professors. Appropriate pedagogical approaches based on experiential learning methods were examined, and game-based learning was identified as the most suitable approach. A game, Beware, was designed and implemented as a computer-based serious game. A systematic evaluation process was carried out, over the years of the delivery of the course, which resulted in improvements to the game, its interface and features. Also, the curriculum and workshop setting were adapted to improve the learning outcome. This iterative and long-term approach to serious game development provides information on continuous improvements and can be used for improving the development process (reducing time-to-market) in future developments. The course concept has been applied to two other courses at the University of Bremen and the Jacobs University with different games with good learning outcomes. Secondly, the game with its new functionalities (i.e. the game engine be.mog) has been used for a game supporting creativity with good feedback.

In order to increase the usability of the game, the next steps would be to increase the flexibility regarding scenario generation and scaffolding, i.e. to make it more adaptable to the learners' competence level and to the environment, they will learn in. Furthermore, work has been started in developing more KPIs and to implement more learning analytics in order to provide learners and teachers with precise information and immediate feedback. The course and the game show that it is possible to use games and blended learning concepts for increasing the awareness of risks in Supply Network and to increase the competence among students to manage these.

Based upon the evaluation outcome, it can be verified that the use of a game-based learning course for mediating the management of risks and risk behaviour in Supply Networks, is possible. It requires a realistic game environment and should be, according to Kolb's learning cycle, be carried out in a workshop setting with debriefing sessions.

Even though the game has proven to be useful to teach SCRM, the development process confirmed two major issues that should be investigated further- first of all the matching of learning mechanics and game mechanics is based on experience and trials. This is time consuming and leads to low learning outcome for the first classes. A better understanding of this relation for supply networks would improve the gereal development process of such games, and thus improve the quality, reduce the cost of development, increase the re-usability and ease the adoption of other scenarios. The second field where more research is needed is related to learning analytics. There has been a tremendous progress in this area during the past few years, and frameworks have been developed and also successfully implemented. However, there is still a challenge to exactly know what to trace and track for such complex fields as decision-making and risk management in Supply Network. Thus more research needs to be carried out in order to improve the real time feedback to the student and the teacher as well as in order to be able to personalise the game environment to the individual needs of the students.

9 Relevant student work

The following students have contributed to the PhD in form of Master thesis and Bachelor thesis, Diplom- and Studienarbeiten.

"In der vorliegenden Arbeit sind Ergebnisse enthalten, die im Rahmen der Betreuung folgender studentischer Arbeiten entstanden sind:"

1. Kerstin Lampe: Risiko Management in Supply Chains- eine Handlungsempfehlung zur Gestaltung flexible Supply Chains, Studienarbeit, Universität Bremen, April, 2009

2. Kerstin Lampe: Verbesserung der Rückverfolgbarkeit in Supply Chains durch den Einsatz moderner Informations- und Kommunikationstechnologien bei Spediteuren, Diplomarbeit Universität Bremen, 2010

3. Anton Feuerhake: Evaluierung verschiedener Identifizierungs- und Bewertungsmethoden für Risiken in Unternehmensnetzwerken, Studienarbeit Universität Bremen, 2006

4. Anton Feuerhake: Entwicklung eines ganzheitlichen Vorgehensmodells zur nachhaltigen Verbesserungen der Kooperation in Unternehmensnetzwerke am Beispiel eines Großunternehmens, Diplomarbeit Universität Bremen, 2007

5. Henning Hesse, Vermittlungsstrategien für Methoden zur Identifikation und Analyse von Risiken in Virtuellen Unternehmen, 2007

6. Thorsten Hohenkamp: Erweiterung von Produktionssystemen in Supply Chains- Risiken und Chancen aus Sicht von Klein und mittelständischen Unternehmen und Großproduzenten, Studienarbeit, Universität Bremen, 2011

7. Ulrike Kübsch- Qualifizierung von Mitarbeitern - Methodenschulungen des Qualitäts- und Risikomanagements; Studienarbeit, Universität Bremen, 2010

8. Florian Haase Bachelorarbeit: be.mog 2.0 BIBA engine for Multiplayer Online Games, 2013, Hochschule Emden-Leer

9. Didac Goncales Sanchez The use of Serious Games to reduce problems and risks in the Supply Chain, Master Thesis, University of Valencia and Universität Bremen, 2009

