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Using the Experiential Learning Cycle to Design a Pure Virtual Serious Game for Developing Teamwork Skills

DIPLOMA THESIS

to achieve the university degree of

Magister der Naturwissenschaften

Teacher training programme: Computer Science and Computer Science Management

submitted to

Graz University of Technology

Supervisor

Assoc.Prof. Dipl.-Ing. Dr.techn. Christian Gütl

Institute of Interactive Systems and Data Science

Graz, October 2018

Dipl.-Ing. Matthias Thomas Maurer, BSc

Erfahrungsbasiertes Lernen als Grundlage für ein rein virtuelles Lernspieldesign im Kontext von Teamwork Training

DIPLOMARBEIT

zur Erlangung des akademischen Grades

Magister der Naturwissenschaften

Lehramtsstudium Unterrichtsfach Informatik und Informatikmanagement

eingereicht an der

Technischen Universität Graz

Betreuer

Assoc.Prof. Dipl.-Ing. Dr.techn. Christian Gütl

Institute of Interactive Systems and Data Science

Graz, Oktober 2018

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Abstract

Teamwork has an important influence on many areas of business, especially where lives depend upon it. The need for extensive, always accessible, and cheap teamwork training is growing steadily. E-learning approaches are able to fulfill this need, as they become more sophisticated in their functionality.

A very promising e-learning approach is depicted by serious games: games with an explicit and carefully thought-out purpose other than entertainment. Educational games - games with an educational main purpose - have already prooven their potential to motivate learners and enhance performance. They have been used for thousands of years, and have been boosted by the appearance of computer games. New concepts and ideas have emerged and continue to emerge in order to meet new needs arising in relation to educational games.

In this thesis, a purely virtual teamwork training game is designed based on scientifically well-founded teamwork- and learning-theory. Furthermore, a prototype of the elaborated serious game design is implemented and evaluated using a study including 18 participants.

It was found that the relationship between teamwork and the prototype was clearly perceived by participants. Furthermore, the usability of the prototype was rated as good. Finally, the prototype has the potential to be extended into a fully-fledged teamwork training game based on the feedback collected.

Kurzzusammenfassung

Teamwork ist ein entscheidender Einflussfaktor in verschiedensten Anwendungsgebieten, vor allem jedoch, wenn Leben davon abhängen. Der Bedarf an flächendeckenden, jederzeit zugreifbaren und kostengünstigem Teamwork Training steigt stetig. E-learning Ansätze sind eine passende Methode um diesen Bedarf zu stillen, die dazu noch zunehmend ausgereifter werden.

Ein vielversprechender E-learning Ansatz sind Serious Games, Spiele mit einem klar angegebenen und wohl überlegten Ziel, das nicht Unterhaltung sein darf. Lernspiele, Spiele mit dem Ziel der Wissensvermittlung, haben ihr Potential Lerner zu motivieren und deren Leistung zu steigern bereits unter Beweis gestellt. Sie werden schon seit tausenden von Jahren genutzt, letztlich wieder vermehrt durch das Erscheinen des Computers. Neue Konzepte und Ideen sind aufgetaucht und machen dies noch immer um die neuen Anforderungen, die an Lernspiele gestellt werden zu erfüllen.

In dieser Arbeit wird ein rein virtuelles Teamwork Trainingsspiel basierend auf wissenschaftlich fundierten Teamwork- und Lerntheorien designet. Darüber hinaus wird ein Prototyp des ausgearbeiteten Designs implementiert und evaluiert. Die entsprechende Studie umfasst 18 TeilnehmerInnen.

Es konnte gezeigt werden, dass es für die StudienteilnehmerInnen einen wahrgenommenen Zusammenhang zwischen Teamwork und dem Prototypen gibt. Darüber hinaus wurde die Benutzerfreundlichkeit des Prototypens mit gut bewertet. Abschließend wurde das Potential des Prototypens zum Ausbau eines voll entwickelten Teamwork Trainingsspiels durch das gesammelte Feedback bestätigt.

Acknowledgments

This thesis was partly supervised by Christopher Cheong and France Cheong of RMIT University, School of Business IT and Logistics, during my stay in Melbourne. During this time, the design and development of the serious game related to this thesis was completed.

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1. Introduction

This chapter explores the theoretical and practical aspects that inspired this thesis. It also outlines the thesis chapters and gives a short overview.

1.1. Motivation and Background

Teamwork is knowing to be an influencing factor in business, especially in areas where the consequences of rarely occurring errors are serious. For example, this is the case in healthcare, where errors might cost lives. But also in other environments, such as science, technology, and engineering, the companies success depends upon their employees having good teamwork capabilities.

With this in mind, it is no wonder that providing these teamwork skills is a high priority for companies from various application areas. In the past, such training was costly when considering the large number of employees a company had to cover and the related costs of trainers, accommodation, and traveling. Alternatives to this traditional training approach have been greatly appreciated as a result.

One of these alternatives is e-learning. This set of technologies is already integrated into various learning, teaching, and training programs. The biggest advantages of e-learning are probably the removal of the need for a trainer, the independence of location, and the independence of time when conducting the training. Also, some of the strongest constraints of e-learning have gradually been eliminated over recent years and continue to be eliminated.

One constraint, which is discussed frequently at the moment, is the inability of conventional e-learning approaches to retain learners. One known way to decrease these high drop-out rates is to incorporate game elements in the e-learning system through so-called gamification approaches. A similar approach, promising even more improvements, is depicted by game-based learning.

Combining games with the advantages of e-learning software in serious games is tempting. The fusion of the teaching potential of conventional e-learning software with the motivating nature of games might be the solution to reduce drop-out rates. A better learning outcome is another advantage often associated with serious games.

There is no clear definition of serious games and gamification, which makes the dividing line between these two concepts blurry. This makes it difficult to clearly differentiate between them. Generally speaking, a serious game requires a game

design strongly calibrated to its learning content. A generic game design approach for all content is impossible to find.

There is a wide variety of serious games focusing on the numerous content areas that have already been introduced. Among these are also games for training and games with a teamwork focus. A lot of them focus on health care related training. Others are related to teamwork skills, but only the minority of them are intended for training purposes. Most games in this area are intended for teamwork research.

The small number of teamwork training games existing lack a sound overall concept. They suffer either from a poor theoretical serious-game design or a required component in the physical world. A well-designed teamwork training game, which can be incorporated into a company's training routine and does not require any off-game support, is still needed.

For this thesis, such a teamwork training game has been designed. It is built upon the experiential learning cycle to train teamwork skills including the four teamwork dimensions: communication, adaptability, orientation, and monitoring. By using the motivational potential of cooperation and competition, a strategic game has been designed for undergraduate students.

By implementing a basic prototype featuring the outlined game design, a first evaluation of the concept is possible. It also serves as a showcase to visualize how the fully fledged game might look. The success of the evaluation strongly depends on how the teamwork-content is incorporated into the serious game and how good the balance between learning features and game features is.

1.2. Outline

This thesis covers two major parts. The theoretical background of serious games with a focus on teamwork training, including a new game design approach, is given in the first section. The second section includes the implementation and evaluation of the previously introduced game design approach and its impact.

Chapter 2, Background, gives an overview of the three major subject areas, which need to be considered in a serious game for teamwork training, namely e-learning, teamwork, and serious games.

Chapter 3, Related Work, takes a closer look at the area of serious gaming in the context of training. To gain an adequate understanding of the current literature, serious games for training, and serious games with a teamwork focus are discussed. The main interest is directed towards serious game design with emphasis on educational games and existing games for teamwork training.

The serious game design for this thesis' teamwork training game is discussed in **Chapter 4, Serious Game Design**. A software, hardware, and visually independent high-level game description of a serious game for teamwork training in needed. Also,

the very basic software architecture of the serious game designed for this study is described.

Moving now to the second part of this thesis, the focus is now on the serious game design that was created. In order to evaluate it, a prototype is needed. The results of this study, its consequences and the lessons learned while conducting the work are discussed in this part of the thesis.

Based on the serious game design, the implementation of a basic prototype is documented in **Chapter 5, Prototype Implementation**. It incorporates the most important teamwork training components, gives an idea of how the fully fledged game looks and allows a first evaluation of the game design.

In **Chapter 6, Prototype Evaluation**, a study consisting of a user experience section and an expert part is used to evaluate the prototype created. Therefore, evaluation research questions are constructed, an evaluation design for the evaluation questions is created, and the results are discussed with regards to the inferior research questions after the study is conducted.

Chapter 7, Lessons Learned, gives insights into the authors perception of the work conducted. This is done for the literature research, the implementation and game design, and the study that was conducted.

A summary and outlook concerning future work is given in **Chapter 8, Summary and Future Work**. The main components of the thesis are outlined and the findings are presented. Furthermore, future work is discussed, especially the requirements for making the prototype a fully-fledged teamwork training game in order to evaluate its usefulness.

2. Background

The aim of this chapter is to give an overview of the three major subject areas, which need to be considered in a serious game for teamwork training, namely e-learning, teamwork, and serious games. E-learning constitutes the overarching subject area defining the wider context in which serious games are embedded. Teamwork, as the content of the serious game, is an integral element of the game design and needs to be examined carefully. The underlying teamwork skills are, loosely speaking, the set of involved skills required for successful teamwork. Serious games are the core focus and build the base for further considerations. These three major subject areas are discussed below.

2.1. E-Learning

E-learning is an important training and learning innovation of recent decades, and has eliminated some of the strongest constraints in traditional learning methods (Horton, 2000; Welsh, Wanberg, Brown, & Simmering, 2003), but it still faces multiple challenges (Fichten et al., 2009). As such, e-learning technologies have been integrated into various learning, teaching, and training programs (Romero Tena, Cabero Almenara, & Barroso Osuna, 2016; Trelease, 2016). The perceived quality of a service is a key factor in the success of any technology, and indicates that this technology will play a major role in the future, although this stage has not yet been reached (Agrawal et al., 2017). Although user satisfaction needs to be improved, e-learning technologies are a useful tool for learning in diverse contexts, as studies show (Liaw, 2008; Brady, Holcomb, & Smith, 2010; Pratt-Chapman, Villalobos, Harvey, & Roccio, 2017). The following section takes, a closer look at the motivation, selected learning theories, and learning methods used in relation to e-learning.

2.1.1. Introducing E-Learning

This section starts with the motivation for e-learning and discusses its justification and benefits compared to traditional learning approaches. A logical first step towards this justification is the definition of e-learning, which is available in different forms in the literature. The discussion is started with the definition of e-learning as *"the use of the Internet to access learning materials; to interact with the content, instructor, and other learners; and to obtain support during the learning process, in order to acquire knowledge, to construct personal meaning, and to grow from the learning experience."* (Anderson, 2008)

This definition is somewhat narrow, requiring not only interaction with an instructor but also with other learners. Carliner (2004) defines e-learning as learning that happens when dealing with educational material presented with the help of a computer, which does not even require internet or support. In between these two definition, every definition is imaginable. In order to be as general as possible, the most general definition is used here, which defines e-learning according to Carliner as the learning resulting from the presentation of educational material using a computer.

Independent of the e-learning definition discussed, its greatest advantage is probably that learning does not depend on time or location. The learner is able to access the materials at any time and in any place, only requiring a computer and possibly internet access. This directly supports self-regulated learning in which learners control their learning environment (Schmitz & Wiese, 2006).

Besides control over the learning environment, the learning content can also be controlled much more easily compared to traditional learning methods. The so-called self-directed learning gives the learner control in predefined scope over the learning content (Knowles, 1975). The learner is not limited by the local offer of learning content and is theoretically able to choose from any learning content provided via e-learning technologies.

This first two advantages of e-learning exist naturally and increase convenience for the learners, but there are also other promises of e-learning which make it attractive for learning providers (Welsh et al., 2003). Big companies, for example, might be interested in consistent and worldwide training, which can be guaranteed by e-learning technologies within a short delivery cycle and low expenses. Additionally, the training sessions can be automatically tracked. Depending on the e-learning system used these promised advantages are not always achieved (Strother, 2002).

All these e-learning advantages seem overwhelming, but in order to be a valid substitute for traditional learning methods, its effectiveness needs to be shown. There are multiple studies from different fields showing the effectiveness of e-learning platforms (North, Strain, & Abbott, 2000; Brown, 2001; Bos-Bonnie, van Bergen, te Pas, Kijser, & van Dijk, 2017). Also, a direct comparison between traditional learning methods and e-learning speaks for e-learning, as multiple authors have found a slightly bigger learning gain when using e-learning technologies (Orey, Zhao, Fan, & Keenan, 1998; Machtmes & Asher, 2000; Noesgaard & Ørngreen, 2015; Lin, Doong, & Lin, 2017). However, there are also findings with inconclusive or mixed results (Whetzel, Felker, & Williams, 1996; Wisher & Curnow, 1999), indicating that e-learning environments need to be carefully designed; a pure deployment of learning content is not enough (Zhang, Zhou, Briggs, & Nunamaker, 2006).

To sum up, it should be mentioned that despite the advantages of e-learning over traditional learning approaches, drawbacks have also been noticed (Kruse, 2004). A lack of interaction or relation, a possible negative impact on socialization skills, and a loss of control regarding assessment can be found among these drawbacks (Arkorful & Abaidoo, 2015).

2.1.2. Learning Theory for E-Learning

A central consideration when dealing with e-learning environments are the underlying learning theories used in this field. As already pointed out, the learning content needs to be structured and presented to the learner in a suitable and meaningful way (including learning activities, learning tools, and assessment among others) in order to facilitate the learning process (Keller & Suzuki, 2004; R. C. Clark & Mayer, 2016). A learning theory enables us to do so by providing a theory on how learning happens. A closer look at frequently used learning theories in e-learning follows.

Three very basic and central learning theories are called behaviorism, cognitivism, and constructivism (Anderson, 2008). The behaviorism learning theory observes the mind's responses quantitatively, ignoring thought processes occurring in the mind. It, therefore, is based on observable behaviors as indicators of learning (Good & Brophy, 1990). The cognitivism learning theory, in contrast, sees learning as an internal process involving multiple types of memory in an information processing manner. Transferring the learning content into the long-term memory is the desired aim. In order to accomplish this, differences between learners in terms of learning styles are recognized. The constructivism learning theory focuses on the learner as an active knowledge constructing individual rather than someone knowledge is given to through instructions (Tapscott, 1998).

The experiential learning theory is another often used theory that defines learning as the process of knowledge creation through 'experience grasping' and transformation (Kolb, Boyatzis, Mainemelis, et al., 2001). In this context, grasping experience is done through concrete experience and abstract conceptualization. Experience transformation, on the other hand, is done by reflective observation and active experimentation. The active and creative nature of the experiential learning theory exhibits a close relation to the constructivism learning theory.

Besides these four central learning theories, multiple others have been introduced, and more recent ones, such as the connectivism learning theory, have been introduced with computer technologies as the application area in mind (Siemens, 2014). Connectivism integrates principles explored by chaos, network, complexity and self-organization theories. It thereby also considers rapid altering knowledge foundations and diversity of opinions. Another consideration will be knowledge composed of objects and the distinction between useful and useless knowledge depending on the current learning context.

An understanding of how learning might happen depends on the learning theory chosen from the existing literature. This directly determines the methods introduced for fostering learning in e-learning environments. One is thereby not limited to one of these learning theories, but a combination of aspects taken from different learning theories is also imaginable.

2.1.3. Educational E-Learning Approaches

Based on learning theories more concrete learning environments and learning requirements can be derived in the context of e-learning. This set of rules about how learning should be structured is called the e-learning (educational) approach, only if a computer is involved. If there is no computer involved, it is called the learning (educational) approach. These e-learning approaches may be realizations of one or more learning theories, supporting the learning process proposed by the learning theories included. Of course, an e-learning approach does not necessarily have to be based on a learning theory.

Although sometimes used interchangeably, the difference with the e-learning theory is that an e-learning approach does not offer an explanation for learning, it only proposes a learning environment or a way of structuring successful learning. An overview of often used e-learning approaches and the related learning processes follows.

Self-regulated learning, for example, is a learning approach (sometimes also described as learning theory (Pintrich, 1999)) suitable for e-learning, which allows the learner to learn in a self-regulated way (Pintrich & De Groot, 1990). The positive effects, in the form of better results, higher motivation, and better planning skills, are widely recognized (Pintrich, 2000; Zimmerman, 2008). A base requirement for self-regulated learning is the ability to take over one's own learning process, which is not natural (Mikroyannidis et al., 2014). A well-designed e-learning environment can guide inexperienced users (Law et al., 2012; Nussbaumer, Hillemann, Gütl, & Albert, 2015).

A similar, but more general concept is self-directed learning, which allows the learner to conceptualize, design, conduct, and evaluate a learning project on his own (Brookfield, 2009). This especially means that, compared to self-regulated learning, the learning content and the learning evaluation are also done by the learner. In relation to e-learning, it is hard to imagine an environment for self-directed learning; however, e-learning environments and even internet access, in general, might be used as tools in a self-directed learning process.

An alternative approach, not defined by the level of user control over the learning process, is collaborative learning, defined as *"a situation in which two or more people learn or attempt to learn something together."* (Dillenbourg, 1999) This vague definition leaves plenty of room for interpretation when it comes to the number of persons involved, the learning method, and the form of collaboration. When considering Anderson's (2008) broad definition of e-learning, which involves interaction between users, e-learning is always collaborative..

A more restricted definition of collaborative learning defines it as *"an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product."* (Laal & Ghodsi, 2012) Using this stricter understanding of collaborative learning enables us to analyze this learning approach in order to understand its characteristics. These characteristics contain the major benefits of this learning approach, which can be divided into four categories, namely

social, psychological, academic, and assessment benefits (Laal & Ghodsi, 2012), see Table 2.1.

Table 2.1.: Benefits of Collaborative Learning (CL)

Benefit Category	Benefit
Social benefits	CL helps to develop a social support system for learners
	CL builds an understanding of diversity among students and staff
	CL establishes a positive atmosphere for modelling and practicing cooperation
	CL develops learning communities
Psychological benefits	Student-centered instruction increases students' self esteem
	Cooperation reduces anxiety
	CL develops positive attitudes towards teachers
Academic benefits	CL Promotes critical thinking skills
	Involves students actively in the learning process
	Classroom results are improved
	Models appropriate student problem solving techniques
	Large lectures can be personalized
	CL is especially helpful in motivating students in specific curriculum
Assessment benefits	Collaborative teaching techniques utilize a variety of assessments

This table shows the benefits of collaborative learning within the four categories of social, psychological, academic, and assessment benefits. This data is taken from Laal and Ghodsi (2012).

2.1.4. Technical Realization and Limitations

A very well-known term when it comes to e-learning platforms is the so-called MOOC, a Massive Open Online Course (Staubitz & Meinel, 2017; Sun, Cui, Chen, Guo, & Shen, 2015; Fidalgo-Blanco, Sein-Echaluce, & García-Peñalvo, 2015). Two very special abilities of a MOOC are open access via the web and its claim of being theoretically able to serve an unlimited number of participants (McAuley, Stewart, Siemens, & Cormier, 2010). In terms of learning theories and learning approaches, no additional restrictions are made. Only the theoretical handling of an unlimited number of participants limits the course in a way, as there cannot be one or more physical persons facilitating the students individually.

The term MOOC describes the setting of a computer-supported course rather than its content or the way this content is presented to the learner. By changing the attributes of a Massive Open Online Course, which are the number of participants (Massive), the registration (Open), and the access (Online), any other computer-supported course can be represented. The only limitation of a MOOC, in regards to the content, is the handling of an unlimited number of participants (Massive), which is a theoretical requirement limiting direct contact between learners and tutors. This circumstance and the fact that MOOCs get a lot of attention in the literature are the two reasons why MOOCs are discussed in this section as prime representatives of computer-supported courses.

MOOCs need to be presented to the audience, and software systems used for this purpose are LMSs, Learning Management Systems (Meinel, Totschnig, & Willems, 2013). The most used LMS is Blackboard followed by Moodle (Pireva, Imran, & Dalipi,

2015). Although both allow similar functionality and Blackboard is used more often, Moodle is the preferred choice in multiple conducted studies (Bremer & Bryant, 2005; Machado & Tao, 2007). Besides user acceptance of LMSs (Ghazal, Aldowah, & Umar, 2017), there is still ongoing research about the educational design of LMSs (Wang, 2017), which also focus on evaluation and assessment (Laflen & Smith, 2017; Park & Jo, 2017).

The biggest drawback when it comes to MOOCs, and LMSs in general, is probably the success and completion rate, which has been problematically low in these courses (Shafaat & Marbouti, 2014). Reasons for this includes the low practical involvement of the learner, a lack of personal support and human interventions, uncontrolled learning environments, and inactive user behavior (Rai & Chunrao, 2016).

A useful approach enhancing the MOOCs in LMSs is gamification; the application of game principles and game-design elements in non-game contexts (Willems et al., 2014; Vaibhav & Gupta, 2014). Gamification approaches are seen as valuable in counteracting the low completion rates MOOCs are experiencing (Gené, Núñez, & Blanco, 2014; Krause, Mogalle, Pohl, & Williams, 2015). Although gamification is recognized as a promising technique for MOOCs, a lack of empirical studies and an incomplete understanding of gamification designed for MOOCs is limiting its application (Antonaci, Klemke, Stracke, & Specht, 2017).

In comparison to gamification, the serious game approach goes a step further in discussing games with a primary focus other than entertainment (Abt, 1970; Michael & Chen, 2005). A wide variety of serious games has emerged in the literature (Botella et al., 2011; Johnson, 2007; Peng, Lee, & Heeter, 2010). A subset of these games deals with teamwork (Bluemink, Hämäläinen, Manninen, & Järvelä, 2010; Bozanta, Kutlu, Nowlan, & Shirmohammadi, 2016), and another subset deals with educational games (Bhardwaj, 2014; Bezuijen, 2012), which focus primarily on educational purposes (Ratan & Ritterfeld, 2009). The main purpose of a serious game is depicted in its fun and entertaining nature (Shen, Wang, & Ritterfeld, 2009; Stapleton, 2004), which is often questioned (Iten & Petko, 2016).

Within MOOCs, there are different learning strategies which can be applied, such as personalized learning (Martinez, 2001), mobile learning (Motiwalla, 2007), and game-based learning (Prensky, 2001) - as already discussed. Each of these strategies aims to improve the usefulness of the basic MOOC approach.

2.2. Teamwork Research and Components

This section is devoted to the motivation for teamwork research, and will give a brief overview of the current literature with regard to the main components of teamwork. To get a rough first idea of what teamwork is about, it is important to consider the definition of a team, which can be described in the following way: *"There is a general consensus in the research literature that a team consists of two or more individuals, who have specific roles, perform interdependent tasks, are adaptable, and share a common goal."*

(Baker, Day, & Salas, 2006) Teamwork is then the joined work of a team to achieve the common goal. The following section will discuss the importance of teamwork as motivation for team research, team research in general, the current state of teamwork training, and the most important teamwork components.

2.2.1. Motivation for Teamwork Research

Teamwork is an important influencing factor in various fields of application, and increases interest in research (Hoegl & Gemuenden, 2001). This is an especially hot topic in environments where consequences of rarely occurring errors are high, such as health care (Leonard, Graham, & Bonacum, 2004). In other environments, the success of companies depends on the teamwork capabilities of the responsible teams, as is the case in many STEM-based (Science, Technology, Engineering, and Mathematics) companies (Smith, Douglas, & Cox, 2009). A lot of attention is directed towards the crucial field of team research to examine the complex structures involved.

One very important component of teamwork, appearing in various forms and manifestations, is communication, which is extensively investigated in the context of health-care (Salas, Wilson, Murphy, King, & Salisbury, 2008). Communication failures are unfortunately an extremely common cause of inadvertent patient harm (Leonard et al., 2004). Complex working environments, such as health care, require standardized communication tools to share concerns about critical situations. This, of course, requires a suitable interpersonal culture for the people involved in order to be able to express their concerns.

It is no coincident that health care is an especially popular application area for team research, as it constitutes high-reliability organizations in which lives depend upon teamwork (Baker et al., 2006). A high-reliability organization is one in which the consequences of errors are high, but the occurrence of an error is extremely low. This low occurrence might be a reason for the people involved to become absent-minded and sloppy when it comes to teamwork, which can have catastrophic implications.

Teamwork training is a suitable tool for reducing errors, as well as improving team behaviours and stuff attitudes (Morey et al., 2002). This study demonstrated these positive effects over eleven months in sixteen emergency departments with nearly 700 participants using the so-called Emergency Team Coordination Course. A transfer to other high-risk areas of care seems absolutely reasonable.

Besides health-care, other application areas, such as industry and the so-called STEM subjects, (Science, Technology, Engineering, and Mathematics) (Smith et al., 2009) depend on teamwork. For example, effective communication is crucial for the creation of successful companies (Spaho, 2011). Also, other factors influening teamwork, such as coordination and mutual support, have implications on a team's success (Hoegl & Gemuenden, 2001). Teamwork, generally speaking, exhibits statistically significant influence on project performance, as studies show (Hoegl & Gemuenden, 2001; Yang, Huang, & Wu, 2011).

2.2.2. Teamwork Research

In addition to the positive effects of successful teamwork, already discussed in Section 2.2.1, Motivation for Teamwork Research, multiple other research focuses are set in team research. Of fundamental interest is the functionality of teamwork, which was viewed from different perspectives. Frequently discussed perspectives could be labeled: components of teamwork, team processes, team knowledge, leadership, and adaptive team performance (Coovert, Winner, Bennett Jr, & Howard, 2017). In the following, each of these, as well as different team roles (M. Belbin, 2012), are discussed to give a rough understanding of there methodologies and objectives.

Components of Teamwork

Components of teamwork are defined as the basic elements of which teamwork is composed, which also separate individual task work from teamwork (Cooke et al., 2003). To get a better understanding of teamwork, the identification of influential components, as well as their relationships with each other, is crucial. The importance of finding a suitable component structure for teamwork is displayed in the various different proposed teamwork component frameworks in the literature.

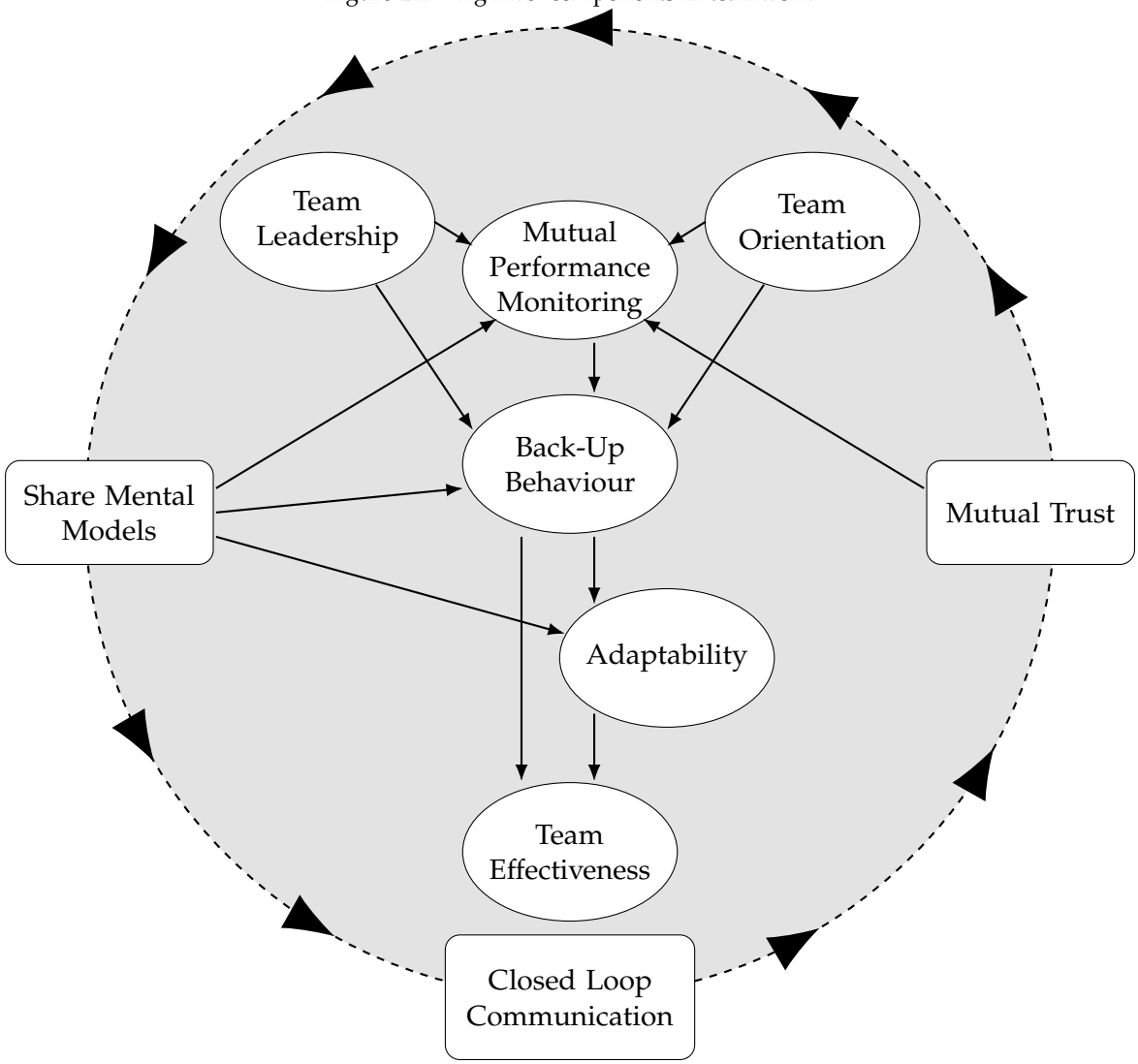
According to Dickinson and McIntyre (1997), for example, these components are: team orientation, team leadership, communication, monitoring, feedback, and coordination. A very similar conclusion was drawn by Salas, Sims, and Burke (2005), who introduced the 'Big Five' in teamwork: team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation. Additionally, three supporting coordinating mechanisms were introduced: shared mental modes, closed-loop communication, and mutual trust. A graphical representation of the teamwork components and their supporting mechanisms, including assumed relations, can be found in Figure 2.1. Rutherford (2017) identified the exact same five main components of teamwork. Some more variation can be found when comparing the components to those found by McEwan, Ruissen, Eys, Zumbo, and Beauchamp (2017).

Team Processes

Team processes describe team behavior over time, namely the three main processes of transition, the action process, and the process associated with interpersonal matters (Marks, Mathieu, & Zaccaro, 2001). Alternative frameworks can also be found, of which one of the most famous was introduced by Tuckman.

Tuckman (1965) introduced four sequential processes through which groups progressed: forming, storming, norming, and performing. His work was supplemented with a pre-forming process, and the performing process was split up into performing I and performing II among others, and the deforming process was added at the end of the teamwork task (Morgan Jr, Glickman, Woodard, Blaiwes, & Salas, 1986). Each of these phases is defined by unique team members' behavior, which is essential for successful teamwork and hence should be integrated into the team's work plan.

Figure 2.1.: 'Big Five' components in teamwork



Graphical representation of high-level relationship among the 'Big Five' and the coordinating mechanisms including assumed relations represented by arrows from Salas, Sims, and Burke (2005), Figure 1.

Team Knowledge

Team knowledge is a very broad topic (Cooke et al., 2003; Coovert et al., 2017), defined as the assortment of the task- and team-related knowledge held by teammates, and their collective understanding of the situation confronting the team. It can be divided into two components: team mental model and team situation model. Measuring these two components of team knowledge is an essential aspect for many types of research concerned with team performance.

The team mental model, the first component of team knowledge to be discussed, is long-lasting and persisting. It exists prior to task performance and is acquired through training and experience. The contained knowledge occurs in a wide variety of forms, including strategic, procedural, and declarative knowledge. Leading to

common and shared expectations within the team, it can be used as a base of knowledge for the whole team.

The team situation model, the second component of team knowledge discussed, is transient for each task performance. It is highly situation specific, dynamic during the course of action, and is established during the task work. One of the main functions of the team situation model is the utilization of team mental model constructs, in addition to helping function for the team members to interpret the situation in a common, consistent fashion.

Leadership

Leadership behaviors are very important for a team's success (Simsarian Webber, 2002) and, hence, an interesting area of team research. The unique role of a leader in a team combines multiple functions, such as information handling and resource managing (Burke et al., 2006). This team role is responsible for information handling and resource managing, as well as for the team's performance. Consequently, the leadership abilities of the leader are highly important, not only for the team's success but also for the team itself.

The ability to lead the team can be differentiated by the exerted leadership style, and many distinct classifications have been introduced. Burke et al. (2006) works with seven leadership styles, which are separated into task-focused leadership styles and person-focused leadership styles. In most cases, a combination of multiple leadership styles is performed. It is highly important to identify relationship between leadership styles and team characteristics, such as team success, in order to optimize teams.

Adaptive Team Performance

The second last area to be discussed, adaptive performance in teams, describes the need for teams to adapt to changing circumstances (Rosen et al., 2011). This adaptation is especially important for teams operating in dynamic environments, to keep the plan for reaching the team's objective up to date. It is modeled using different elements, such as individual team members' characteristics, an adaptive assessment/planning/learning/feedback cycle, and a change of team information.

In order to guarantee a successful application of the team adaptation performance, guiding principals can be used. Rosen et al. (2011) introduced six of these principals, among which are the team's abilities to self-assess, the team's recognition of a need for change, changes in strategy impacting team performance, and a profile of team adaptation over time.

Team Roles

The theory of team roles was first rigorously investigated by Belbin (1981) and describes the different behavioural tendencies for different persons on a team. Time after time Belbin's team role theory has been critiqued (van de Water, Ahaus, & Rozier, 2008; Manning, Parker, & Pogson, 2006). Manning et al. (2006), for example, provide a questioning review of Belbin's team role theory, stating a need for an adequate framework for relating personality to team roles. This idea was picked up by Mathieu, Tannenbaum, Kukenberger, Donsbach, and Alliger (2015), introducing a classification similar to the one from Belbin, but related to the measures of the well researched 'Big 5' personality construct (Barrick & Mount, 1991). It should be mentioned, that besides this general team role theory there are also team role theories relevant to particular areas of application (Tempest & Mcintyre, 2006).

M. Belbin (2012) identified nine team roles, each of which refers to a tendency to behave, contribute, and interact with others at work in certain distinctive ways. It is important to distinguish between the team role and team functionality, where the latter refers to the demands of a person's job related to technical/operational skills. The roles are plant, resource investigator, coordinator, shaper, monitor/evaluator, teamworker, implementer, completer/finisher, and specialist. Each of these roles has its own behaviour pattern and allowable weaknesses, which are weaknesses commonly associated with the strengths of the role's behaviours.

Although Belbin's team role classification is the first acknowledged and also the most explored one, it comes with a major drawback: The related questionnaire is not open to the public. Due to this fact, not only will Belbin's team role classification be discussed, but also the much newer team role classification of Mathieu (Mathieu et al., 2015), which comes with the Team Role Experience and Orientation (TREO) questionnaire.

2.2.3. Teamwork Training

Teamwork training in a general setting describes an activity for improving team-work performance regardless of the context.(Morey et al., 2002; Shapiro et al., 2004). As basis for such a training the components and processes discussed in Section 2.2.2, Teamwork Research, can be used. Currently-used teamwork training approaches mentioned in the literature are discussed in this section. After this section, more concrete teamwork components are identified as the basis for a teamwork training.

When it comes to teamwork training, the term team building is well-known and often used. Team building activities are activities promoting teamwork, demonstrating different aspects of team behavior, and fostering cognitive processes about achieving high team performance (Goncalves, 2006). They also allow a team to overcome disunity, frustration, group problems, and conflicts. Behaviors or topics involved are, for example, communication, problem-solving, using strengths and avoiding the weaknesses of team members, and trust.

Team building activities are normally used after a team is newly assembled, but teams that have existed for some time before the team building activity can also achieve positive results. An example of this is cohesion, which is *"the tendency for a group to stick together and remain united in the pursuit of its instrumental objectives and/or for the satisfaction of member affective needs."* (Carron, Widmeyer, & Brawley, 1985) It was shown, that team building is an effective tool for influencing cohesiveness in sports teams (Senécal, Loughead, & Bloom, 2008). The team building activity, called team goal-setting is shown in Table 2.2.

Table 2.2.: Team Goal–Setting Team Building Activity

Principle	**Implementation Strategy**
Selecting the team goals.	1. Athletes are provided with a list of performance indices (e.g., turnovers, steals, blocked shots, free throw shooting percentage). 2. From the list, each athlete independently identifies the four most important performance indices to establish for team goals. 3. Subunits of five athletes agree on the four most important performance indices that should be set for team goals. 4. The team as whole then agrees on the four performance indices that team goals will be set.
Establishing the target for the team goals.	1. Each athlete independently identifies the target levels for each of the four team outcomes. 2. Subunits of five athletes agree on the target levels. 3. The team as a whole then agrees on the target levels.
Coaches remind players of the team's goals.	1. The goals are posted in the team's locker room.
Evaluation, feedback, and reevaluation are essential for team goal–setting effectiveness.	1. The sport psychology consultant meets with the team to review and discuss the team's goals after each block of three games. Modifications to the team's goals or target levels were made if deemed necessary.

This table shows the team goal–setting team building activity introduced by Senécal, Loughead, and Bloom (2008). It describes the training, divided into four principles, each of which consists of one to four steps.

With the rise of computer technologies, so-called virtual teams emerged, potentially bringing up a special need for teamwork training. These virtual teams are characterized as *"internationally distributed groups of people with an organizational mandate to make or implement decisions with international components and implications."* (Maznevski & Chudoba, 2000) Despite the differences when compared to ordinary teams, it is possible in virtual teams to enhance the perception of collaboration and trust by using standard team building tools (Holton, 2001).

The entrance of technology into society not only influences how teams work but also how teams get trained. In high-risk industries such as aviation, health care, and nuclear power production, high-fidelity simulations are used for training in teamwork skills (Beaubien & Baker, 2004). Planning and task coordination, collaborative problem solving, and communication skills can be positively influenced using a simulator, as a study shows for action teams (A. P. Ellis, Bell, Ployhart, Hollenbeck, & Ilgen, 2005), i.e. teams, which *"conduct complex, time-limited engagements with audiences, adversaries, or challenging environments in performance events for which teams maintain specialized, collective skill."* (Sundstrom et al., 1999)

2.2.4. Teamwork Components

As a basis of teamwork training, a solid understanding of the concepts and components involved is needed. When looking at Section 2.2.2, Teamwork Research, one can choose from a wide variety of perspectives on the subject, depending on the teamwork training focus. This teamwork focus is a direct consequence of the anticipated training outcome or learning objective of the training. To get a deeper understanding of teamwork and its procedures on a meta level, all of the previously mentioned aspects can be studied. A training of practical teamwork skills might be best based on the components involved in teamwork (A. P. Ellis et al., 2005; Haferkamp, Kraemer, Linehan, & Schembri, 2011; Ramachandran, Presnell, & Richards, 2016).

When looking at the Section 2.2.2, Teamwork Research, and the components of teamwork, various different frameworks can be found. Although the findings related to these frameworks are sometimes inconsistent, there is an unexpressed agreement on the basic components, which are stated repeatedly by different authors. Very frequently, stated components and concepts include leadership, communication, orientation, monitoring, and adaptability. These five components are identified as the main components in this thesis and will be used for further elaboration of a training game. Following the interpretation of Salas et al. (2005), these components are described below.

Working Definitions

Team leadership is defined by the ability to direct and coordinate the activities of other team members; assess team performance; assign tasks; develop team knowledge; skills, and abilities; motivate team members; plan and organize; and establish a positive atmosphere (Salas et al., 2005). Behavioral markers of team leadership, meaning typical behaviors associated with good team leadership, are listed below.

- Facilitate team problem solving.
- Provide performance expectations and acceptable interaction patterns.
- Synchronize and combine individual team member contributions.
- Seek and evaluate information that affects team functioning.
- Clarify team member responsibilities.
- Engage in preparatory meetings and feedback sessions with the team.

Closed-loop communication is characterized by the exchange of information between a sender and a receiver irrespective of the medium (Salas et al., 2005). Behavioural markers of closed-loop communication are listed below.

- Following up with team members to ensure a message was received.
- Acknowledging that a message was received.
- Clarifying with the sender of the message that the message received is the same as the intended message.

Team orientation is defined by the propensity to take others' behavior into account during group interaction and the belief in the importance of the team's goal over individual members' goals (Salas et al., 2005). Behavioural markers of team orientation are listed below.

- Taking into account alternative solutions provided by teammates and appraising that input to determine what is most correct.
- Increased task involvement, information sharing, strategizing, and participatory goal setting.

Mutual performance monitoring is defined as the ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor teammate performance (Salas et al., 2005). Behavioural markers of mutual performance monitoring are listed below.

- Identifying mistakes and lapses in other team members' actions.
- Providing feedback regarding team member actions to facilitate self-correction.

Adaptability is defined by the ability to adjust strategies based on information gathered from the environment and reallocation of intrateam resources (Salas et al., 2005). That is, altering a course of action or team resources in response to changing conditions (internal or external). Behavioural markers of adaptability are listed below.

- Identify cues that a change has occurred, assign meaning to that change, and develop a new plan to deal with the changes.
- Identify opportunities for improvement and innovation for habitual or routine practices.
- Remain vigilant to changes in the internal and external environment of the team.

2.2.5. Teamwork Components and Collaborative Learning

Striking parallels between the learning approach of collaborative learning and teamwork components can be seen when comparing Section 2.1.3, Educational E-Learning Approaches, and Section 2.2.4, Teamwork Components. Collaborative learning can be described as teamwork with the goal of learning given content, as will be seen later on. A closer look at this relationship and its implications follows.

Especially clear is the relationship between teamwork components and collaborative learning when investigating students using collaborative learning approaches (Stacey, 2007). As a student group's common and shared objective is to learn and persist in a team structure, it also fulfills the definition of a team. These two fields of interest are closely related (Van den Bossche, Gijselaers, Segers, & Kirschner, 2006).

This close relationship is also visible when comparing the previously used definitions of both terms. As already discussed, collaborative learning is *"an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product."* (Laal & Ghodsi, 2012) The close relationship is

obvious, when it is compared to teamwork - defined as working in a team, which *"consists of two or more individuals, who have specific roles, perform interdependent tasks, are adaptable, and share a common goal."* (Baker et al., 2006)

The main differences in the definitions concern the type of goal, and the roles of the people involved. The shared and common goal of a team is not explicitly mentioned in the definition of collaborative learning but can be assumed, since the solution to the problem, completion of the task, or creation of a product implies such a commonness and is definitely shared. In contrast to this mainly linguistic difference, the people's roles, which are predefined in a team, posses a real difference compared to collaborative learning.