10. Daniela Fricke: Die Bedeutung unternehmensinterner und –externer Kooperationsbeziehungen bei der Durchführung des CE-Konformitätsbewertungsverfahrens bei kooperativ hergestellten Produkten, Diplomarbeit, Universität Bremen, 2011

11. Daniela Fricke, Entwicklung eines Fragebogens für Unternehmen zur Überprüfung der CE-Konformität von Zulieferprodukten hinsichtlich der Anforderungen der Maschinenrichtlinien 98/37/EG und 06/42/EG, Studienarbeit, 2010

12. Silvia Schmidt: Risikomanagement im Produktlebenszyklus, Studienarbeit Universität Bremen, 2011

13. Matthias Hagen- Intelligent Cargo in Supply Chains – Konzeption eines Planspiels, Masterarbeit, Fachhochschule Münster, 2011

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11 Annex A List of analysed games

This list gives an overview of games that has been analysed for finding relevant games that might be usful for the addressed topics. The analysis was carried out twice, first before the course and game development started, and then a second time before large changes were introduced to the game and the curriculum in order to improve the learning outcome

Table 22: List of analysed games

2008	Bezeichnung	Thema/Inhalt/Modellbereich
	ALYSSA Planspiel Handel	Globale wirtschaftliche Zusammenhänge
	ALYSSAmicro Planspiel Handel	Globale wirtschaftliche Zusammenhänge
	APOSIM	Controlling für Apotheken
	Auftragsabwicklung	Produktionsstrukturen und Logistiksysteme
	Balanced Scorecard	Zielsysteme
Akt.	Bankenplanspiel MICROBANK 2008	Bankmanagement
Akt.	Bankenplanspiel SIMUBANK 2008	Bankmanagement
	Banking - das strategische Bankenplanspiel	Bankcontrolling
	Banking Game	Bankwirtschaft
	BAPPF	Betriebswirtschaftliche Grundlagen
	BERYLLA Planspiel Dienstleistung	Führung eines Dienstleistungsunternehmens
	BERYLLAmicro Planspiel Dienstleistung	Führung eines Handelsunternehms
	Betriebswirtschaft für Ingenieure in der Energietechnik	Betriebswirtschaft
	BO-Cash	Betriebswirtschaftliche Grundlagen
	Börsenplanspiel BOERSIMO	Handel mit Aktien
	BOSS	Bankbetriebswirtschaftslehre
	Brainjogger-Planspiel: Bankfilialmanagement ifc	
	Brainjogger-Planspiel: Kundenmanagement (CRM) ifc	Customer Relationship Management
	Brainjogger-Planspiel: Maschinenbau ifc	
	Brainjogger-Planspiel: Qualitätsmanagement ifc	
	Brainjogger-Planspiel: Schulmanagement ifc	
	Bruno0s Bretzeln	
	Business Game	Entscheidungsfindung
	Business.Plus	Allgemeine Betriebswirtschaftslehre
	BusPlus	Betriebswirtschaft eines Verkehrsbetriebes

Neu	Committees der Vereinten Nationen	
	COMPEX	Wettbewerbssimulation
	ComputergestütOLIGOPLAN - ein Unternehmens-planspiel für Wirtschaftsschulen	Betriebswirtschaftsgrundlagen
	CORPSIM - Der Firmensimulator	Allgemeine Unternehmenssimulation
	DentSim	Betriebswirtschaft für Techniker
	Der Emissionshandel für Treibhausgase in der Simulation (SET-UP)	
	Die Werkzeugbox 2002 (Euro)	Allgemeine Betriebswirtschaft
	Do it!	Existenzgründung
	ECOREL	Gesamtwirtschaftliche Zusammenhänge
	ETrain-M Entscheidungstraining Management	Entscheidungstraining
	EUROGAME - L	Sprachentraining für Betriebswirte
	EuroPLAN	Gesamtwirtschaftliche Zusammenhänge in der EU
	Existenzgründung im Umweltbereich	
Neu	Existenzgründungsplanspiel	Existenzgründung
	Existenzgründungsplanspiel GRÜNDER II	Existenzgründung im Handel
	Getränkemarkt 2002 (Euro)	Grundfragen der Betriebswirtschaft
	Gründer II	Existenzgründung
	HAMASI: Filial-Simulation	Versicherungsfilialen
	Handelsplanspiel HS 1	Entscheidungen in Handelsbetrieben
Akt.	HandSim 2 Unternehmenssimulation Handwerk	Handwerkstypische Entscheidungen
	HeiCON Ganzheitliches Controlling	Ganzheitliches Controlling
	iDECOR	Betriebswirtschaftliche Entscheidungen
	IMAC-Managementplanspiel: Archive (Sem.)	
	IMAC-Managementplanspiel: Bibliothek (Sem.)	
	IMAC-Managementplanspiel: Buchhandel (Sem.)	
	IMAC-Managementplanspiel: eCommerce (Seminar)	Entscheidungsstrategien
	IMAC-Managementplanspiel: IuD-Services (Sem.)	
	IMAC-Managementplanspiel: Museen (Sem.)	
	IMAC-Managementplanspiel: Verlag (Sem.)	Betriebswirtschaft in Verlagen
	Insurance Management Training	
	InterLAB - Die einzigartige Kommunikationsplattform	
	INTOP	Internationaler Wettbewerb
	INTOP 2000	Internationale Geschäftstätigkeit
	Investor	
	Investor Banken	Bankbetriebswirtschaftslehre
	Investor Industrie	Industrie-Betriebswirtschaftslehre