Stacey (2007) showed, that collaborative learning was achieved by developing a group consensus of knowledge, communicating different perspectives, receiving feedback from others, and discussing ideas. Those aspects are reflected in the teamwork components orientation, which includes taking others' ideas and solutions into account, discussing ideas, and monitoring, which is concerned with monitoring others' work and giving feedback. Communication is used as a tool in both subject areas.

An interesting difference is the absence of a leader in collaborative learning, based on the symmetry of the people involved, compared with teamwork. In teams, a leader is responsible for deciding which solution or path of action is taken, whereas in collaborative learning ideas are discussed until a final understanding is negotiated and reached (Stacey, 2007). This negotiation of understanding does not mean, that it is the same for all learners - but none of the learners takes in a predefined major role in the decision-making process. It is important to understand, that a functional, informal leader, not determined in the beginning might emerge during a collaborative learning process (M. Belbin, 2012).

As a result of this close relationship between collaborative learning and teamwork, training in one area will most likely also be beneficial for the other. One of the few exceptions is training-directed specific roles in a team for team training since there are no predefined roles in collaborative learning - although they might emerge during the course of action.

2.3. Serious Games

This section intends to show the motivation for serious games, with a focus on skills training, and demonstrate their usefulness. Then, a look at the definition of serious games, their origin, and the corresponding research landscape is taken.

The growth of interest concerning serious games (which are in our context always digital) in research (Boyle et al., 2016) and also in industry (Hollins, Westera, & Iglesias, 2015) is widely recognized. The reasons, therefore, seem to be obvious - fusing the motivating nature of games (Przybylski, Rigby, & Ryan, 2010) with the

teaching potential of conventional e-learning software (Downes, 2005). In other words, learning can be made a fun experience.

A major reason for this growing interest is the observable inadequacy of conventional e-learning software, such as MOOCs, to retain learners until the end of the course (Gené et al., 2014). These high drop-out rates can be decreased using game elements in so-called gamification approaches, which might also increase the learning scores (Krause et al., 2015). Similar and even more improvements are promised by game-based learning approaches (Westera, 2015).

Combining games with the advantages of e-learning software is tempting. A learner can access the materials from all over the world, at any time (Hoy, 2014). Additionally, when compared to conventional learning, the maintenance costs for e-learning are very low, especially when considering the unlimited number of users. Besides the organizational advantages of e-learning software, there are many more associated with serious games.

The advantages of serious games are diverse, and include: motivational aspects, cognitive flow advantages for learning via their ability to monitor the user and allow social learning, providing a safe environment for experimentation, and allowing learning-by-doing (Westera, 2015). However, it has been shown that such claims, especially when used very generally, have weaknesses when it comes to engagement, learning, and impact.

Before having a closer look at certain aspects of serious games, the difference between a serious game and a simulations will be discussed. Simulations are simplified, dynamic and accurate models of reality (Sauvé, Renaud, Kaufman, & Jean-Simon, 2007). A game, in contrast, is a fictitious or artificial situation in which the player is expected to perform (Sauvé et al., 2007). Although there is a clear difference between serious games and simulations (Coovert et al., 2017; Marlow, Salas, Landon, & Presnell, 2016) these two terms are often used interchangeably (Feinstein & Cannon, 2002). To some extent, based on the definitions used in this paragraph for simulation and game, each serious game about teamwork involving teamwork can be seen as a simulation.

A look at the definition of serious games, their origin, and the corresponding research landscape will now follow.

2.3.1. Definition

Djaouti, Alvarez, Jessel, and Rampnoux (2011) attributes the first occurrence of the term 'Serious Game' to the appearance of the book 'Serious Games' written by Abt (1970). The explicit definition of a serious game reads as follows: *"Games may be played seriously or casually. We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean, that serious games are not, or should not be, entertaining ."* (Abt, 1970) Following this definition, Abt introduced several computer and non-digital serious games in this book for training and education.

The definition of serious games nowadays has changed from the first one given by Abt (1970) (Göbel et al., 2014). The focus on the educational purpose was removed, which widens the definition. This allows the integration of serious games, for example, to be directed towards to advertisement or health promotion. For this thesis a serious game is defined as a **digital game with an explicit and carefully thought-out purpose other than entertainment.**

The subset of serious games with the primary focus on education is labeled as educational games and corresponds to the initial definition of a serious game from Abt (1970). The answer to the question still seems unclear after the prioritization of content.

Content Prioritization

Prioritization is a central question when combining the 'game' component with the 'serious' component of serious games. When looking at the literature, one can find different answers to this question. Following the literal interpretation of 'serious games' as a special form of a game, the entertaining component is seen as the primary focus (Zyda, 2005). Alternatively, a serious game can be defined, as a game with a main purpose other than entertainment, as seen before (Abt, 1970; De Gloria, Bellotti, & Berta, 2014).

In terms of practical relevance, the question of prioritization can be answered by comparing serious games with different levels of prioritization based on their desired impact. This, however, would require a set of games, which differ from each other only based on, for example, the number of included game mechanics for serious purposes. Also, the transfer of such a result could be difficult due to a strong dependence on the implementation used.

A theoretical discussion about the prioritization of 'game' and 'serious' content in a serious game can be answered by investigating the relationship between serious games, video games, and games. For our purposes, a computer or video game is defined as a game carried out with the help of a computer program (Smed, Hakonen, et al., 2003).

In particular, the question whether a serious game is a game or not, in combination with the definition of a game, might bring valuable insights. Rowe (1992), for example, defines a game as an abstract object not having an instrumental value. Following this definition, a game is not allowed to have a serious component, which means a serious game is not a game. Of course, there are also other definitions which would allow serious games to be games (Suits, 1967).

2.3.2. Origin of Serious Games

This section is intended to explore the history and origin of serious games and games in general. Also, their first usage as training tools for military purposes or in

high-cost private sectors show interesting aspects of this training approach.

Games are a central component of human history. The oldest known games are more than 3000 Years old (Laamarti, Eid, & Saddik, 2014). Some of them are known to fulfill a serious purpose, such as the game Mancala which was used for counting animals and food. Especially for children, playing and learning is closely linked (Samuelsson & Carlsson, 2008). Although, (serious) games have always been present, a new interest emerged at the beginning of the 20th century.

Educational games (serious games with an educational purpose) have been used since at least the early 1900s (Rice, 2007). Mostly used in educational circles, these first educational games were paper-based.

This trend was boosted by war, which led to multiple training games in the area of warfare. Torrey (1945) describes how the Norden bombsight, a mechanical tool for training bombardiers, was used in World War II. A later example is the game 'The Bradley Trainer', which trained new recruits of the American army in operating a Bradley tank in 1981 (Laamarti et al., 2014).

However, the corporate sector has also started to explore the possibilities presented by serious games. Windsor (1954), for example, reports the first use of flight simulators from United Airlines using visuals, sounds, and movement. Some years later, in 1973, the video console Odyssey introduced serious games, such as 'The Oregon Trail' and 'Lemonade Stand' (Laamarti et al., 2014). The first one was designed to teach school children about 19th-century life on the Oregon Trail, and the second one is a business simulation game.

The main focus of serious games until 1970 was clearly directed towards simulation games. This is also reflected in the literature at that time. Abt (1968) investigated games for learning in 1968 with a focus on simulators. Subsequently, many different concepts emerged in the literature to support the serious game approach, which at that time also considered games other than simulations, as shown in the next section.

2.3.3. Serious Games as an Area of Research

As a relatively young research area, there are multiple fields of interest when it comes to serious games. Besides the motivation already discussed at the beginning of this section, important game elements and dynamics have also taken center stage (Jennett et al., 2008; Csikszentmihalyi, 1990; Ferrara, 2013). Having only been used in entertainment games thus far, these concepts are now examined more closely in order to understand their functions and incorporate them into serious games.

Furthermore, game design was extended to serious game design to meet the new requirements of this subject area (Wouters, Van der Spek, & Van Oostendorp, 2009). The creation of games fostering learning, as one example of serious games, need a solid theoretical base in order to be successfully implemented. One area of growing interest when it comes to serious games is assessment and adaption, which can be

used in nearly all serious games (Bellotti, Kapralos, Lee, Moreno-Ger, & Berta, 2013). These newly added research focuses are discussed below as serious concepts, derived from the serious component of serious games.

Game Concepts

There are numerous game concepts that are already a fixed element of entertainment games now beeing scientifically examined in the context of serious games. They contain concepts describing the motivational aspects of games, such as flow or immersion. Also loosely related to these concepts is persuasion, which also considers other factors for engagement. These three concepts will now be discussed. They constitute some of the most commonly explored concepts in the context of serious game design.

The term flow was introduced by Csikszentmihalyi (1990), describing a state of concentration and deep enjoyment, which was later adopted by (serious) game research (Bezuijen, 2012; Bellotti et al., 2013; Kiili, de Freitas, Arnab, & Lainema, 2012). Important elements of the flow concept are automatic actions, clear goals, feedback, concentration on only the task at hand, loss of self-consciousness, a lack of worrying about loss of control, and a transformation of time.

A concept that is clearly distinct from flow, but still linked to it, is immersion, which is concerned with the specific, psychological experience of engaging with a computer game (Jennett et al., 2008). It, therefore, does not need to be the most optimal experience, and sometimes it is not even a fulfilling experience. Nevertheless, immersion involves a loss of awareness of the real world and time, as well as a sense of being in the task environment. It is the result of a good gaming experience.

Getting players to play a serious game is crucial. An approach to do so, namely the persuasion concept, has gained more and more attention recently (Khaled, Barr, Biddle, Fischer, & Noble, 2009; Ferrara, 2013; de la Hera Conde-Pumpido, 2017). This concept tries to influence behavior, feelings, or thoughts. This not only requires persuasion technology, but also the incorporation of the target group's culture (Khaled et al., 2009). A very recently published theoretical framework explained how to design a serious game in order to persuade players using three types of persuasion: exocentric, endocentric, and game-mediated (de la Hera Conde-Pumpido, 2017).

Exocentric persuasion, as a game-centric approach to persuasion, refers to the persuasive strategies used within digital games to convey a specific message to the player during the game session. Endocentric persuasion, as a player-centric approach to persuasion, refers to the strategies used within a digital game to engage and motivate a player to play a game and keep playing it. Game-mediated persuasion, as a context-centric approach to persuasion, is not directly related to games with the primary intention of persuading players beyond the game session, but is related to game use in a specific context to change or reinforce the attitudes of players towards an object or concept that is distinct from the game. Context is understood here as something that has to be maintained and constructed on an ongoing basis.

The term 'player types' describes the findings of different behaviors and preferences among video game players (Hamari & Tuunanen, 2014). There are different typologies available in the literature, most of them using five key dimensions based on the players' motivation for play, including Achievement, Exploration, Sociability, Domination, and Immersion. These five dimensions may occur in a specific player to a certain level leading to a fine grained description of the player's preferences in terms of motivation. This information is useful for improving game design and might also be used for adapting a given game to a certain player.

In order to describe a game, a vocabulary of it's elements is required, and expressions often used are game mechanics, game rules, and game elements. Game mechanics, defined as methods invoked by agents (separated entities in the game) for interaction with the game world, are a central building block of a game (Sicart, 2008). In close relation to game mechanics are game rules, which form the normative boarder of a game. Game elements, which play an important role in gamification, can be considered as building blocks of a game, which are neither performative as game mechanics nor normative as game rules (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). Examples are scoreboards and user interfaces. As the definitions of these three terms are rather vague, overlaps and fuzziness is a logical result. There is a need to define these core concepts (Sicart, 2008).

Arnab and Clarke (2017) uses a broader definition of game mechanics, although it is not explicitly mentioned. In previous content related papers, the missing game mechanic definition is discussed (Arnab et al., 2015). Examples for game mechanics are cut-scenes, action points, levels, tokens, game turns, questions and answers, selecting and collecting, resource management, capturing and eliminating, feedback, goods and information, time pressure, tutorials, tiles and grids, infinite gameplay, appointments, movements, assessment, and a game status.

A very famous game concept is the in-game story, which is used to wrap the game mechanics into an appealing and reasonable package (Murray, 2004; Rollings & Adams, 2003). There are differences in how important the story is for different genres. Tetris, for example, does not require a very sophisticated story. Role-Play Games, such as Final Fantasy, on the other hand, require a good story.

Serious Concepts - The Non-Gaming Aspects of Serious Games

Serious concepts, concepts newly added to the game design in order to create the serious game design, will now be discussed. The overarching research focus is the game design itself, dealing with the composition of serious game elements in order to create a serious game. Closely related to this design is the so-called learning goal-game mechanics mapping, as in the case of an educational game. It can be used as a design tool during the design process or as an evaluation tool for existing games in order to evaluate the relationship between game actions and learning. Also, the different qualities of learning outcomes is an interesting research area when dealing with educational games. Another education-related concept is assessment and adaptation, which can be used in a serious game in order to track player actions

and to adapt the game to the players' needs. These four major concepts will now be discussed in more detail.

Before making the first design decision, the quality of the learning outcome needs to be considered, which can be cognitive, affective, communicative or directed towards motor skills (Wouters et al., 2009). Cognitive learning outcomes encompass textual and non-textual knowledge as well as cognitive skills, such as problem-solving, decision making, and situation awareness. Affective learning outcomes are attitudinal changes, also including behavioral and motivational changes. Communicative learning outcomes describe the skills required for social and team activities, such as communication, cooperation, and negotiation. Motor skills as learning outcomes include the transition of declarative knowledge to procedural knowledge, and later on, training of motor behaviors. The chosen learning outcome is then used in the serious game design.

The area of serious game design is a fairly new one, and requires the combination of educational theory and game design, among other aspects (Kiili, 2005; D. B. Clark, Tanner-Smith, & Killingsworth, 2016; Rienties & Toetenel, 2016). In recent years, multiple authors have started to investigate the area of serious game design by introducing different design frameworks, as well as serious games with different focuses (Kiili, 2005; Jabbar & Felicia, 2016; Lameras et al., 2017). A central element is the fusion of game design with learning design to support those two dimensions of serious game design in there two very different and sometimes competing objectives: learning and entertainment.

Numerous methodologies of serious game design have emerged, introducing a wide variety of serious game design elements (Slimani, Sbert, Boada, Elouaai, & Bouhorma, 2016). In addition to different methodological categories (entertainment or educational), other aspects, such as the level of detail, main purpose, orientation, application, and many others were introduced. A total of eleven distinguishing characteristics symbolize the wide spectrum of possible design approaches.

Learning design and game design are two concepts explicitly or implicitly included in every serious game design framework (Gros, 2016; Kiili, 2005). The link between these two design elements, often described as the link between learning mechanics and game mechanics (Arnab et al., 2015; Gros, 2016; Callaghan, McShane, Eguíluz, Teillès, & Raspail, 2016; Baldeón, Rodríguez, Puig, Gómez, & Grau, 2016) is of crucial importance. It can be used for analyzing the main pedagogical and entertainment features as well as for designing serious game.

In contrast to learning and game design, a design element often not (explicitly) mentioned in the serious game design frameworks is the content (Grey, Grey, Gordon, & Purdy, 2017; Kiili, 2005; Jabbar & Felicia, 2016). This is an optional element, required for education and training (De Gloria et al., 2014). Being restricted to one specific type of content allows the introduction of more concrete game mechanics for supporting the serious game framework.

The 4-C model, which is a serious game design framework for training teamwork skills, which includes a concrete mapping of learning mechanics with game me-

chanics, is one example of a serious game design framework that considers concrete content (Ramachandran et al., 2016). The model includes the four quantities, namely cohesion, cognition, coordination, and communication. Each of these quantities is assessed by a simple ratio of in-game count data in combination with the results of optional direct querying methods.

One concept which should also be considered in the design phase of serious game development is 'assessment and adaptation'. In educational games, assessment and adaptation are two closely linked concepts of great influence (Yannakakis & Hallam, 2009; Bellotti et al., 2013; Maurer et al., 2017). The current state of the learner can be assessed, and based on this information the game can be adapted to satisfy the player's learning needs. A common distinction is the one between invasive assessment, which interrupts the game flow, and non-invasive assessment, which does not interrupt the game flow. These concepts can also be used for game evaluation purposes. This is done using relevant in-game indicators, such as motivation or learning gain, which can be assessed and used to justify the game.

2.3.4. A Word on Game Engines

Although the creation of games, whether it be serious games or leisure games, can be done from scratch, this is not the gold standard.

For game creation, a so-called game engine is used, which is a piece of software for creating games (Bishop, Eberly, Whitted, Finch, & Shantz, 1998). This game engine already includes common game elements, which allows easy adaptation of any given content. It can be seen as a game framework, which needs to be complemented by some content. In practice, there are different game engines for different types of games, since adapting them to the specific type enhances performance by omitting unneeded features.

Xie (2012) for example investigated the game engine Unity, other game engines mentioned are Quake, Unreal Engine, Source, BigWorld, and CryENGINE. A growing interest in Unity emerged because it is easy to use, free for small companies and private persons, and can be used for many platforms. Currently, it supports 29 platforms including iOS, Android, Windows desktop, Mac OS desktop, Linux desktop, and WebGL (Unity, 2017a).

Unreal engine, another widely used game engine developed by Epic Games, is a successor of the game engine used for the creation of the first-person shooter, known-as Unreal (Lewis, Brown, Cranton, & Mason, 2011). It was primarily developed for first-person shooter games and is also used in other genres, such as MMORPGs and RPGs.

There are multiple online articles comparing different game engines, which nearly always include Unity and Unreal (DEALS, 2016; "The 3 Best Video Game Engines," 2017; Aspis, 2017; Banerjee, 2017). Statistica [1] states that Unity was used by 62%

[1] [22.11.2017] http://statistica.io/

of game developers in the UK in 2014, and Unreal reached second place with 12% ("Unity dominates game engine market," 2016; DEALS, 2016). A prime advantage of Unity is its multi-platform capability.

Another very useful feature of Unity is its network framework (Unity, 2017b). It allows a multiplayer game to be created without an additional server component by using one of the clients as a server. This client who also acts as a server is called the host. The limitation of this feature is that the host needs to be online while the game is running, which might not be feasible for all types of games.

2.4. Summary

This chapter gives an overview of the three major subject areas, which need to be considered in a serious game for teamwork training: e-learning, teamwork, and serious games.

E-learning is the learning which occurs by the presentation of educational material using a computer. These e-learning environments are most often based on learning theories or derived learning approaches, such as collaborative learning. The content is then presented via a Learning Management System (LMS). A famous member of one of the different types of courses presented on LMSs is the MOOC, the Massive Open Online Course. Despite their huge advantages, such as independence of time and location, they suffer from low success and completion rates.

Teamwork is defined as the work happening within a team, which consists of two or more individuals, who have specific roles, perform interdependent tasks, are adaptable, and share a common goal. It is known, that good teamwork can save lives in health care and also has positive effects on a team's success. There are multiple ways to approach teamwork. An important one for teamwork training is called components of teamwork, which examines the components involved and their relationships with each other. The main components, which are communication, orientation, monitoring, and adaptability, are also important elements of collaborative learning. This close relationship between collaborative learning and teamwork means that training in one area will also most likely be beneficial for the other.

Educational games, or games with an educational main purpose, have already proven their potential to motivate learners and enhance performance. They have been used for thousands of years, and in more recent times, been boosted by the military and economy. Their appearance in a computer game context made game concepts, such as flow and persuasion, the focus of research. Also, new concepts were introduced for the special needs of serious games, such as serious game design or the classification of learning outcomes.

The next chapter discusses related work in the context of creating a serious game with a teamwork focus.

3. Related Work

In this chapter, the focus of the previous chapter is constrained and a closer look is taken at the area of serious gaming in the context of training. Serious games for training and serious games with a teamwork focus are discussed in order to get an adequate impression of the current state in the literature. Attention is mostly directed towards two areas of interest: Firstly, serious game design with emphasis on educational games, secondly, games that have already been introduced in this area.

First, serious games for skills training or, educational games, are discussed. This especially includes serious game design as a very central element of this thesis. The special characteristics of the educational component are discussed here as well. Furthermore, games that have already been introduced for skill training are discussed in application areas other than teamwork.

Second, serious games with a focus on teamwork are discussed. This includes games with training purposes, as well, as games with an analytical purpose. As it turns out, the majority of serious games are used for teamwork research.

3.1. Serious Games for Skills Training

This section discusses the use of serious games for training. Well-known types of serious games include educational games, games for health training, and games fostering desired behavior pattern associated with skills, such as teamwork skills or fire safety skills. First, the serious game design for training games is looked at, and then training games that have already been introduced are discussed.

3.1.1. Serious Game Design for Training

One aspect of related work regarding serious games for training is concerned with the design of those games. It contains multiple elements that can be found in serious games in general but also elements representative for this type of serious game.

Elements of Serious Game Design

A serious game naturally combines multiple disciplines, which need to be considered in the design phase (De Gloria et al., 2014). Besides the game design required for the 'game' component and the content required for the 'serious' component of a serious game, a learning theory is also required in order to transfer the content to the player of a training or educational game.

The game design provides the basis of the 'game' component of the serious game for engaging, motivating, and persuading the player (Bergeron, 2006; Westera, 2015). By using well-known game genres and structures (Rollings & Adams, 2003), players are prevailed upon to play the game and, in the best case, to experience flow - an optimal experience (Csikszentmihalyi, 1990).

Besides game design, the content is required to add a 'serious' component, which is educational in our case, to the game to form a serious game (De Gloria et al., 2014). Naturally, extensive research of the corresponding subject area is required to adequately cover the important relationships and concepts within the game. Based on the insights gained, mapping learning mechanics and game mechanics links the game with the content (Arnab et al., 2015).

Serious games for training, requiring a theory on how to teach the chosen content (De Gloria et al., 2014) goes on step further than the creating of a serious game with a subject area. Instead of assuming that playing a serious game, including a chosen content, will automatically trigger a learning process, an intentional effort is made to foster learning (Maurer et al., 2017).

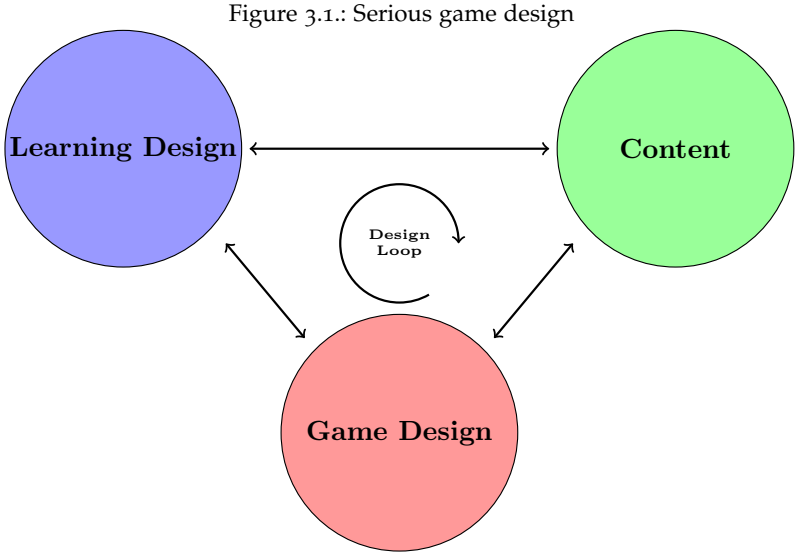
A serious game design for training games includes the three interdependent design elements: content, learning design, and game design. When determining these three key design elements one has to account for the dependencies among them. Which of these elements is discussed first might depend on the prioritization of the 'game' and 'serious' component of the favored serious game, since each decision concerning one of these areas might influence the others. Therefore, it could be tackled in a cyclic design approach allowing more control over the decisions made. A graphical representation of these relationships is given in Figure 3.1.

A Base for Serious Game Design

An often used learning approach to incorporate content into a game and, hence, representing the base of serious game design, is experiential learning (De Freitas, 2006). This approach is strongly based on exploratory learning patterns and shows a link with the constructivism learning theory.

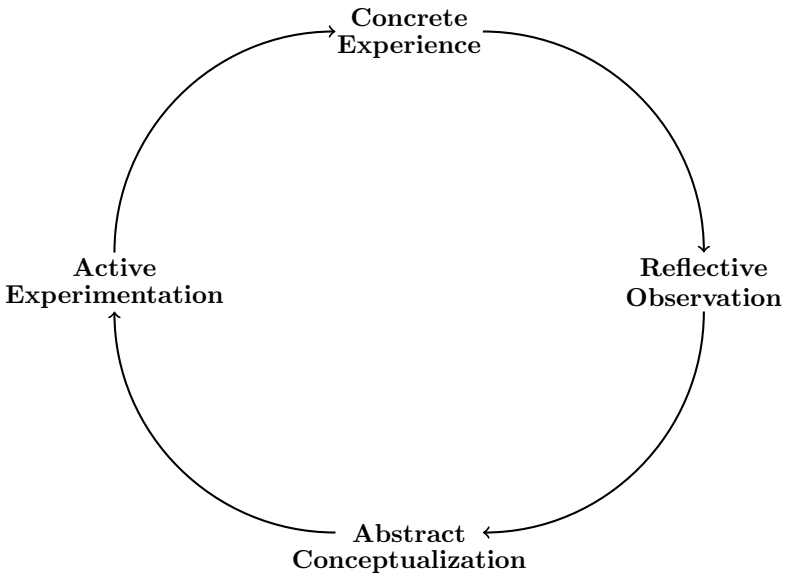
Following the concepts of experiential learning, the learning process may be modeled in a cycle containing the four stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, 2014; Miettinen, 2000). A graphical representation of the experiential learning cycle is given in Figure 3.2.

Figure 3.1.: Serious game design



Graphical representation of the main serious game design elements (De Gloria, Bellotti, & Berta, 2014).

Figure 3.2.: Experiential learning cycle



Graphical representation of the experiential learning cycle (Kolb, 2014).

In order to enable such an experiential learning cycle, the learners need time and the possibility to perform multiple experiments. The time factor, also supported by other sources (Ellenbogen, Hu, Payne, Titone, & Walker, 2007), suggest a game design designated for a longer time period, preferably multiple days or even weeks. This, however, does not mean that learning attempts have to be made all of the time. Besides the time requirement, the game design needs to account for the possibility to perform multiple experiential cycles.

Another crucial element needed for an experiential learning cycle is a problem of some sort, which requires an experiential solving approach in the first place (Kolb, 2014). The problem builds the basis for every learning process (Barrows, 1986). This problem might be the generation of a fixed-valued performance proving the learning gain, typically depicted by a computer opponent. Alternatively, human players can compete with each other, allowing a more flexible problem situation and variable performance limits.

A very central question is the one regarding the game type or genre which need to be suitable for the experiential learning cycle. By investigating the vast amount of game genres one can find the genre of strategic games (Rollings & Adams, 2003). This game genre is described later on, and it turns out that it is suitable to be used in combination with the experiential learning cycle. A closer look at this genre is taken after the discussion about learning outcomes and motivational aspects.

Learning Outcomes in Serious Game Design

Besides the process of learning, the desired learning outcome, for which the revised bloom taxonomy can be used, is also highly important. The revised bloom taxonomy is a multi-tiered model of classifying thinking according to six cognitive levels of complexity (Forehand, 2010). The six included tiers build upon each other, starting with remembering, understanding, applying, analyzing, and evaluating; and concluding with creating. A graphical representation of the revised bloom taxonomy is given in Figure 3.3.

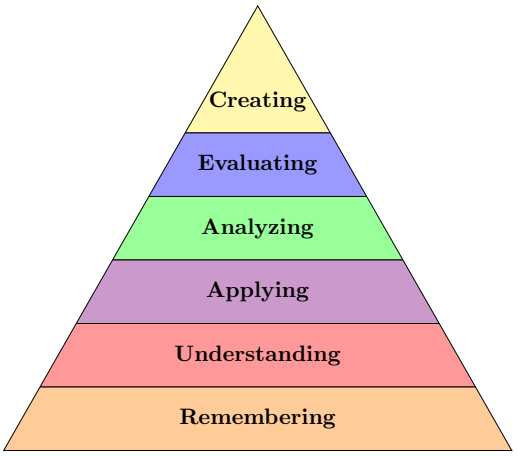
In order to train skills or competencies practically, at least the third tier in the revised bloom taxonomy - applying - needs to be targeted. Ideally, the players also operate on higher levels of the taxonomy, such as the applying or even evaluating tier.

Competitive and Cooperative Serious Game Design

One very central consideration apart from the educational concerns, based on traditional game design, is the methodology for getting the game played. In order to promote the game, competition is an important aspect (Vorderer, Hartmann, & Klimmt, 2003).

In order to access the motivating effect of competition (Schlütz, 2002), a problem is normally created by a competition between the players for the best in-game performance. It is important that the in-game performance directly correlates with the

Figure 3.3.: Revised bloom taxonomy



Graphical representation of the revised bloom taxonomy (Forehand, 2010).

desired behavior, such that a good performance leads to a high in-game performance.

This competitive situation can be coupled with cooperation by introducing teams. Teams of four people seem to be best suited for this purpose (Kameda, Stasson, Davis, Parks, & Zimmerman, 1992). There is evidence that teams of four are suboptimal (Schwabe, Goth, & Frohberg, 2005) in terms of performance, which might be explained by emerging team dynamics for larger team sizes. If training is desired for situations such as team dynamics, a team size of four seems reasonable.

The Strategic Genre - A Suitable Game Type for the Experiential Learning Cycle

The strategic game genre will now be discussed. This seems to be a suitable genre for incorporating the experiential learning cycle. As a genre rooted in board games, it is divided into turn-based and real-time strategy games, as discussed by Rollings and Adams (2003). Pure strategic games are naturally turn-based, which allows the players to think about the consequences of their possible moves. Real-time strategy games add time pressure to the game mechanics, forcing the player to limit the time spent on strategic considerations.

The three central elements of strategy games include the theme, the presentation layer, and the perspective. The theme is used to arouse the player's interest, and conquest, exploration, and trade are frequently used. The presentation layer is used to interact with the game mechanics and should structure the sometimes complex mechanics. It is essential for user acceptance. The perspective determines the player's self-perception in the game. It can range from a game world grand-scale manipulation to small group control.

The role of the player in a strategy game is generally a central one - a leader, commander, or even a god - without using an avatar. This enables the player to control certain in-game units and perform strategic actions to expand and progress.

In this scenario, the units can be workers, warriors, buildings, or even geographical areas. The focus is directed towards an abstract representation of the game world, giving all necessary information about the current state of the game and a visual appearance that makes the game appealing. Therefore, the visuals should not distract the player too much from the game mechanics, which is one big reason why most strategy games are 2D top-down or 3D isometric and tile based.

The following section will take a closer look at one very successful representative of strategic games, namely Ikariam. This game features very special game mechanics, which ensure that the game is not played continuously but spread over a period of time.

The Strategic Genre - A Case Study: Ikariam

To get a better understanding of this genre, the successful strategy game Ikariam[1] is examined and an analysis is conducted based on the considerations of Rollings and Adams (2003). This game is a free browser game introduced in 2008 by Gameforge, a German online-game company. It is played by over 51 million players in 60 countries using 38 different languages ("Ikariam," 2017). As such, it won an award for best online or browser game from 'BÄM!', as well as the German computer games award in 2009. It was also voted the best strategy game of 2011 at the 'Browsergame of the Year Award'.

Theme and game mechanics. The theme of Ikariam is classical Greece, on a group of islands. The player takes over a city on one of these islands and can manage it by gathering resources, constructing buildings, recruiting an army, looting from other players, founding other cities, and trading with other players. A screen shot of the city viewport is given in Figure 3.4. In the following, a simplified explanation of the quite complex game mechanics is given.

Resources can be found on each island. There is always the base resource wood and one of the luxury goods: wine, marble, glass, or sulfur. These resources are collected by assigning workers to the corresponding sites. How many workers can be assigned depends on the expansion level of the site, which can be raised by paying in resources. This site and its expansion level are valid for all cities of the island. A screen shot of the island viewport is given in Figure 3.5. The maximum number of workers available to the player depends on the number of inhabitants and is influenced by the city hall expansion level and the inhabitants satisfaction, which can be influenced by different factors. A special resource is gold, gained from workers not assigned to a site. It is also used as trading currency.

Buildings are a central element of Ikariam, as they unlock multiple opportunities for actions. There is a limited number of buildings spots in the city where buildings can be constructed. They start with level one and can be upgraded to unlock new possibilities or upgrade positive effects. The warehouse, for example, controls the maximum number of resources which can be held by a player. This limit rises with

[1] [06.11.2017] https://ikariam.gameforge.com

Figure 3.4.: Ikariam city viewport

One of the three viewports in the game Ikariam. It shows the city including the already constructed buildings.

Figure 3.5.: Ikariam island viewport

One of the three viewports in the game Ikariam. It shows the island the player's city is located on. On this island there are two resource sources: wood and wine.

each new level of the building. The barracks enable the training of better military units, the trading station reaches further away islands and so on with rising expansion levels.

The army is used to protect the player's city from being looted by players and to loot

from other players. The units are trained in the barracks. These units cost resources and need to be paid with gold over time. When another city is attacked, the armies attack each other, which results in the loss of some units and eventually in the victory of one of the parties involved. If the attacker wins, he or she gets resources from the attacked player.

Trading enables the players to get access to resources not available in their current position, or to quickly get the required resources. Trading is done using the trading station, which shows offers for players within the scope of the trading station. This scope rises with each new expansion level. The currency used for buying and selling resources is gold. Additionally, trading ships are needed, which can be purchased with gold.

Later on in the game it is possible to found more cities, which also require a special building. By expanding this building, a player can found more and more cities. This, however, is only possible on fixed spots on in-game islands. The surrounding islands can be accessed by using the world viewport of the game (a screen shot of this viewport is given in Figure 3.6).

Figure 3.6.: Ikariam game world viewport

One of the three viewports in the game Ikariam. It shows the entire game-world consisting of multiple islands, including the player's island.

Presentation Layer. The presentation layer can be divided into static panels, which are always visible, and transient ones, only shown in certain situations. The static panels allow easy navigation and show the basic data. Furthermore, it grants access to some transient panels. This panel can be found in Figures 3.4 to 3.7.

The transient panels are used to display more detailed information about the state of the game and to manipulate the world. They can be reached either through the

Figure 3.7.: Ikariam game presentation layer

The city viewport of the game Ikariam. It shows a transient panel including information about the chosen building.

static panel or by clicking on units in the game world, such as buildings, cities, and working sites.

Perspective. The perspective the user is experiencing is the one of a dictator. He has the absolute power over everything happening in his realm, including multiple cities. Starting from assigning workers over shipping resources to trading and raiding - everything is controlled by the player.

3.1.2. Selected Examples of Existing Serious Games for Training

The second area of interest consists of the serious games already introduced in the literature, which are important in terms of related work. These games will now be discussed, along with their related application areas, which include the most commonly covered topic: healthcare.

Serious Games for Training in Health Care

Health care is one of the biggest application areas when it comes to serious games and growth is forecasted for the next few years (Susi, Johannesson, & Backlund, 2007). There are different types of health care games; some are intended to inform about healthy living, others train health care personnel, and others provide physical training to healthcare patients. The last two types are relevant for training purposes.

Training for surgery, or other health care interventions where an error might cost a life, are predestinated for training methods that include serious games. A review lists seventeen serious games specifically designed to train professionals in medicine, the majority of which are highly relevant to surgical trainees (Graafland, Schraagen, & Schijven, 2012). Another thirteen commercially available games were identified for the training of laparoscopic psychomotor skills. People can be trained technical and non-technical skills relevant to the surgical field using serious games that have already been introduced into health care.

With the dropping of prices for virtual reality simulations, this technology is also used for training laparoscopic skills (Grantcharov et al., 2004). The results of the Grantcharov et al. (2004) study show, that training with a laparoscopy simulator is able to improve surgical operative performance. Another advantage, compared with practising on animals, is that the performance is not biased by anatomical variation or physiological responses.

Games which require some kind of exercise (exergames) have already been introduced on the games market and are now also a focus for serious games research (Göbel, Hardy, Wendel, Mehm, & Steinmetz, 2010). These kinds of games bring physical, social, and cognitive benefits (Staiano & Calvert, 2011), but mental issues can also be treated with exergames. For example, it has been shown that a 12-week exergame intervention for subsyndromal depression in older adults was able to achieve significant improvements in depressive symptoms, mental health-related quality of life, and cognitive performance (Rosenberg et al., 2010).

Serious Games for Training in Other Domains

Another high-risk application area, where lives are at steak, is fire safety. It is difficult to provide the required skills training using traditional methods; however, a serious game approach brings along several advantages (Chittaro & Ranon, 2009). The biggest of these advantages could include the opportunity to receive training in a variety of emergency situations, which is hardly possible with traditional methods.

A simulation of a fire emergency is used due to the unavailability of a comparable and harmless situation in real life, but there are also other reasons for simulating certain training situations, such as high costs. Experiencing a foreign culture and training people to interact with this culture normally requires a stay at the place in question, but this can be avoided by using a serious game. This was, for example, done for Afghan culture (Zielke et al., 2009). Such games could also be used to train professionals of various disciplines in their working environment in another culture.

For similar reasons, which include high costs in terms of money and time, learning a language within the natural environment of the corresponding country is problematic. A serious game approach combining language and cultural learning shows very promising results (Johnson, Vilhjálmsson, & Marsella, 2005). Especially learners of difficult languages, such as Arabic, might benefit from such applications.

3.2. Serious Games with a Teamwork Skills Focus

This section will discuss related work in the area of serious games focusing on teamwork aspects. By investigating what has already been done in this area, an overview of the current state of research is gained. These insights will be used as a basis for any further considerations.

The literature has introduced a wide variety of serious games related to teamwork skills. An overview of the ones discussed here can be found in Table 3.1 and Table 3.2. One explanation could be Coovert et al.'s (2017), identification of serious games as a suitable tool for team research. Each of these games is somehow related to teamwork - some of them analyze certain aspects of teamwork, while others try to induce a behavioral change towards better teamwork skills. All of them combined can be used to gain a comprehensive image of the current gold standard in the area of serious games with a focus on teamwork.

To discuss the serious games focusing on teamwork in the literature, three categorizations are introduced in the following: main purpose of the game, game focus, and data analysis. A game's main purpose determines whether it is a serious game for analyzing teamwork, or a game for teaching teamwork.. The game's focus, in this context, describes which aspects of teamwork the game focuses on. Data analysis methods are especially important in the case of training games.

Following the considerations in Section 2.3, Serious Games, the definition of a serious game should be reviewed once again to categorize the games discussed into analysis-focused and teaching-focused games. A central element of the serious game definition is the main purpose - which is not directed towards entertainment. This, of course, means that every game that is created with research considerations at its base is a serious game. When looking at Table 3.1 and Table 3.2 some games are purely created to analyze a certain aspect of teamwork during the performance of teamwork-related tasks, not to teach teamwork itself. Of course, some learning will happen due to the engagement with the topic, but no direct attempts at teaching teamwork are made. This is why the section below categorises games ranging from purely analysis-focused games to purely teaching-focused games. In Table 3.1 the dominant characteristic is stated.

Another distinguishing characteristic of a serious game directed towards teamwork is the focus area. As discussed in Section 2.2, the literature investigating teamwork has no clear definition of which components are included in teamwork. This results in many different theories and frameworks explaining teamwork. Due to this discord of theories and the overwhelming scope of the field, teamwork games usually focus on certain aspects of teamwork. These certain aspects are denoted as the focus area of each game in Table 3.1.

One of the main differences between analysis-focused and teaching-focused games is the data analysis or interpretation. In the area of analysis-focused games, the analysis needs to be done once to draw conclusions from the collected evidence. For this purpose the analysis does not need to be automated, it can happen by

Table 3.1.: Related work introducing teamwork SGs

Game	Reference	Purpose — Focus — Analysis
Gazebo	Roberts, Wolff, Otto, and Steed (2003)	analysis — team performance, player contributions, collaboration — team performance: time-to-task completion, self assessment: perceived effectiveness
Tinsel Town	Devine, Habig, Martin, Bott, and Grayson (2004)	analysis —relationship: team effectiveness and participants' diversity — in-game score
Crossing Ravine Tower of Babble Castle Builder	J. B. Ellis, Luther, Bessiere, and Kellogg (2008)	training — team building — observation, debriefing
eScape	Bluemink, Hämäläinen, Manninen, and Järvelä (2010)	analysis — influence of individuals to group interaction — manual chat analysis
Infiniteams	Kaplancali and Bostan (2010)	analysis — leadership in online environments — in-game score, manual chat analysis, online survey
DREAD-ED	Haferkamp, Kraemer, Linehan, and Schembri (2011)	analysis — decision making, communication — in-game performance, observed communication, self assessment skills questionnaire
GaMeTT	De Leo, Goodman, Radici, Secrhist, and Mastaglio (2011)	analysis — level of presence: virtual team-building — questionnaire
TeamUp	Bezuijen (2012)	training — not described — unknown in-game performance indicators
Let's team!	Guenaga, Eguíluz, Rayón, Núñez, and Quevedo (2014)	analysis —confidence (communication, commitment, emotional aspect relation)— direct in-game questionnaires, unknown score indicators
SimVenture	Bhardwaj (2014)	training — lasting impact of decision making, communication — questionnaires
4-C Model	Ramachandran, Presnell, and Richards (2016)	analysis— coordination, cohesion, communication, cognition — questionnaires, in-game indicators
ColPMan	Nonaka, Miki, Odajima, and Mizuyama (2016)	analysis — decision making — manual chat analysis: visualization, characterization - no analysis
Zoom	Bozanta, Kutlu, Nowlan, and Shirmohammadi (2016)	analysis — perceived team cohesiveness — questionnaire
Artemis	Luu and Narayan (2017)	analysis — relationship: motivation, communication skills, efficacy, satisfaction — various (self-evaluation) questionnaires

Various serious games focusing on teamwork introduced in the literature. The name of the game, its authors, and the rough content of the corresponding source is given for each game. The rough content, given in column three is split up into the game's main purpose, it's game focus and its data analysis/collection methods. More details can be found in Table 3.2.

using transcription or other manual approaches. In contrast to this, teaching-focused games need to provide data analysis after each game, or even during the game - if performance-dependent feedback is desired. Although such feedback/performance measurement is not necessary, it seems to be essential to validate the game's usefulness. This feedback, therefore, needs to be computed automatically or a domain expert needs to analyze the performance. The automated version is clearly better suited for comfortable, easily accessible training.

It is not surprising that most games listed in Table 3.1 have an analytical purpose since they are used in research. Only three exceptions are listed: the game collection including Crossing Ravine, Tower of Babble, Castle Builder, the game TeamUp, and SimVenture.