	KRASIM (Krankenkassensimulation)	
	Leadership and Performance	Unternehmerisches Denken
Neu	LeanSys - Schlanke Fertigung, KVP und Führung	
	LEARN! Planspiel	Betriebswirtschaftliche Simulation
	LearnSim	
	Logistics Parcel Service	Paketlogistik
	LUNARIS - Computersimuliertes Szenario	Komplexitätsmanagement in Teams
	MACRO	Wirtschaftspolitik
	Manage!	Hotelsimulation
	Management-Planspiel MarGiT	Betriebswirtschaftsgrundlagen
	MARGA Industry	Betriebswirtschaftsgrundlagen
	MARGA Service	Dienstleistungswettbewerb
	Marketing Game	Deckungsbeitragsrechnung im Marketing
	Marmelade - Planspiel zur Messebeteiligung	Messebeteiligung
	MasterGame	Unternehmensführung allgemein
Neu	Mein Unternehmen (Seminare)	Unternehmerisches Handeln
	MICROBANKplus	Bankbetriebswirtschaftslehre
	Monte Carlo Simulation	
	MS Antwerpen - Verhalten in kritischen Situationen	
	NOWA - Einzelhandelsplanspiel	
	OEKO2 - Öko²	Ökologisch-ökonomisches Gesamtsystem
	OEKOWI	Wirtschaftlich-ökologische Zusammenhänge
	OMNILOG	Betriebswirtschaftliche Grundlagen
	OPTIKSIM	Betriebswirtschaft für Augenoptiker
	ORGAREF Verwaltungsreform	Neues Steuerungsmodell
	P&C Insurance Simulation Game	
	PAV - Planspiel Arbeitsvorbereitung	
	Planspiel "EUROPA 2005" - Eine EU-Simulation	Europapolitik, -forschung
	Planspiel Buchhandel	
	Planspiel Glasmarkt	Marktwirtschaftliche Grundfunktionen
	Planspiel INTERACT	
	Planspiel Kostenmanagement	
	Planspiel PROST - Simulation der Produktionssteuerung	Produktionslogistik
	Planspiel und Workshop für schwierige Genehmigungen	
	Planspiel: WETTBEWERB-Unternehmensspiel	Allgemeine Betriebswirtschaftslehre
	PLUS - Planspiel urbaner verkehrlicher Systeme	Verkehrsplanung
	PriManager - Primaner managen eine AG	Existenzgründung