Table 3.2.: Related work introducing teamwork SGs - Type of game

Game	Type/Genre	Story
Gazebo	virtual task	A group of people have to create a gazebo by working together.
Tinsel Town	strategic game	Players manage a movie studio as a group. The group's overall goal is to maximize the profit by making strategic decisions.
Crossing Ravine Tower of Babble Castle Builder	puzzle games	Cooperate and share resources in a group to reach different goals.
eScape	action-adventure game	A group of four players must solve five problems or puzzles together in order to flee from a prison.
Infiniteams	MMOG	Desert island survival game with a random leader in the group.
DREAD-ED	strategic game / simulation	Players occupy a specific role with unique abilities in an emergency management team. They need to work together in order to prevent as much harm as possible.
GaMeTT	team building / virtual task	In this team building activity players have to step onto 30 numbered markers randomly placed in a virtual environment in sequential order as quickly as possible with their avatars.
TeamUp	adventure game	The group of players needs to solve puzzles together in abandoned temples in order to reach places and/or the next level.
Let's team!	adventure, RPG	The players are on an island, where they have to build a civilization together. They can gather resources and use them for their purposes.
SimVenture	strategic game / simulation	The player sets up, manages and grows a business by making decisions based on market, competitor research, customer research, and response to performance feedback.
4-C Model	simulation / virtual task	Different mini-games and simulations within the medical sector.
ColPMan	strategic game / simulation	Each player operates a virtual supply chain of a large-scale make-to-order company by making its production and delivery decisions. They need to cooperate in order to solve problems and reach goals.
Zoom	team building / virtual task	Each player is handed a picture, which needs to be ordered sequentially. Picture B follows picture A, if B is a 'picture within the picture' of A. They need to fulfill this task by talking in a virtual environment.
Artemis	simulation / tower defence	Players with unique roles cooperate in order to destroy enemy ships, and protect their own ship and space stations. They do it by jointly navigating a space ship.

Various serious games focusing on teamwork introduced in the literature. The name of the game, it's type or genre, and the in-game story is given for each game. The literature in which each game was introduced is given in Table 3.1. The term 'virtual task' in the 'Type/Genre' column specifies, that in this game a specific task need to be fulfilled without any context.

Serious Games with a Training Purpose

The aforementioned game collection (the game collection including Crossing Ravine, Tower of Babble, Castle Builder, the game TeamUp, and SimVenture) focuses on design decisions made when developing games for team building as one manifestation of teamwork skills training (J. B. Ellis, Luther, Bessiere, & Kellogg, 2008). Although team building might be an important factor in a team's success, it can barely be seen

as teamwork competence since it is a process, and hence, might be out of scope. The second game mentioned, TeamUp!, is the product of a master's thesis and focuses on the implementation aspect (Bezuijen, 2012). The theoretical framework used is inadequately described and it lacks scientific justification due to the thesis' focus. The last mentioned game, SimVenture, is already used in a university context (Bhardwaj, 2014), but its game design is unfortunately not accessible.

Serious Games with an Analytical Purpose

All the other games (Gazebo, Tinsel Town, eScape, Infiniteams, DREAD-ED, GaMeTT, Let's Team!, the 4-C Model, ColpMan, Zoom, and Artemis) focus on analyzing one or more certain aspects of teamwork. It is important to understand that those games are not intended to directly teach teamwork skills, but might be a useful tool to gain more insight about how to construct a game in order to do so. Bluemink et al. (2010), for example, investigated the influence of individuals on group interactions. One interesting finding was that unequal participation of individuals weakens the group's possibilities for developing a shared understanding. In relation to this, they also found that it is crucial to design tasks in a manner that forces players to work together.

Such a teamwork-enforcing design can be found in the Artemis game (Luu & Narayan, 2017). Each player fulfills a role on a spaceship: steering the ship, firing the weapons, or navigation. This is a very radical approach to enforce teamwork, but a similar approach is also used in other games (Bozanta et al., 2016; Nonaka, Miki, Odajima, & Mizuyama, 2016; Haferkamp et al., 2011; Roberts, Wolff, Otto, & Steed, 2003). This teamwork-enforcing design takes away the possibility for the player to decide if she or he is willing to work in the group rather than working alone. This might be done on purpose, or not - one should be aware of this fact. The willingness to start teamwork and decide when teamwork is appropriate could also be seen as a teamwork skill.

The game GaMeTT is used for researching the level or presence in team-building activities in a virtual environment (De Leo, Goodman, Radici, Secrhist, & Mastaglio, 2011). They aimed to find out which user groups are more responsive to virtual training. The game does not introduce a complex game; it consists of the simple task of moving the avatar to a spot at the right time. This simple structure is limiting with respect to the software application area - it only seems to be applicable to the study that was conducted.

The trend of focusing on the theoretical aspects of the game is also visible in other games, such as 'Let's Team!'. Guenaga, Eguíluz, Rayón, Núñez, and Quevedo (2014) introduced this game on a solid theoretical basis but a limitation of this study was the absence of data gathering and analysis. Also, Ramachandran et al. (2016) and Devine, Habig, Martin, Bott, and Grayson (2004) introduce a well-described theoretical approach to constructing a serious game but, their work was also limited by the absence of an analysis.

There are also examples from the other extreme: evaluating a game based on in-game data and questionnaire results, but not explaining the game in an appropriate manner. Kaplancali and Bostan (2010) introduced the game 'Infiniteams', and provided a data analysis of the game's perceived effectiveness, but did not adequately explain the software content.

3.3. Research Questions

Based on Chapter 2, Background, and the preceding considerations in this chapter, a research question will be formulated at this point.

As we have seen, there are a wide variety of serious games related to teamwork already introduced in the literature. Only a small fragment are directed towards training in aspects of teamwork. Games that provide training in teamwork competencies suffer either from a poor theoretical serious game design or they require an additional physical component supervised by a teamwork expert.

This thesis, therefore, aims to investigate the possibility of creating a well-founded serious game for teamwork competencies training. This game should be designed for purely virtual use, meaning with no need for a physical component or a teamwork expert. The related research question (**RQ**) reads as follows:

How can a purely virtual serious game be designed to develop teamwork skills?

Due to the great importance of some aforementioned concepts in the literature, sub-research questions are formulated to examine them in more detail. On the one hand, there is the experiential learning cycle used to explain and foster learning in games. On the other hand, there are the motivational approaches considered in games, such as competitive and cooperative approaches or the game's genre, e.g. the strategic genre. This leads to the following two sub-research questions:

SRQ1 How suitable is the experiential learning cycle for integration into a teamwork training game from the perspective of learning and teaching?

SRQ2 How suitable is a competitive and cooperative approach in combination with a strategy game for creating a teamwork training game?

3.4. Summary

This chapter discusses related work in the area of teamwork training composed of serious games for training purposes and serious games with a focus on teamwork.

Serious games for training require a well thought through serious game design, containing learning design, content, and game design. A fundamental tool to combine the game with the content is a learning approach, such as the experiential learning cycle. The anticipated learning outcome, which can be characterized by the revised

bloom taxonomy, plays a central role by integrating the chosen learning approach. Other aspects that are also used in entertainment games, such as motivation through cooperation and/or competition, also need to be considered.

Games introduced for training are strongly dominated by the healthcare sector. This high-risk environment, which sometimes decides upon life or death, desperately needs a safe way to train stuff in the required skills, such as laparoscopic psychomotor skills. However, serious games are also used for training in areas other than healthcare, especially when the alternative training is dangerous, time-consuming, and/or expensive.

A wide variety of serious games for teamwork were introduced in the literature, but only the minority are intended for training purposes. The main part of these games is used for team research, as serious games have proven to be a suitable tool in this subject area. These games, which aim to train people in teamwork skills, suffer either from a poor theoretical serious game design or a component required in the physical world.

The research question **'How can a purely virtual serious game be designed to develop teamwork skills?'** is introduced, and supported by two sub-research questions.

In the next chapter, a serious game for teaching teamwork skills based on the experiential learning cycle is designed.

4. Serious Game Design

This chapter will discuss the basic serious game design for this thesis' game about teamwork training, which leads to a high-level game description. The aim is to describe the serious game for teamwork training independently of the software, hardware or visualization. This includes the basic idea and the educational design goals of the game forming the foundation for the abstract serious game design. This abstract educational game design is based on related work in Chapter 3, composed of three elements, namely educational content, learning design, and game design. As a main element of the design process, the mapping between the teamwork competencies taught and game mechanics is identified. In a final step, the very basic software architecture of the serious game that was designed is described.

4.1. Basic Idea and Design Goals

In the previous two chapters, multiple approaches and ideas concerning serious games and in particular educational games have been shown. There are also educational games focusing on teamwork training to be found in the literature. Some of them focus on the game aspect, pushing the learning design into the background or omitting it completely. Others have a detailed educational approach with learning design as a central component but, require off-game support from a trainer in order to be useful. What is missing is a well designed educational game, including learning design and game design in combination with well-founded educational content, functioning without the support of physical educators during the game.

The intended area of application and the target user group exert a very strong influence on design goals. In order to ease the testing, as well as to increase the usefulness both, the area of application and the target user group are taken from the context under which this design process is happening - the academic area. Furthermore, for a strategic game following the example of Ikariam, discussed in Chapter 3, Related Work, embedding the experiential learning cycle is anticipated.

The target user group, as the first design criteria, is undergraduate students, which enables easy testing of the game that was created, as well as later application of the teamwork training game. It seems natural to limit the target group in a first design attempt in order to deduce better design approaches and to discover weak spots in the realization. Also, undergraduate students as a primary user group provide an easily accessible, and logical consistent testing population.

Based on the training of undergraduate students, the objective is to design a serious game for teamwork training in which the individual team members are trained and not the team as a whole. We, therefore, use the teamwork components identified in Chapter 2, Background, as a basis. Each individual playing the game should be trained in these teamwork components. The aim is to alter their behaviour to a more desirable one in future teamwork situations. It is assumed, that the team in the training situation is assembled for a short period. Hence, training of the team as a whole seems inappropriate.

The area of application, as the second design criteria, is an organized group game within a university course. Although a combination of multiple unrelated students from different courses might be a valid option, the advantages of an already established group feeling, amongst students involved in the same course, is appreciated. It counteracts the sense of isolation that is sometimes felt.

Besides these two extrinsic design goals, there is a major intrinsic design goal for implementing the teamwork skills training game, namely a well-conceived and state of the art learning design. Besides game design and content, it is one of the three major design elements involved and could be seen as the most important one with respect to the training quality of the learning game. For a successful training game, all three of these aforementioned elements are equally important, as each contributes in a different way.

An important consideration within the game design is the one dealing with motivational aspects of the game. In this regard, it should be possible to use the motivating potential of competitive and cooperative elements. These two approaches fit well with the strategic genre, which is also a suitable genre for incorporating the experiential learning cycle as discussed in the previous chapter.

4.2. Serious Game Design

In the following, a serious game design approach is described including the three interdependent design elements: content design, learning design, and game design based on the considerations of Chapter 3, Related Work. When determining these three key design elements, one has to account for the dependencies among them. Which of these elements is discussed first might depend on the prioritization of the 'game' and 'serious' component of the favored serious game, since each decision concerning one of these areas might influence the others. Therefore, it could be approached with a cyclic design approach, allowing more control over the decisions made. The result of such a cyclic design approach will now be described. A graphical representation of these relationships is given in Figure 3.1.

4.2.1. Educational Content Design

Before discussing the content that is incorporated in the game, the desired learning outcomes of the planned game are discussed. These have been influenced by the wider subject area of teamwork. Due to the inherent nature of teamwork, it always occurs in a team and is mostly of practical relevance, although theoretical teamwork knowledge may be used to induce practical teamwork skills (Hatlevik, 2012). This practical essence of teamwork suggests mainly communicative learning objectives best targeted with a multiplayer game for gaining access to teamwork dynamics.

For achieving a mainly communicative learning outcome the components involved in a teamwork process need to be identified. There are many possible ways to partition the subject area of teamwork, and they have been utilized by various authors (Coovert et al., 2017). Although there are many different teamwork taxonomies, the cores features of these taxonomies overlap very strongly, as shown in the previous chapters.

Condensing the taxonomies of various authors and the considerations in Chapter 2.2, Teamwork Research and Components, lead us to five teamwork components, which are orientation, monitoring, adaptability, communication, and leadership. These five teamwork components now need to be linked to the game mechanics, as shown in Table 4.1. A more concrete mapping is given in the game design section.

4.2.2. Learning Design

Following the considerations in Section 3.1.1, Elements of Serious Game Design, the experiential learning cycle is used, as shown in Figure 3.2. The basis for this learning approach is the possibility for the learners to conduct multiple experiments and their awareness of this fact. A comparison of these multiple experiment outcomes entails learning due to the experiential learning theory.

The experiential learning approach requires a problem to be solved, and this is addressed by introducing a multiplayer environment in which teams of four players try to beat each other in terms of a team score. By comparing team score gains from different time periods, the team can evaluate their scores in order to get insights into their performance. A comparison to other teams' scores allows an overall performance comparison for the teams. These scores represent the practical teamwork capabilities of the corresponding team.

When using the team score as a substitute for team performance, it is crucial that the score really expresses a good team performance. This means that a good team performance leads to high performance indices for the teamwork dimensions involved and that these high indices result in a high team score. Reversed, a bad team performance has to yield low performance indices and a low team score. This is important because it is assumed that teams adapt their behavior to one that yields a high team score in order to solve the stated problem - beating the other teams. The chosen performance indices are discussed in the game design section.

Table 4.1.: Generic teamwork component mapping

Component	In-Game Realization	Metric
Orientation	Introduce team and individual goals by e.g. introducing scoring for team and individual performance.	A weighted ratio of team efforts and overall efforts.
Monitoring	Introduce changing environmental conditions influencing the chosen path of action to gain a high team score. Allow comparison with other teams if there are any.	Measure quantities related to access of monitoring tools, i.e. average time spent using these tools and number of times accessed.
Adaptability	Introduce possibilities to change the chosen path of action to meet changed environmental requirements. Introduce a light version of trial and error game mechanics.	Average time to adapt course of action to changed environmental conditions. Time spent finding 'good' solution with trial and error approach.
Communication	Distribute different functions (such as monitoring and adaptability) over multiple players. Force players to exchange resources/information.	Average reaction time to messages received when using text chats. Compare speaking time/number of words used with those of other players. Use communication frequency.
Leadership	Monitoring of communication behavior, analysis of communication logs.	Compare characteristics of communication quantities.

A example of generic, and high-level mapping between teamwork components, game mechanics, and performance indices.

In order to be able to pass through the experiential learning cycle as often as possible and to promote cognitive learning processes, the game is constructed for a longer time span. It is not necessary for the players to play the game for the whole time span, as short gaming sessions over several days or even weeks are desired. In this way, the players deal with the game over a longer time period, which increases the possibilities for cognitive processes leading to learning gains.

The measures discussed in this section are important for the game design that is invisible to the player, such as the experiential learning cycle, which is hidden within the game mechanics. Visible measures also need to be incorporated to support this design. The most important game element for this purpose may be leaderboards which allow access to the team scores. These leaderboards should be accessible to the player throughout the gameplay and should allow an easy comparison of their own performance at different time intervals as well as a comparison with other teams.

In addition to unrestricted access to the leaderboard, it is also reasonable to give each player a small mandatory analysis update of the team performance based on

the leaderboard. Within regular time steps, the leaderboard is shown to the players in order to promote performance monitoring and the experiential learning cycle.

To sum up the learning design section, it is desired to have an experiential learning cycle lasting several days or weeks, including a competitive in-game performance situation for teams of four requiring practical teamwork, which directly influences the in-game score.

4.2.3. Game Design

Each of the five most common concepts of teamwork - leadership, communication, orientation, monitoring, and adaptability - has special requirements with regard to its usage in a serious game. Leadership, for example, may enhance the relationship among team members leading to better project success (Yang et al., 2011) but can hardly be taught to all players in a symmetrical multiplayer game, due to the unique position of a leader in a team. Therefore, this component will not be considered in the game.

The three teamwork components orientation, monitoring, and adaptability require some kind of feeling and awareness of being in a group with a common task or goal. Team orientation, for example, stresses the priority of team goals versus individual goals, as well as sharing information and problem-solving. Performance monitoring and adaptability could also be interpreted in the context of one's own scope, but in this team setting it is clear that these terms explicitly focus on team monitoring and team adaptability.

In order to incorporate monitoring and adaptability, one could include asymmetric information about team performance, as well as asymmetric capabilities to alter the team's course of action. It is important to understand the close link between monitoring and adaptability. Furthermore, it is also important to separate those two functions in a game to be better able to evaluate how such functions are used in combination with communication.

Communication does not necessarily require a team structure to be taught. It could also be imparted in a highly competitive situation where loose cooperation is needed to gain advantages. Of course, this would alter the form of communication. In a team structure, communication might be more cooperative whereas in a competitive environment self interests are of higher priority.

An important step in designing an educational game is to link learning content to game mechanics. A general, example approach is given in Table 4.1, showing possible links between the four components of teamwork identified and used and game mechanics in a multiplayer game. The metrics included in the table use similar simple quantities to Ramachandran et al. (2016).

Before further developing the links between the four components of teamwork that were used and game mechanics, the game genre, motivational aspects, and the in-

game story of the proposed approach is discussed. The genre discussion is especially important since it defines the basic game mechanics and the type of game.

Motivation

A very central question, besides the game genre, considers the motives of the players - why do they play the game? Why should they follow the team and/or individual objectives? The serious game implementation will use competition, a known key element in games, for both purposes. How successful these approaches are in the individual case also depends on one's player type, discussed in Section 2.3.3, Game Concepts.

Challenge is an important construct when it comes to intrinsic motivation (Malone, 1981). Intrinsic motivation, the behavior driven by a person's internal rewards, is a very powerful tool when it comes to giving meaning to activities. This is also true for the special case of challenge - the competition.

Competition is regarded as a key element of the player's entertainment experience (Vorderer et al., 2003; Schlütz, 2002). The competition arising from a social situation, in which the player competes with another player, is of huge interest. This kind of competition is called social competition. Using human opponents in social competition is a highly useful tool to enhance the playing experience, but might also lead to aggression in the case of being defeated.

The fact that all players compete against each other in a highly competitive situation leads to one winner and a lot of losers which is a potentially problematic situation. This presence of defeat introduces the possibility of a victory - one cannot be without the other. The level of challenge decides the value of a victory. In this sense, the value of victory is very high in a game situation where everyone is against everyone.

The same reason that makes a victory over many players more valuables, makes a loss in this situation less devastating. One can use the excuse that there were too many players, which makes winning a difficult task. This can be compared to a lottery situation, where losing is not really a bad thing, but winning is extraordinary. Additionally, losing against a human player is not as frustrating as losing against a computer (Williams & Clippinger, 2002).

In order to allow and support competition in the serious game implementation, each player should be able to compare their current scores. This includes the team scores as the team objective, as well as the individual player scores as an individual objective. Hence, the access to a score ladder will be possible from within the game.

Teamwork Components - Game Mechanics Mapping

Starting with the four teamwork components - orientation, monitoring, adaptability, and communication - a feasible, more concrete mapping with game mechanics is needed, based on the general mapping given in Table 4.1. These considerations are

based on the game mechanic term discussed in Section 2.3.3, Game Concepts. The mapping strongly depends on the range of possible game mechanics, which are determined by the type of game. In our case, the strategic game genre enables us to incorporate teamwork activities very naturally.

The basic game mechanics for a strategic game are based on the game architecture of Ikariam are described in the case study in Section 3.1.1, The Strategic Genre - A Case Study: Ikariam. The most important ones used in the proposed design are stressed here once again. They are resource gathering by deploying workers in gathering sites, creating or upgrading buildings by spending resources, and the bonuses gained by creating and upgrading buildings. It is essential, that the building time within the game flow starts low and rises over the course of the game in order to encourage players to play the game repeatedly over a given period of time.

To begin with, a closer look at the identified teamwork components would be appropriate. Each of the chosen components has a vague and inconsistent definition across the literature. Also, some of the concepts can be clearly divided when they are abstract concepts, but cannot be separated in practice. For example, communication is also integral when it comes to adaptability. The start is done with the teamwork component definitions of Salas et al. (2005).

Orientation

A very central success criterion of a team is team member orientation. Even if one team member is not working towards the team goal, despite possible individual objectives which might conflict with the team goal, the team outcome suffers. The same holds true if not all team members' opinions and ideas are considered in the decision making process. This would easily isolate single team members. For transporting these ideas into the implementation, a formal definition is needed.

The team orientation of a team member is defined by her or his willingness to note and consider other team members' contributions, as well as prioritization of team goals versus individual goals. The attitudinal nature of this component requires either invasive assessment by querying the orientation attitudes directly or non-invasive assessment by interpreting in-game action influenced by the player's orientation attitude.

Since non-invasive measurement is favored in games to maintain the flow, a suitable interpretation of in-game events is needed for a player's team orientation. There are two possible quantities which can be focused on following the definition: the prioritization of goals and the tendency to consider team members' contributions.

For prioritizing individual and team goals, both have to be included in the game. It seems clear, that these goals need to be conflicting with each other in some way. If this is not the case, the player could simply fulfill both type of goals and hence, no prioritization has to be done. By having both types of goals, one can calculate the ratio of actions taken in order to reach the team goal to overall actions taken. This number in the interval between zero and one can be used as an indicator of how strongly oriented the player is towards the team goal.

Assessing the tendency of a player to consider team members' contributions is difficult to measure non-invasively. This requires an analysis of the communication, which needs to be converted to text if not in textual form already. An automated analysis of texts that include multiple parties needs to be done, which is a challenging task even when done manually. Querying the player invasively on how they perceived the acceptance of their contribution and other team members' contributions seems to be the easier choice. In any case, a group communication channel would be required.

With respect to the strategic serious game, the team goal is naturally based on the resource income. The simplest way would be to translate the resources possessed by all players directly to a team score. This approach may not be very satisfying and would also not be beneficial for the team feeling. To make this game mechanic more appealing, one can introduce resource transfers to a team account and team buildings.

By introducing a team account for resources, the player perceives more control over his in-game resources and it also promotes a team feeling. The player can decide for himself if, and how many resources he wants to transfer permanently from his account to the team account. It also makes it clear that the players are connected and that cooperation is useful.

Team buildings can replace or complement resource spending, which makes the process more interesting. Instead of just changing some numbers, one can actually see a change happening. Of course, an expanding building can be used to visualize the rising resources in the team account, which will have the same effect. Buildings might bring other bonuses for all players of a team as well.

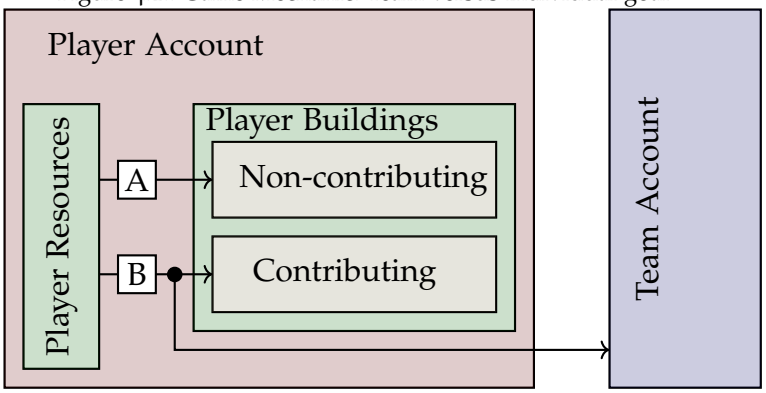
The individual goal of the player also has to be based on the resources income and needs to be in conflict with the team goal. An easy way to achieve this behavior is to allow resource spending on buildings that do not contribute to the team goal. Since these resources are spent they cannot be transferred to the team account in any way. The only thing missing is a reason for doing this, such as an individual score.

An individual score based on the team's in-game performance, as well as player-specific building scores can be used as the individual goal. The building score could be based on the buildings created by a player. A building, therefore, contributes to the individual score and might also contribute to the team score. The contribution to the team score can be context dependent.

To sum up, the player is able to contribute resources from the player account either in a way that helps to reach the team goal or in a way that does not help to reach the team goal. Resources can be spent on useful buildings in terms of reaching the team goal, or can be directly transferred to the team account. In this way, they contribute to the team goal. They can also be spent on buildings that do not contribute to the team goal, but only support the individual goal of the player. This relationship is shown in Figure 4.1.

Monitoring

Figure 4.1.: Game Mechanic: Team versus individual goal



Graphical representation of the game mechanic 'team versus individual goal'. It is used to evaluate the orientation dimension of a player's teamwork skills. Resources spent on not-contributing buildings (A) and resources spent on either contributing buildings or put towards the team account (B). A simple orientation metric can be calculated as $B/(A+B)$.

Monitoring other team members within the workflow allows for early error detection and ensures better team performance. In order to do so, each team member has to be aware of the task and the responsibilities of their teammates, that is, the environment. Also, the monitoring process needs to be supported by the available infrastructure to make it possible in the first place. By considering a formal definition, the incorporation of this aspect in serious game implementation can be discussed.

Mutual performance monitoring is concerned with developing a common understanding of the environment, and with applying strategies to monitor team members' performance. Feedback is also part of this teamwork component. It is crucial to a team's success to keep track of other team members' work and not just one's own work. This behavior allows early error detection and a correction of lapses by using feedback.

For this teamwork component, two major quantities can be focused on: the development of a common understanding of the environment, and the application of strategies for monitoring team members' performance. Assessing the degree to which a common understanding evolved within a team might be done best using invasive methods. Meeting requirements for monitoring a team member's performance can be measured easily.

In order to be able to measure someones efforts to monitor team members' performance, the game mechanics could offer this possibility explicitly. A certain view or option could allow a player to do such a performance check. The time spent using this tool could be combined with the number of communications started after using this tool, in case a lack of performance is present, to draw conclusions about the manifestation of this teamwork component.

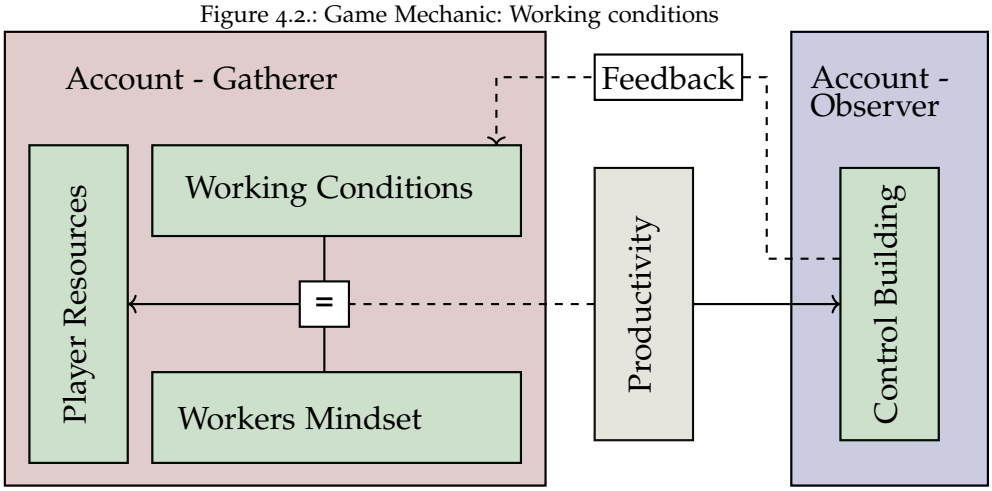
With respect to the strategic serious game, focusing on the application of strategies for monitoring team members' performance allows us to avoid invasive methods. A simple way to achieve this mechanic would be the introduction of control buildings. In addition, a player-specific quantity that can be monitored needs to be introduced.

This quantity has to have an influence on how the team goal is achieved, and in this case it may influence the resource gathering speed.

A reasonable quantity to monitor could be the working conditions within each gathering site. One option could be working bonuses given to the workers. Depending on the (for the deciding player) unobservable state of the workers at one site, the gathering speed is changed, with one bonus option to gain the maximum gathering speed. This worker state changes in regularly and randomly influenced time intervals to random values. This state could then be identified by a team member having a control building. A shortcut button to message a team member in the corresponding building menu could be used to track the monitoring tendency of the player.

To sum up, the productivity of the player's workers (gathering resources) depends upon the alterable working conditions set by the player for all sites and workers. It also depends upon the unobservable, unalterable, randomly changing mindset of the workers (also referred to as environment variable), which need to be mirrored by the working conditions in order to get high productivity. The productivity can be observed by a team member which is able to see which changes to the working conditions are required in order to gain the highest productivity. How detailed the information presented to the team member is depends upon the expansion state of the control building. This relationship is shown in Figure 4.2.

Figure 4.2.: Game Mechanic: Working conditions



Graphical representation of the game mechanic 'working conditions'. It is used to evaluate the monitoring dimension of a player's teamwork skills. The productivity depends upon the working conditions and the workers mindset, which need to coincide for a high resource gathering performance. The productivity can be monitored by a team member (observer), which can report the productivity back to the player (gatherer). It can then be adjusted to gain higher productivity. Each player is a gatherer and observer to exactly one team member.

Adaptability

A related, but clearly different teamwork component influencing the team's success is the tendency to observe changes in the environment related to the team's goal. The path of action for completing the team's objective is usually made at the beginning of the teamwork process. Hence, changes which would lead to a different path of action for completing the team's objective need to be discussed in the team and sometimes

alteration is required. With the help of a formal definition, the discussion on how this dynamic can be integrated into the serious game implementation can be started.

Adaptability is characterized by the ability to adjust strategies based on new or changing information gathered from the environment. Depending on the kind of adaption, different metrics can be defined. These metrics can include simple binary quantities showing if an adaption happened or more complex ones, such as the average time taken to adapt after new information is available.

With respect to games, the adaptability can be incorporated by different means. Two obvious ways are to either introduce a changing environment or to allow the discovery of information regarding the approach for finding a solution. The difference would be mainly based on the authenticity of the method used. An environmental change could be either included locally for one team or globally for all teams. The same holds for the validation range of newly discovered information.

Another difference would be the implementation effort for the adaptability-information discovery mechanic. Whereas changing environments, such as weather conditions, can naturally change very frequently, the same does not hold for newly discovered information. Each piece of newly discovered information must lead the team closer to the correct behavior/goal/specifications. In the first case, an easy random behavior could be used, whereas in the second case more complex mechanics might be required.

With respect to the strategic serious game, a changing environment can be created by giving bonuses on the team score when transferring resources in a certain way/format. This could be either the type of resource, the number of resources, or even a combination of both, including a ratio between resources. The bonuses can also be coupled with a combination of buildings and resource transfers.

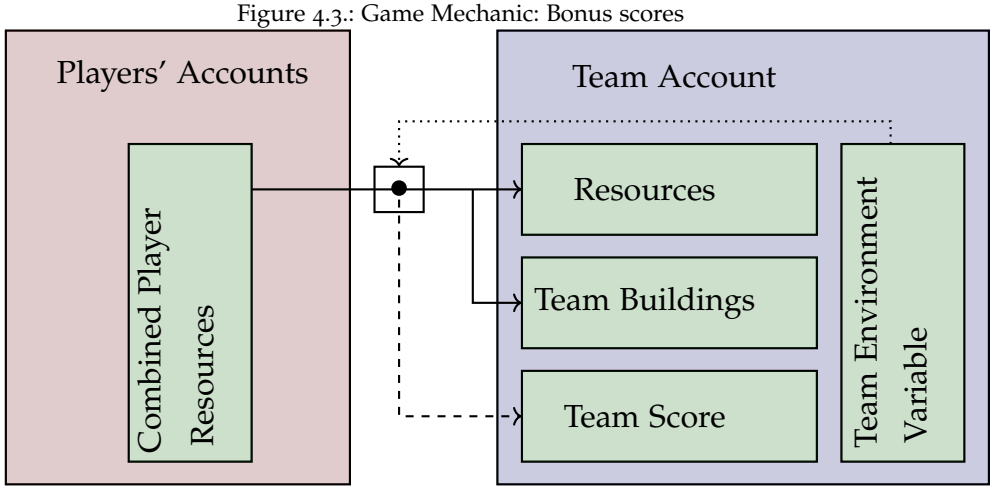
To sum up, players on a team transfer resources to the team account and receive team bonus scores. These bonuses are dependent upon a changing environmental variable, which is the same for all players, and visible to all. This relationship is shown in Figure 4.3. This mechanic brings advantages to teams that adapt to environmental changes.

Communication

The ever-present aspect of teamwork communication, connects each of the aforementioned teamwork components. It is the way to exchange information, discuss strategies and find solutions in a team. This is why communication is of central importance when it comes to the team's success or failure. This aspect is included in the serious game implementation based on the following definition.

Closed-loop communication is concerned with exchanging information. This especially includes precautions that the information sent is the same as the information received to prevent miscommunication. It seems to be impossible to reliably measure the rate at which communication is performed successfully, regardless of whether a non-invasive or invasive method is used. Even if all parties involved think that

Figure 4.3.: Game Mechanic: Bonus scores



Graphical representation of the game mechanic 'bonus scores'. It is used to evaluate the adaptability dimension of the team's teamwork skills. The players on a team can transfer resources to the team account, which increases the team score. Depending on the team environmental variable (visible to all players), bonuses are granted in addition to the points received by the team.

their communication was successful, it does not mean that it actually was successful, which is a big problem when dealing with communication.

A simpler approach for serious game purposes may be to find a way of including the teamwork component communication. Instead of taking the transfer of information as the basis for communication, one could consider the basic communication behavior. This can be done, for example, when considering written messages in an email-like environment. Interesting quantities are for example the quantity of communications started by a player or ended by the player.

Besides information on communication start and end, behavioral data related to communication can be interpreted. This could be, for example, the average time needed to return a message. However, not only the average time is of interest, and the number of times the player saw the new message without reading it could also be tracked. Another promising quantity is the ratio of written words divided by the number of overall included (written and received) words.

With respect to the strategic serious game, the group internal, group external, or both types of communication are used for this purpose. It is clear that a group communication channel is needed for an efficient decision-making process. This leads us, in combination with the existing message system including all players, to two possibilities where the communication component metric can be applied.

The communication behavior will be strongly influenced by the game settings concerning the resource gathering. Assuming that all members of a team are able to simultaneously gather all available resources, no trading and hence no group external communication would be required. One game mechanic that is already included, the limited number of workers, currently restricting the players' possibilities. This would force the players to distribute different work tasks in order to be functional as a team. Further suitable limitations could encourage players to communicate more.

Possible resource gathering limitations with impacts on communication are, for example, the single resource game mechanic, the site experience game mechanic, and the resource fluctuation game mechanic. All three of these game mechanics try to force the player to only gather one of the available resources. In combination with a lower number of players per group than resources, trading and, hence, communication is required.

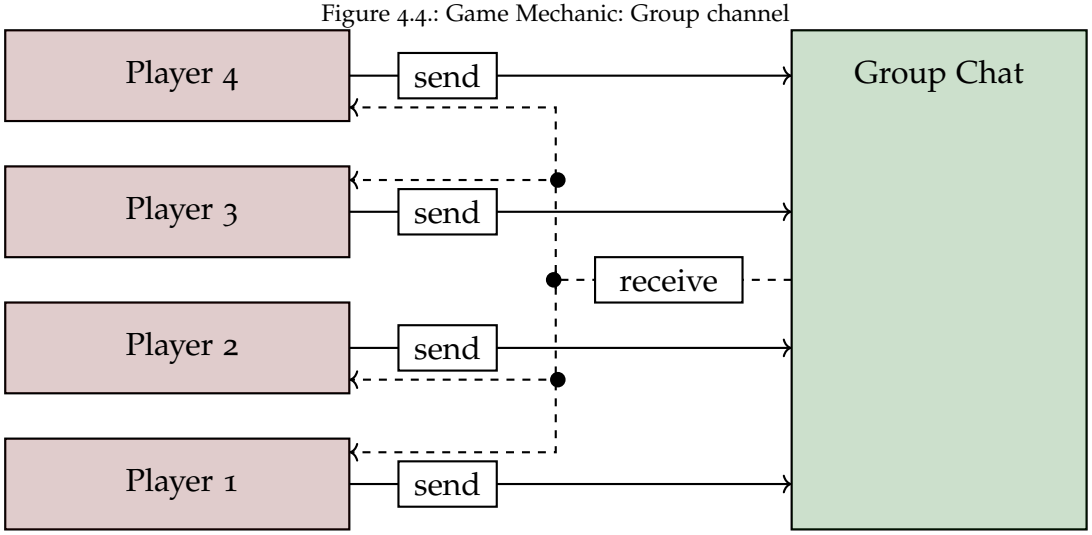
The single resource game mechanic simply allows to only build one of the available gathering sites, and in this way, restricts the access to the other resources. It is the most simple of the three approaches and might lack in-game justification.

The site experience game mechanic grants each site experience point when gathering resources. A higher number experience points automatically raises the gathering speed. In this way, the number of resources gathered would be highest when only gathering one resource type. This game mechanic does not prevent the players on a team from group intern gathering all the resources, but this behavior would be less successful when it comes to gaining a high team score.

The resource fluctuation game mechanic, in contrast to the previously presented game mechanics, change the initial situation of all players. Instead of equal gathering speeds for all players, each player starts with one resource having a high gathering speed and all others having a low gathering speed. The difference should be so high that focusing on only one resource seems reasonable to most players.

To sum up, communication is measured very simply by counting the words and messages exchanged. The basic functionality is shown in Figure 4.4. There are a range of possible game mechanics that foster communication among players.

Figure 4.4.: Game Mechanic: Group channel



Graphical representation of the game mechanic 'group channel'. It is used to evaluate the communication dimension of the player's teamwork skills.

Conclusion

In summary, there are multiple ways to incorporate teamwork components using different game mechanics. For this thesis, only a subset of the aforementioned game mechanics is used. The decision about which ones are chosen for the presented approach is made in the following section for the teamwork components orientation, monitoring, adaptability, and communication. These game mechanics are listed in Table 4.2.

Orientation is considered in the serious game implementation by the team versus individual goal game mechanic; the tendency to consider others' contributions is left out. In a further step, one could also incorporate text analysis. This leaves us with the team versus individual goal game mechanic, which is included by introducing a team account and team buildings forming the basis of the team score.

Monitoring is considered in the serious game implementation using the working conditions game mechanic. Each player is able to adopt the working conditions of each of there sites in the form of working bonuses. The bonus is a percentage of the resources gathered, ranging from zero to ten percent for outstanding work. Depending on the current mindset of the workers this bonus setting increases or decreases the resource income. The mindset of the workers can only be observed by one of the player's teammates when they have a certain control building. A shortcut to the text message functionality enables tracking of the monitoring and feedback behavior. Also, the number of times the control building is visited is taken into account.

Adaptability is considered by the team score bonus game mechanic. This includes the transfer of resources and the construction of team buildings. Having constructed a certain team building the information about the bonuses is revealed to all players of the team. The conditions to get a bonus change over time.

Communication is considered in the serious game implementation by introducing the group channel game mechanic. For each player, the average number of words per message and the number of sent messages are tracked. This information is intended to give insights about the player's involvement in group discussions.

Table 4.2.: Teamwork component mapping for implementation of the serious game

Component	**Game mechanic**	**Metric**
Orientation	Team versus individual goal	Tracking the number of resources spent for the team account and resources spent without contributing to reaching the team goal.
Monitoring	Working conditions	Tracking of the times at which the control building is visited. Tracking of sent or missing feedback.
Adaptability	Bonus scores	Tracking of the bonuses gained by the team.
Communication	Group channel	Tracking the number of words and the number of messages for each player.

This table shows the game mechanics used in the serious game implementation.

Story

The in-game story, discussed in Section 2.3.3, Game Concepts, is used to wrap the game mechanics into an appealing and reasonable appearance, and is a very central and important game element. Although it is not of primary importance in a strategy game, it can be used to motivate the available in-game actions and provides reasons for them (Rollings & Adams, 2003).

The story needs to explain multiple game mechanics, such as resource gathering, building creation, player grouping, the existence of the team account, the individual goal, and the team goal. This list can be supplemented by considering more and more fine details of the game design and depends strongly on the chosen level of detail.

The decision for a specific story can be based on its ability to justify the game mechanics, but also on other considerations, such as its motivating capabilities and its level of related controversy. Adventure stories with pirates might be more appealing in comparison to accounting activities. Controversial stories, including sex, violence, religion, and/or politics need to be handled carefully. Of course, motivation and the level of controversy also depend on the target user group.

A suitable story can be depicted by a religious war among different gods. In this setting, each player is the leader of a town worshiping a certain god. The scenario is set in the past, in a certain culture, such as the Viking, Roman, Egyptian, Greek, Maya or even an imaginary culture. In this context, gathering resources and creating buildings is natural. The teams are grouped based on the god they are worshipping.

Based on the common in-game beliefs of a team, the team goal is to strengthen their god as much as possible. This can be done by building temples for their god and sacrificing resources to them, which explains the team account and the team goal. The individual goal can be defined as becoming the ruler of the most important town.

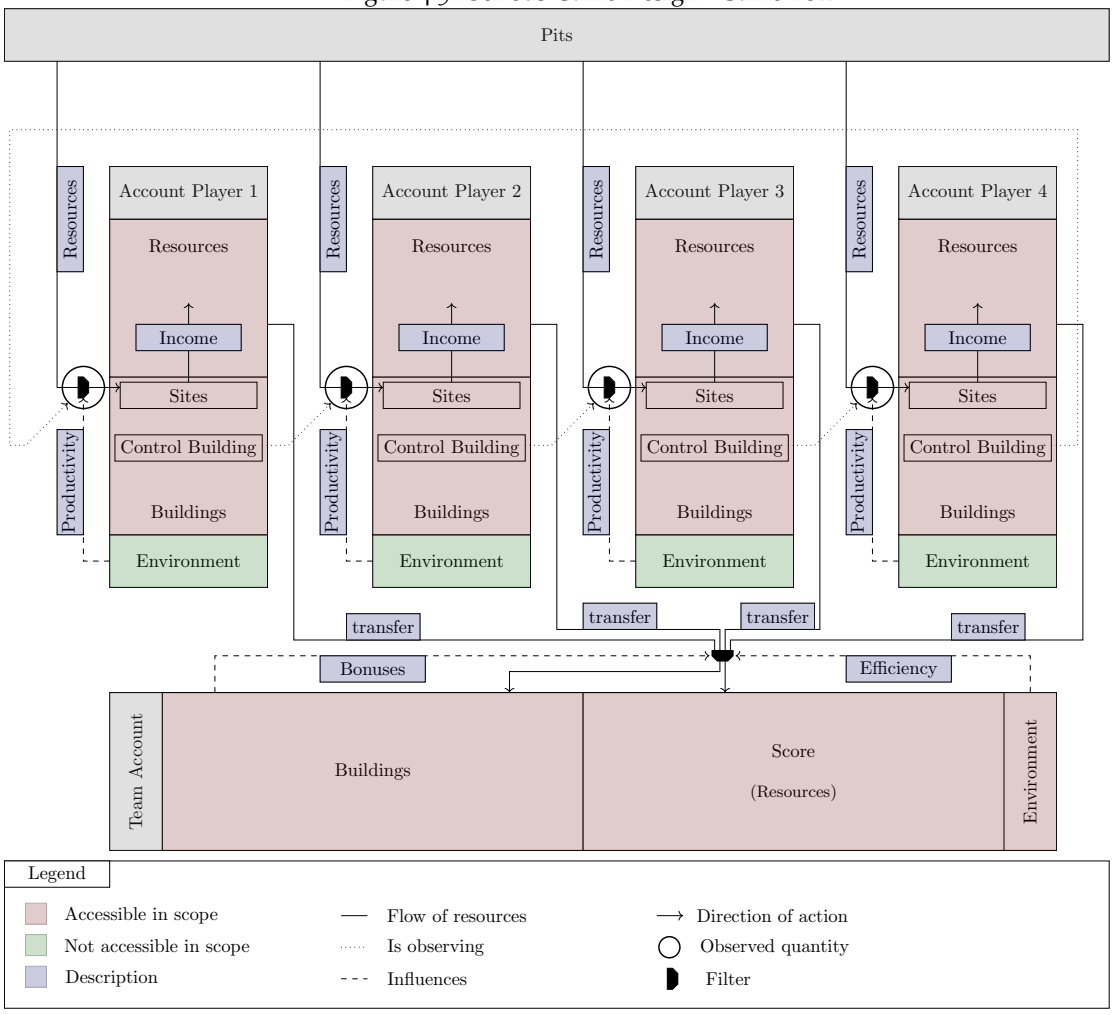
This in-game story includes religion and war, which can both be considered as controversial areas. The level of controversy is reduced by placing the game in the past and using an outdated religion or even an imaginary one. A certain level of controversy is present in many successful leisure games, such as Assassins Creed, Final Fantasy, and Zelda to name but a few, which may indicate their motivating capabilities.