	Progame	Aktives Prozessverständnis
	Projektmanagement-Simulation SimulTrain	Projektmanagement
	Public Management Game	Führung einer Verwaltungsorganisation
	QPR Business Game	Strategisches Denken
	RailPlus	Verkehrsbetrieb
	riva - Versicherungsplanspiel	
Neu	Roma Termini	Entscheiden in kritischen Situationen
	rubicon!	Steuerung eines diversifizierten Konzerns
Neu	SaGuSped - Sammelgutspedition	
	Sima & Co. (Seminar)	Betriebswirtschaftliche Grundlagen
	SIM-Absatz	
	SIMBA	Betriebliche Abläufe
	SimBA Consulting	Unternehmensführung
	SimBA Insurance	Betriebswirtschaft für Versicherungen
	SIMBA mit MISS SIMBA	kaufmännische Aufgaben
Neu	SIMON Zukunftsnavigator für Apotheken	Performance-Improvement
Neu	SIMON Zukunftsnavigator für die Pharmaindustrie	Performance-Improvement
Neu	Simulationsspiel Lieferkette/Supply ChainM	
Neu	SimulTrain	Projektmanagement
	SimulTrain (1. Eintrag)	Projektmanagement
	SimulTrain (2. Eintrag)	Projektmanagement
	SimulTrain (4. Eintrag)	Projektmanagement
	Speditionsmanagement	Logistikservice-Netzwerk
	Strategisches Planspiel STRAGA	Strategisches Managment
	SunFun 2002 (Euro)	Grundlagen der Betriebswirtschaft
	TangoNet	Management von Beziehungen
	TAU (Technik, Arbeit, Umwelt)	gesellschaftliche Problemfelder
	Teswin Products	Betriebswirtschaftsgrundlagen
	The Complete Project Manager	Projektmanagement
	TOPIC 2000	Betriebswirtschaftsgrundlagen
Akt.	TOPSIM - Banking	Bankenwirtschaft
Akt.	TOPSIM - Basics	Allgemeine Unternehmensführung
Akt.	TOPSIM - Business Development	Unternehmens-/Geschäftsfeldentwicklung
Akt.	TOPSIM - Car	Automobilhaus
Neu	TOPSIM - Change Management	Veränderungsprozesse
Neu	TOPSIM - Destinations Management	Tourismus
Neu	TOPSIM - easyManagement	Betriebswirtschaftliches Grundwissen
Akt.	TOPSIM - easyStartUp!	Unternehmensgründung
Akt.	TOPSIM - eCommerce	E-Business / E-Commerce
Akt.	TOPSIM - Euro	Strategische Unternehmensführung

Akt.	TOPSIM - Facility Management	Gebäudemanagement
	TOPSIM - General Management I	Allgemeine Unternehmensführung
Akt.	TOPSIM - General Management II	Allgemeine Unternehmensführung
Neu	TOPSIM - Global Management	Produktentwicklung / Technologiemanagement
Akt.	TOPSIM - Insurance	Versicherungswesen
Akt.	TOPSIM - Logistics	Logistik / Supply-Chain-Management
Akt.	TOPSIM - Macro Economics	Volkswirtschaft
Akt.	TOPSIM - Manager	Allgemeine Unternehmensführung
Akt.	TOPSIM - Marketing	Marketing
Akt.	TOPSIM - Merchant II	Handel
Akt.	TOPSIM - Portfolio Management	Vermögensverwaltung
Akt.	TOPSIM - Project Management	Projektmanagement
Akt.	TOPSIM - Startup	Existenzgründung, Entreprenuer-, Intrapreneurship
	UGS GAME: Das innovative Gründungsplanspiel	Existenzgründung
	UNI-Bank	Bankbetriebswirtschaftslehre
	Unternehmensplanspiel Euro Manager	Unternehmensführung
	Unternehmensplanspiel Global Manager	Globalisierung
	Unternehmensplanspiel LUDUS	Industrie-Betriebslehre
	Unternehmensplanspiele Delta	
	USUM III	Allgemeine Betriebswirtschaftslehre
Neu	VerSimBi - Ein Unternehmensplanspiel für Auszubildende	
	ViStra - Visionen u. Strategien	liberalisierter Strommarkt
	Wettbewerbsplanspiel 0Stratego0	Führung einer Einzelhandels-Filiale
	WiN-Absatz	Betriebswirtschaft
	WiN-Kiosk	
	Winning Major Sales	Key Account Management
	Wissensmanagement-Planspiel	Wissensmanagement
	WIWAG	Betriebswirtschaftliche Grundlagen
	WN-Simpolis	
	zbb-Sim Logistikplanspiel für den Lebensmittelhandel	Logistik

12 Annex B publications directly used in this thesis

Since most of the publications has the same main author, these are numbered, to get an easier overview for the reader of the used publications.

1. Azadegan A, Baalsrud Hauge J, Harteveld C, Bellotti F, Berta R, Bidarra R, Riedel J and Stanescu I (2013) The move beyond edutainment: Have we learned our lessons from the entertainment industry?, gala conference 2013

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