4.2.4. Recap - Game Description

The combined considerations concerning the serious game design are visualized and described in this section. The game abstraction is visualized in Figure 4.5. This figure and the related game mechanics are described in the following.

Each player has an account containing sites in which workers gather resources. The distribution of the fixed number of workers over the five sites, each providing a

Figure 4.5.: Serious Game Design - Game flow



Graphical representation of the serious game design.

different resource type, is done by the player. In this manner, resources are gathered and transferred from the gathering sites to the players' accounts. An environment variable that is unobservable for the corresponding player influences productivity. This is represented by a filter in Figure 4.5. The environment variables of different players are not related and they change over time.

Within the player account, each player is able to spend resources in order to create buildings, bringing different bonuses. For example, the player is able to expand a site in order to increase the resource gathering speed for the corresponding site. Furthermore, a control building can be created to observe the productivity of a team member's site and the related environment variable. This information can be communicated to the player concerned in order to adapt the site options and to increase the productivity.

Each player can transfer resources from their personal account to the group account. The decision regarding what the transferred resources are used for is up to the player transferring them. They can either be used for direct conversation into team points or for team buildings, bringing bonuses for the team points conversion process. An observable team environment variable influences how many team points are received by the transformation of the resources, is represented by a filter in Figure 4.5.

Game mechanics not shown in Figure 4.5 are the group chat, the resource transfer mechanic among players, and the individual scores. The team chat is used for team discussions leading to a team strategy on how to approach the game and for information exchange. The resource transfer mechanic among players can be used to transfer resources between players. The individual scores are raised by creating non-team buildings. Also, the resources currently possessed by the player and the team score add to the individual score.

4.2.5. Manifestation of the Experiential Learning Cycle

A description of the game designed is given, and the experiential learning cycle is also incorporated - but how does it manifest? In this section of the thesis the four phases of the experiential learning cycle, namely *Abstract Conceptualization*, *Active Experimentation*, *Concrete Experience*, and *Reflective Observation* are discussed on a team level in terms of the game design that was created. It is important to keep in mind that team processes happen within this team. Also, the behavior described in the following depicts the hoped-for behavior of the team and the players - there is no way to make sure they follow this pattern.

The starting point is designated with the team's *Abstract Conceptualization*, which is formed out of all team members' abstract conceptualizations. Based on this, the *Active Experimentation* takes place when the team tries to gain a high team score. This phase optimally consists of a planning stage and an execution stage. During the planning, the team's course of action is set, and the execution stage is concerned with executing the plan of action.

The execution stage also contributes to the *Concrete Experience* phase by providing empirical values for the team. Also, the feedback provided by the game in terms of the team score achieved is used for this purpose.

The whole experience is then used in the *Reflective Observation* phase. On the one hand, the team score achieved can be compared to the score of other teams. On the other hand, the measures set in the active experimentation phase can be compared to those set in other experiential cycles, and conclusions about their usefulness can be drawn. This might lead to another *Abstract Conceptualization* and the cycle can be performed once again.

The length of an experiential learning cycle is variable and depends on the individual players since the leaderboard is always available. Of course, it has to feature the necessary tools to make the comparisons described. The repeated mandatory prompt of the leaderboard is intended to trigger experiential learning cycles for inexperienced players.

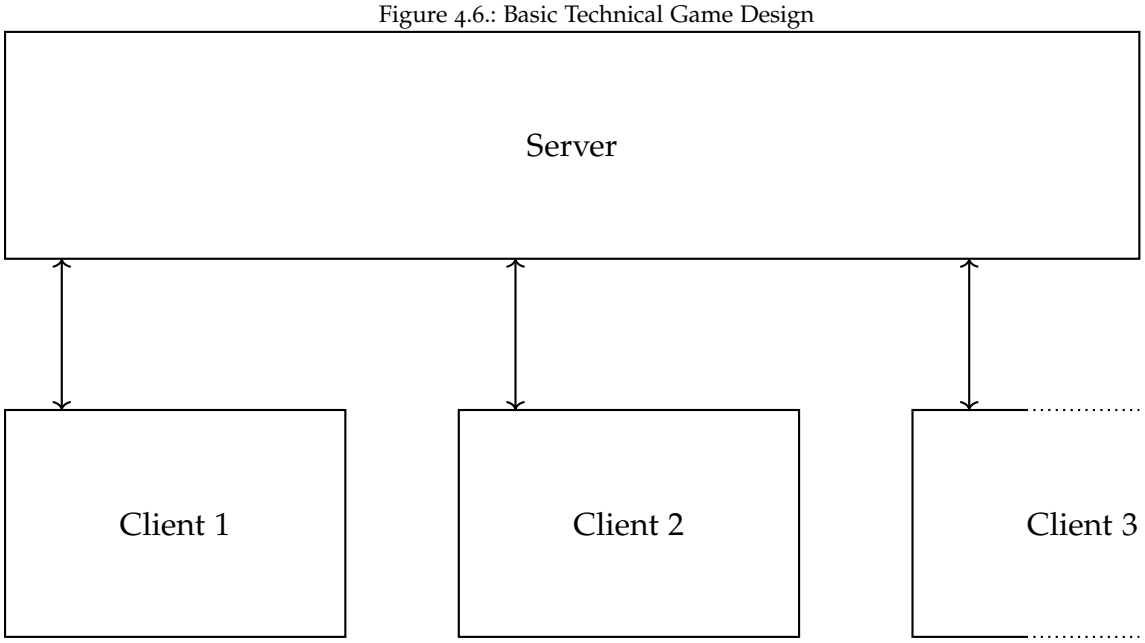
4.3. Basic Software Architecture

So far the goals and the corresponding high-level design of the game have been identified. In the next step, the very basic software architecture of the proposed game is discussed based on pedagogical considerations, without focusing on technical details, such as programming language or the software used. This section should show the structure of the game from a technical point of view with as few software considerations as possible.

The approach discussed requires a separate game server. A server is needed in the architecture since multiple players play the game and, hence, an exchange is required. This server cannot be placed on one of the player's computers(clients), since there is no player who plays the game all the time. The only solution is the usage of a separate game server.

The basic functionality of this game server involves the storing, updating, and provision of the current state of the game for all clients involved. It is reasonable to incorporate the game logic on the server, in order to guarantee the same game state on every client's machine. The client is used purely for representing the current state of the game with respect to the specific player and for game world manipulation. A graphical representation is given in Figure 4.6.

Figure 4.6.: Basic Technical Game Design



Basic technical game design for the game implementation including a server and multiple clients.

In the following, the basic server and client design is discussed. The server design constitutes the main components, as it is the game including the game state and the game state manipulation methods. A very central server component represents the communication API defining the format of all communications allowed with

the server. The client is used purely to visualize the state of the game and to allow gameworld manipulation by using the server's communication API.

In this manner, the communication API methods are discussed, and can be interpreted as the set of available manipulation methods for the clients on the server as well as the game state fetching methods. Additionally, the processing of the messages sent using the communication API is examined on the client and on the server.

4.3.1. Server

In this section, the technical design of the server-side implementation of the game is discussed. The following section will describe the message processing, which is the main component of the technology independent server-side game implementation.

Message Processing

Message processing is required for accessing the current game state and for performing gameworld manipulation, and is the only communication between the game server and the game clients. A message consists out of information about the performed action and an authentication.

The following will show the distinction between two types of messages, which are requests and responses. A request is a message sent from the client to the server, and is always intended to request either information about the game state or a game state manipulation. A response, on the other hand, is always sent from the server to the client and contains either feedback about a requested game state manipulation or an update on the game state.

Independent of the message type, each message contains information about the action performed, and describes the type of request or response. An overview of all actions is given in Table 4.3. A response never contains authentication, a request always does.

Requests

The requests sent from the client to the server contain an action and the corresponding data for the action. Additionally, a request contains a randomly created tracking code returned from the 'login' request, except for 'login' requests which require the login credentials. The tracking code is used as a replacement for the login credentials. A schematic graphical representation of server-side request processing is shown in Figure 4.7.

The actions considered within the request processing are: 'login', 'build', 'reassignWorkers', 'changeWorkingConditions', 'transferResources', and 'sendMessage". An overview of these actions and their purpose is given in Table 4.3.

Table 4.3.: Action values overview

Action	Type	Purpose
login	request response	Used to register for game updates, to retrieve tracking code, and basic game data.
build	request response	Used for upgrade a building, request contains building data, response contains the information about whether the request was successful.
reassignWorkers	request response	Used to reassign workers at the player's sites, request contains new working assignments, response contains the information about whether the request was successful.
changeWorking-Conditions	request response	Used for adjusting the working conditions.
sendMessage	request response	Used to send an in-game message, request contains the message, response contains the information about whether the request was successful.
transfer-Resources	request response	Used to transfer resources between players or to the group account, request contains transferred resource data, response contains the information about whether the request was successful.
resourceUpdate	response	Updates the owned resources of the player regularly.
buildingUpdate	response	Regularly updates the buildings owned by the player.
workerUpdate	response	Regularly updates the assigned workers of the player.
groupbonus-Update	response	Updates the bonus scores for the game.
leaderboard-Update	response	Transfers the group and individual rankings to the client.
monitoring-Change	response	Adjusts to the working condition change of the observed team member.
individualpoints-Change	response	Updates the points of the player.
grouppoints-Change	response	Updates the points of the team.

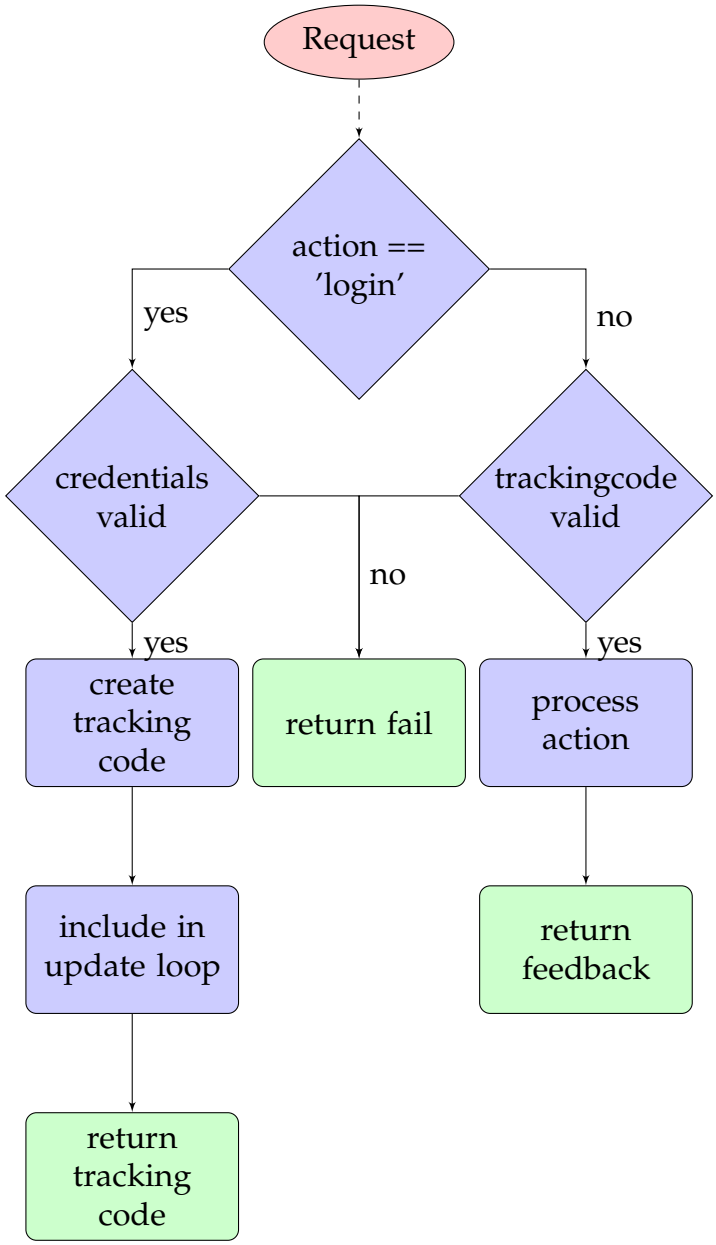
An overview of all actions required for server-client communication. The type of action can be 'request', 'response', or both, and describes which message type this action is used for. The purpose column describes the purpose, as well as the information contained in the corresponding message.

Responses

There are two types of responses sent from server to client, and these are player triggered responses and update responses. Player-triggered responses are sent by the server as a response to a player request. This also includes responses to a player triggered by an action sent from another player, such as an in-game message. Update responses are sent at regular intervals to update the game state for fast changing quantities, such as resources, as a response to the 'login' request.

Update responses are sent regularly after the successful 'login' request using an up-

Figure 4.7.: Server-side socket request processing



Graphical representation of the server-side socket request processing work flow.

date loop, including the actions: 'resourceUpdate', 'buildingUpdate', 'workerUpdate', 'groupbonusUpdate', and 'leaderboardUpdate'. An overview of these actions and their purpose is given in Table 4.3.

Player-triggered responses can be sent as a result of a preceding request of the same or a different player. A request with the actions 'login', 'build', 'reassignWorkers', and 'individualpointsChange' only trigger a response for the same player. Requests with the actions 'sendMessage', 'grouppointsChange', 'transferResources', and 'changeWorkingConditions' not only lead to a response for the same player, but also for the

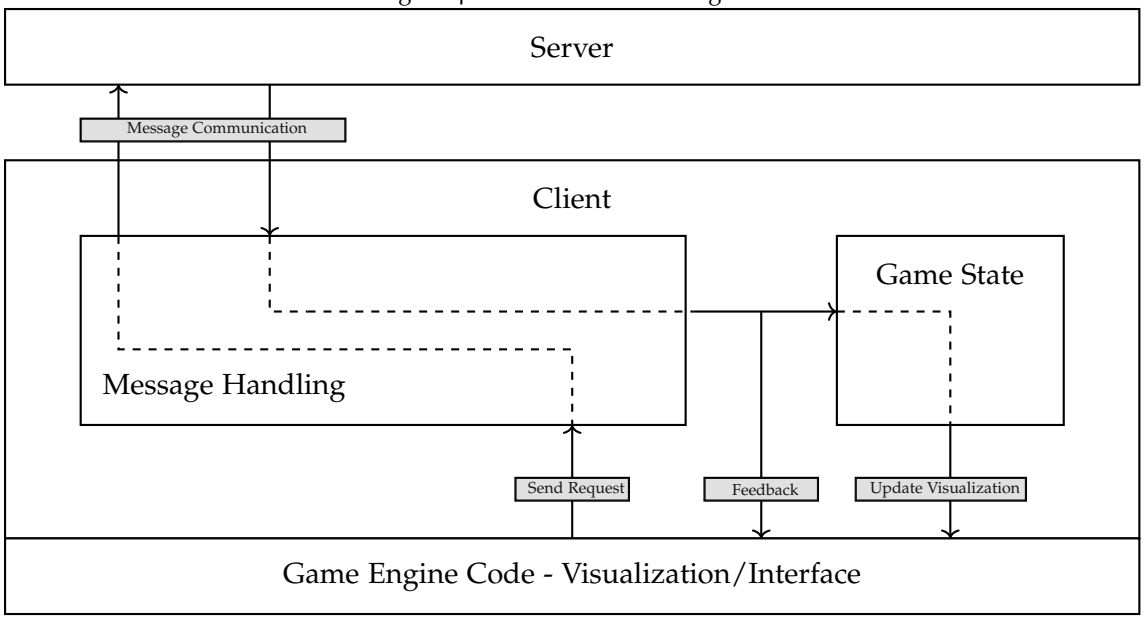
other players involved, if the request is successful and the players are logged in. A response with the action 'monitoringChange' is always triggered by another player due to a successful 'changeWorkingConditions' request. An overview of these actions and their purpose is given in Table 4.3.

4.3.2. Client

The client is used to visualize the current game state and to allow game state manipulations. For client creation, the so-called game engine is used, a piece of software for creating games (Bishop et al., 1998). This game engine already includes common game elements, which allows easy adaption to given content. It can be seen as a game framework, which needs to be complemented by some content. In practice, there are different game engines for different types of games, since adapting them to a specific type of game enhances performance by omitting unnecessary features.

In order to make the game playable, it is imperative to have an adequate copy of the current game state, which is located at the server, on the client at any time. In order to do so, the relevant game state information is transferred from the server to the client upon login. Then, messages from the server, responses, are used to keep the game state up to date. Finally, the game state has to be visualized using the game engine. These two required elements, namely 'Game State' component and the 'Message Handling' component are discussed below. An overview of the procedure described can be found in Figure 4.8.

Figure 4.8.: Basic technical design - client



* Basic technical design for the client.
* The received messages from the server, the responses, are used to update the client-side game state and to show update-messages. Game world manipulation by using the game engine interface triggers a request to the server.

Game State Storage

The game state storage is a required element for the client since it mirrors the server's game state and in this way, makes an adequate view of the current game state possible.

Besides storage of the game state, this element also triggers game state updates upon a change of the game state. Therefore, the 'Game State' entity contains multiple methods for changing the game state, and also interacts with the game engine to change the corresponding visualization. Response messages are responsible for game state updates.

Message Handling

The message handling is of crucial importance since it allows game state updates and game world manipulations. Game state updates are received from the server in the form of response messages, and are used to update the game state storage element. Game state manipulations are triggered by the user and lead to a request message, which gets sent to the server.

The main component for the client's message handling is the 'Message Handling' component, which fulfills two purposes. First, it is used to receive data from the user via the game engine visualization to trigger a request to the server. Second, it receives responses from the server in order to update the game state and/or to display feedback to the player.

Game State Update

Game state updates result from response messages received from the server, and are responsible for updating the game state visualization. As an intermediate stage, the game state storage is updated to mirror the server side game state. This then also triggers an update of the corresponding visualization.

Gameworld Manipulation

By using the game's user interface, the player is able to trigger gameworld manipulation in the game engine's code. This code then calls the 'Message Handling' component to trigger a request message to the server. This is the whole game manipulation procedure.

As a result of the game state manipulation request, the server returns a response message containing feedback and a game state update. The game state update is processed like every other game state update received from the server. The feedback is shown to the player and might include error messages upon failure and a success message upon success.

4.4. Discussion

This chapter identifies possible ways to measure the capabilities of a player regarding the four teamwork components: communication, monitoring, adaptability, and orientation. For communication, the measured quantities are already defined (number/frequency of messages/words); however, the other components are still missing a concrete metric definition. This is true not only for the indices themselves, but also for the underlying calculation quantities.

The adaptability component, for example, is evaluated based on the team bonuses gained. It is not yet clear how the underlying quantities, the team bonuses, will form a suitable adaptability metric. Neither is known to interpret such an metric when it is defined.

The orientation metric, in contrast, can already be defined as the ratio between resources spent for reaching the team goal and the total amount of resources spent. However, it is not yet clear which of the resources spent count as resources contributing to the team goal.

The situation for the monitoring metric is somehow inverse to the one for the orientation metric. Here the underlying calculation quantities appears to be known (number/frequency of control building visits, number of feedback messages), but how the monitoring metric should be calculated based on these quantities is still unclear.

What all these possible teamwork indices have in common is that their interpretation is not clear. It seems reasonable to gain these insights from the indices interpretation by conducting studies and creating suitable indices based on the team performance, which then need to be evaluated by teamwork experts.

4.5. Summary

This chapter deduces a serious game design based on the experiential learning cycle for the four basic teamwork skills, namely communication, adaptability, orientation, and monitoring. The design goals and requirements are defined for a target group of undergraduate students in the context of a university course.

The game will be a strategic game that uses a cooperative context with four players per in-game team. These teams then play against each other in order to obtain the motivation which is present in a competitive situation. The players are always able to access the team performance in order to adapt their course of action.

In the basic game, the players are able to collect resources, build structures and create products in order to manipulate the game world. Furthermore, they are able to transfer resources to their team account for team buildings, or to the team storage to increase the team score. For interaction among players, a team text channel can be used. Also, players can exchange items (resources) with each other.

For measuring the individual dimension of each player, different metrics are in place. Orientation is evaluated by the number of resources spent on the team account versus the number of resources spent for other purposes, such as an individual score. Monitoring is analyzed based on the control building that each player may build and their usage of it. Adaptability is rated based on the team's ability to meet the requirements of the current conditions in spending resources, which change over time. For an evaluation of the communication, a simple count of words and messages for each player is used. More insights on how to calculate and/or interpret the component indices need to be gathered by future studies.

The basic software architecture for this type of game features a server-client characteristic. The server holds the game state and the game logic. The client is only used for game state visualization and for game state manipulation. A messaging API is used for this purpose.

The next chapter will discuss the prototype implementation, featuring some of the game mechanics discussed.

5. Prototype Implementation

This chapter is used to design a prototype of the teamwork training game outlined in Chapter 4, Serious Game Design. The aim is to initiate validation of the design with regard to its relationship with teamwork, as well as its user interface, which is a central element of a strategy game.

To begin with, the requirements for the emerging prototype will be introduced, as well as the idea and goals associated with it. Based on these considerations, the general technical design and the technologies used are discussed. The software implementation details are then described in terms of the communication format, the server-, and the client realization. To get a better picture of the implementation, viewports of the game are shown. Finally, the limitations of the prototype are discussed.

5.1. Idea and Goals

Chapter 4, Serious Game Design, outlined a well-founded theoretical approach to teamwork training using a serious game. This approach now requires validation in practice. Therefore, a prototype implementation is needed, including the outlined serious game design. Based on the scope of this thesis, a basic prototype showing the fundamental functionalities of the game is targeted.

The basic prototype includes all game mechanics associated with the four teamwork components, as well as the graphics used and the importance of user interface is reduced. On the one hand, this ensures that the serious game concept is evaluated, since all relevant game mechanics are in place. It also gives a proper idea of how a fully fledged version of the game could look. On the other hand, the implementation effort is kept within the required boundaries since only basic, very iconic visualizations are used.

The basic prototype allows for some initial validation of the game design, with respect to the game's perceived relationship with teamwork. Furthermore, the user interface can be evaluated due to its structure and handling, but an evaluation of the visualization is not meaningful due to the focus of the prototype.

Next, the requirements for the implementation of this basic prototype will be discussed.

5.2. Requirements

An important step in each software development process is the determination of requirements. This includes functional requirements and non-functional requirements. The former are defined functions of a system. The latter do not describe the behavior of a system, but can rather be seen as criteria for judging the operations of a system. Often, functional requirements are defined as what a system can do, and non-functional requirements are defined as how a system is supposed to be.

In the following, the functional and non-functional requirements for the prototype are listed. Functional requirements are written in italics, non-functional requirements are not italicized.

[A] The most important requirement is probably the incorporation of the serious game design developed in Chapter 4, Serious Game Design. Therefore it is split up into multiple distinct requirements

- **[A.1]** *The prototype should train each player in teamwork capabilities for future teamwork tasks. This, of course, has to be evaluated first.*
- **[A.2]** Training in teamwork capabilities should be done with a game using the game mechanics associated with the teamwork components orientation, monitoring, adaptability, and communication from Chapter 4, Serious Game Design.
- **[A.3]** The basic software architecture should be a client-server design.
- **[A.4]** The prototype should be a strategic game featuring a game world and a user interface.

[B] The next set of requirements describe the game world visualization. It is a concretization of the requirement **[A.4]**.

- **[B.1]** The game world should be composed of 3D buildings.
- **[B.2]** Each type of building and level of building in the game world should be visualized differently.

[C] The third set of requirements describe the user interface of the prototype. It is a concretization of the requirement **[A.4]**.

- **[C.1]** The user interface should consist of a permanent top panel showing the general game state, a not always visible data visualization panel on the right-hand side of the screen, and a not always visible feedback panel at the left bottom of the screen.
- **[C.2]** *Selecting a building in the game world by clicking on it should bring it into focus, and bring up the data visualization panel for detailed information and game world manipulation.*
- **[C.3]** *The chat function should be accessible via the top panel. The chat should be shown in the data visualization panel.*
- **[C.4]** *The resource transfer function should be accessible via the top panel. The resource transfer menu should be shown in the data visualization panel.*

[C.5] *The leaderboard function should be accessible via the top panel. The leaderboard should be shown as a screen overlay. There should be a possibility to change between the team and the individual leaderboard.*

[D] The software that was created (client and server component) should be theoretically platform independent in order to make it playable for a wide range of users. The word 'theoretically' is used here since the incorporated technologies should be technology independent, but the development and testing will happen on Windows.

This list of requirements should now be considered when talking about the general technical design in the next section.

5.3. General Technical Design

In this section, the general technical design of the prototype is discussed. The biggest influence on this design probably has requirement **[A]**, the inclusion of the serious game design. This especially means that all of the considerations of Chapter 4, Serious Game Design, can be found again in this section.

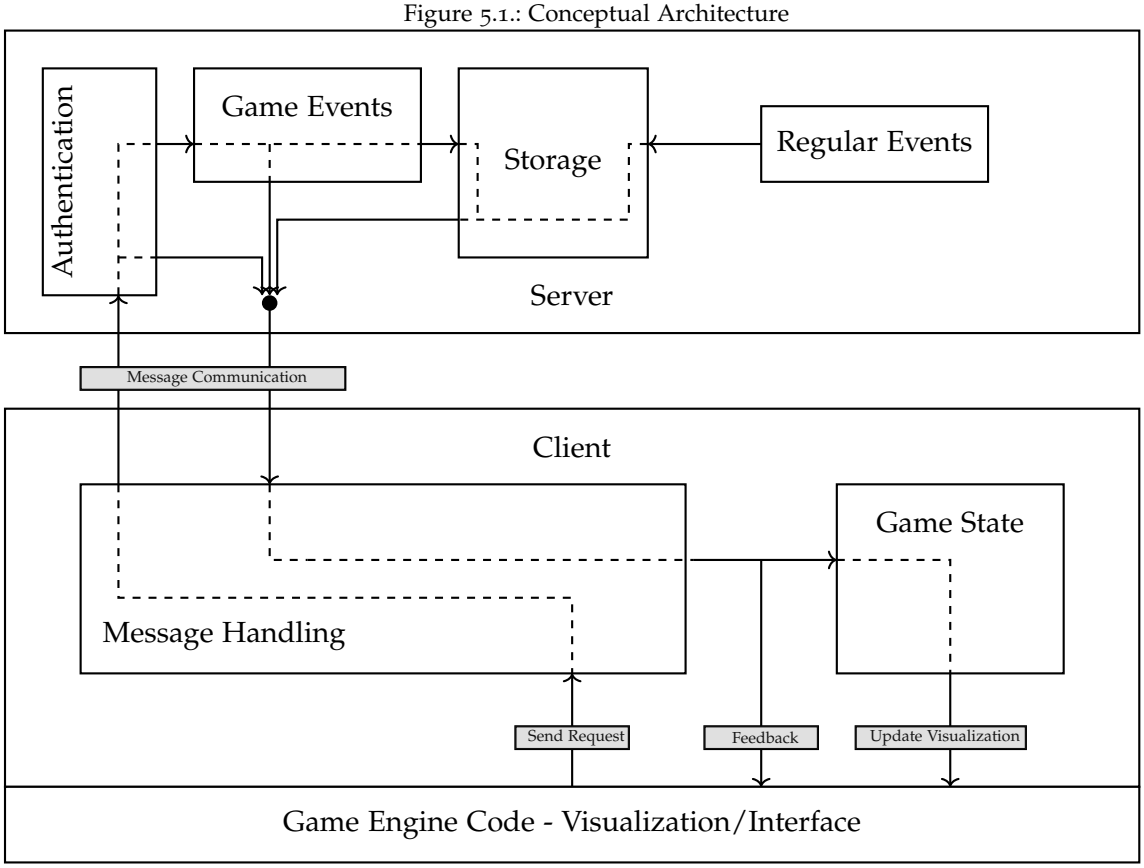
The development is split into two components: the server and the client. Both of these components need to work independently of each other. The server is responsible for the game logic and represents the game world including its laws. The client can be seen as the acting entity in the game world, following the game world's rules and acting according to them.

Each of these two components is composed of multiple sub-components. The client, as already discussed, consists of the message handler, the game state storage, and the visualization. The server is composed of the authentication, the game events, the storage, and the regular events sub-component. Their interactions are shown in Figure 5.1. Each sub-component is explained in the following.

Client - Message Handling
This component fulfills two purposes, sending messages to the server and receiving messages from the server. Messages sent to the server are triggered by the user via the game engine visualization. Response messages from the server are directed to the game storage component and/or feedback is shown via the game engine visualization.

Client - Game State Storage
This component depicts the game state relevant to the logged in player, which is mirrored from the server. It is kept up to date by incoming responses from the server. Such updates of the game state are immediately transferred to the game engine visualization to make them visible to the player. The player cannot directly change the game state on the client, only the game state on the server can be manipulated. In turn, this manipulation is mirrored to the client.

Figure 5.1.: Conceptual Architecture



* Conceptual architecture including server and client.
* Client: The messages received from the server (responses) are used to update the client-side game state and to show update messages. Game world manipulation triggers a request to the server by using the game engine interface.
* Server: Responses are send from the Authentication, Game Event, or Storage component. They are either player triggered, or as a regular event after the log in.

Client - Visualization
Probably the most important component in a game, the visualization makes the game state visible to the player. It is also responsible for gathering the player's input for the game world manipulation. This component is secondary in this prototype. Requirements **[B]** and **[C]** are concerned with this component.

Server - Authentication
Only messages from admitted players are allowed to be processed. This is controlled by the authentication component. Each request has to have a tracking code or login credentials to receive a tracking code. Unsuccessful authentication returns a corresponding response to the client. After successful authentication the request is forwarded to the game event component.

Server - Game Events
The input is validated and the associated actions are performed in the game event component. If the specified action is not valid or the provided data is insufficient a corresponding response is submitted to the client. Otherwise, the game state manipulation or the data fetching is done using the storage component.

Server - Storage
The storage component of the prototype includes a runtime storage of the game world and all game relevant data. It also stores information about the logged in players and their socket connections. It is updated either by message request from the players, which are delivered from the game events component or by the regular events component.

Server - Regular Events
This component triggers regular events, such as the resource update, or the change of desired working conditions and so on. It directly addresses the storage component, which might lead to a response sent to the players.

5.4. Technologies Used

This section is intended to discuss available technologies that are used to create games. From this range, the technologies for this thesis will be chosen.

There is a wide variety of technologies available for creating software for any purpose, and the same holds for games. One very central component of each game is represented by its visualization: the front end, as it is the one thing the player notices first. Nevertheless, the core component is the logic, which defines the game. The software and protocol used are discussed next.

5.4.1. Software Used

Since a server-client architecture is used, the following section has two parts - one part for the game client and one part for the game server. Also, requirement **[D]** is considered here.

Game Client

As discussed in Section 2.3.4, A Word on Game Engines, a game engine is a central element when creating game. It includes the very important graphical assets a game is based on. This prototype uses a game engine in order to profit from its easy graphic-asset handling.

As Unity has superb multi-platform capabilities, and is also one of the most often used game engines, it is also used for this prototype. Unity's network features are not used since a separate, continuously running server seems to be the easier solution in this context.

Game Server

When looking at *SimilarTech*, a sales insight platform that crawls through websites and records the technologies used (Schmeiser, 2016), we can get an insight into which technologies are currently being used. The top web framework technologies used

within the top 10.000 websites are PHP (17.52%), ASP.NET (8.25%), Ruby On Rails (2.35%), and Node.js (1.89%) ("Top Framework Technologies," 2017).

Tilkov and Vinoski (2010) explains the advantages of Node.js, which is based on JavaScript. One very big advantage is the single codebase. Since JavaScript is essential for client-side web development it seems natural to also use it for the server side. This reduces error sources through natural compatibility. Also, its Event Loop allows concurrent handling of multiple requests without waiting times by using a single thread.

Lei, Ma, and Tan (2014) show that Node.js can handle many more requests than PHP. They also conclude that it is lightweight and efficient for I/O intensive applications, such as our game server. These findings are also backed by Chaniotis, Kyriakou, and Tselikas (2015) which emphasizes its cross-platform capabilities.

It seems like Node.js is an emerging technology with theoretical and practical advantages over the currently most used web framework technology, PHP. This and its cross-platform support is why this technology is used in this project.

5.4.2. Communication Protocol

The software used for the server, as well as for the client has already been discussed. The missing element at this stage is the communication between these two instances. Therefore, a communication protocol is needed.

The most important consideration when talking about the communication protocol used is the need for bidirectional communication. When considering, for example, the very popular HTTP protocol, it is obvious that communication has to always be triggered by the client. With this setup, it would not be possible to follow the basic software architecture designed in Section 4.3.

The WebSocket communication protocol, on the other hand, seems to be suitable for our purpose (Fette, 2011). This protocol, starting with an opening handshake, enables two-way communication using TCP as a basis. It has been picked up from many programming languages and frameworks, including C# and Node.js, and, hence, will operate as the communication protocol for the designed prototype.

5.5. Implementation Details

There are no longer any issues with using the technologies introduced to implement the outlined serious game. The blueprint of the game is known and the tools have been selected. However, there are still some decisions to make. To begin with, there are some game design details as well as the communication format, which have not been discussed yet. Additionally, it is not clear which predefined packages will be used for the JS server and the C# client. These open points are addressed below.

5.5.1. Game Design Details

First, the game design details have been settled. In most cases, there was no special reason for selecting the values as shown in the following. They can be seen as an initial guess. Playtesting needs to be used to adapt these values in order to create a well balanced game. The unresolved areas include the resources, the buildings, the calculation of the points, the working conditions, and the group bonus.

Resources included in the game are wood, stone, wool, clay, and copper. Five resources were selected based on the number of resources in the browser game Ikariam. In relation to these five resources, there are five gathering sites, the living quarters for a population bonus, the embassy for requesting working conditions, and the market for getting individual points. The buildings are listed in Table 5.1.

Table 5.1.: Considered prototype buildings

Name	**Function**
Sawmill	This is the gathering site for the resource wood. It can be expanded to level three. Only one gathering site can be expanded to level three and a prerequisite for this expansion is that all other gathering sites are expanded to at least to level one. Using this building, the player can assign workers to the sites and change the workers' working conditions.
Marble Mine	Same as the Sawmill, but for the resource stone.
Sheep Farm	Same as the Sawmill, but for the resource wool.
Clay Pit	Same as the Sawmill, but for the resource clay.
Copper Mine	Same as the Sawmill, but for the resource copper.
Living Quarters	Used to increase the population. Each of the three levels gives a multiplication bonus based on the number of workers.
Embassy	Can be expanded to level one, which allows a team member's working conditions to be checked.
Market	Can be expanded to level three, each level raises the individual points.

An overview of the buildings included in the prototype with a short explanation.

The calculation formula for the points in the game, namely the team points and the individual points, have not been discussed yet. The group points are calculated as the sum of the spent resources of all team members, whereas the group bonus can bring additional points for the team. The individual points for each player can be calculated as the sum of the player's group points and the individual points gained from expanding certain buildings. In the prototype, the only building yielding this individual point bonus is the market.

The group bonus is realized as a number from zero to four, changes every six minutes, and is the same for all teams. Each number represents a resource, for which the players get four times the points compared to the other resources when transferred to the group account.

The last game design detail to be discussed is the working conditions. They are represented by a number from zero to four and change every five minutes for each player. If the desired working conditions coincide with the applied working conditions the resource income is raised by 50%. Within the client the numbers are interpreted as working condition descriptions, see Table 5.2.

Table 5.2.: Working conditions description

Number	Description
0	Low working hours, low income
1	Medium working hours, medium income
2	High working hours, high income
3	Flexible working hours, medium income
4	Bonus for good work

An overview of the working conditions and their descriptions in the client.

5.5.2. Communication Format

Besides the communication protocol already discussed, and which will be used, a communication format is required. JavaScript Object Notation (JSON) is a commonly used one that is closely related to JS and, hence, Node.js. This data format is text-based, language-independent, and lightweight data interchange format, as described by Crockford (2006). Furthermore, he states that *"JSON's design goals were for it to be minimal, portable, textual, and a subset of JavaScript."* (Crockford, 2006)

Due to the close relationship of JSON with Node.js, this communication format is used for the prototype. The base JSON structure for messages is shown in Figure 5.2. It contains the action field describing the type of data sent. An optional trackingcode is used for requests in combination with an action other than 'login'. The data field contains action specific data in an action specific format and is optional.

```
{
    "?trackingcode" :   String,
    "action"        :   String,
    "?data"         :   JSON
}
```

Figure 5.2.: An example structure of the JSON used to send data between server and clients. The trackingcode is only sent in the case of client-to-server communication and never for the action 'login'. The field action describes the underlying action of the data exchange. The field 'data' is only used if necessary and contains action specific data in an action specific format.

5.5.3. Server - Packages/Modules Used

In Node.js there are two ways to import functionality into someone's code - modules and packages. Modules accompany code, which needs to be loaded, whereas

packages need to be downloaded first by using a node package manager. Afterwards, they can be loaded like modules.

The prototype uses imported functionality for three purposes - socket communication, conversion functionality, and for access to the file system. Socket communication is based on the socket.io and express package, as well as the HTTP module. The base64url package and crypto module are used to create random strings for the tracking code. The file system is accessed with the help of the fs module for loading the in-game building data. An overview of all packages and modules used is given in Table 5.3.

Table 5.3.: Node.js packages and modules used in implementation of server.

Package	**Type**	**Used Functionality**
express	package	Web framework used for socket communication and REST interfaces.
socket.io	package	Socket.IO enables real-time bidirectional event-based communication via sockets.
http	module	This interface is designed to support many features of the HTTP protocol in an easy-to-use manner.
base64url	package	Used to convert to and from base64url.
crypto	module	This module provides cryptographic functionality, used to generate random bytes.
fs	module	This module provides an API for file system interaction.

An overview of the used node.js packages and modules in the game server implementation.

5.5.4. Client - Assets Used

In their asset store[1], Unity provides a wide range of so-called assets. They are created by Unity developers and third-party developers. These assets are software components or graphical elements, which can be integrated into games developed with Unity.

In this prototype, the asset *SocketIO for Native and WebGL builds*[2] was used to embed the socket communication. Its functionality includes the ability to communicate with SocketIO servers.

[1] [17.05.2018] https://assetstore.unity.com/

[2] [17.05.2018] https://assetstore.unity.com/packages/tools/network/socketio-for-native-and-webgl-builds-76508

5.6. Viewpoints

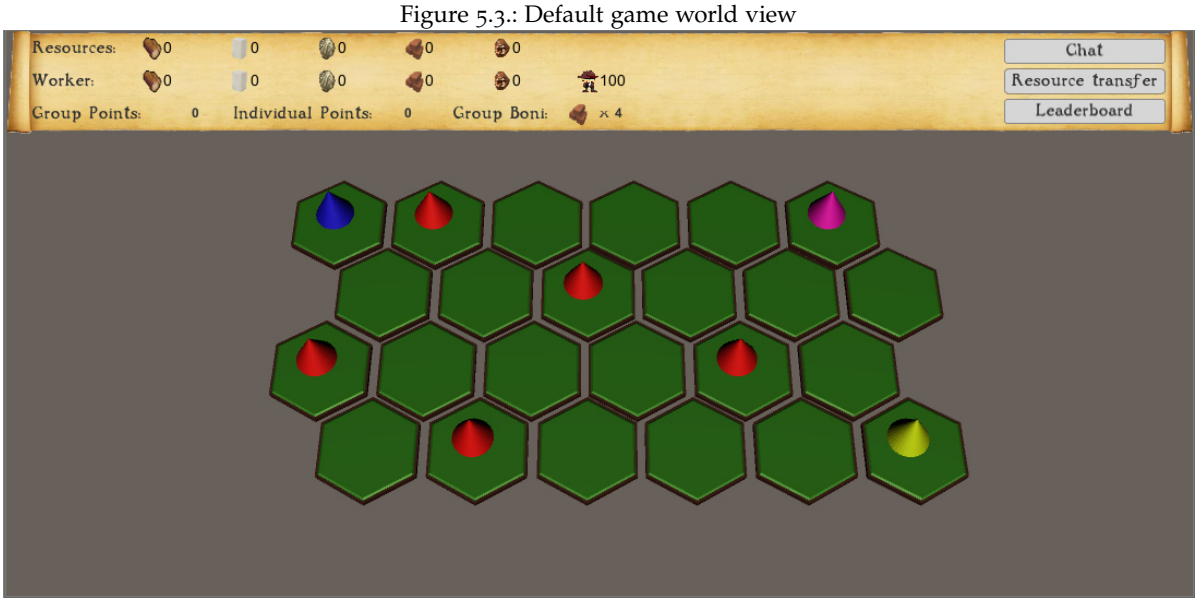
In this section screenshots of the implemented serious game are shown in order to get a better picture of it. This includes mainly pictures of the user interface as well as pictures of the game world. Also, the visualization of the four teamwork-related game mechanics is shown.

5.6.1. Game World

The game world constitutes one half of the game visualization. There are mainly two states the game world visualization can occupy, namely the idle state, showing the whole game world, and the focused state, showing only the building or tile in focus.

Figure 5.3 shows the entire game world including multiple empty tiles and tiles with buildings. The buildings are visualized by cones, and the color of the cone describes the building type.

Figure 5.3.: Default game world view



Default game world view.

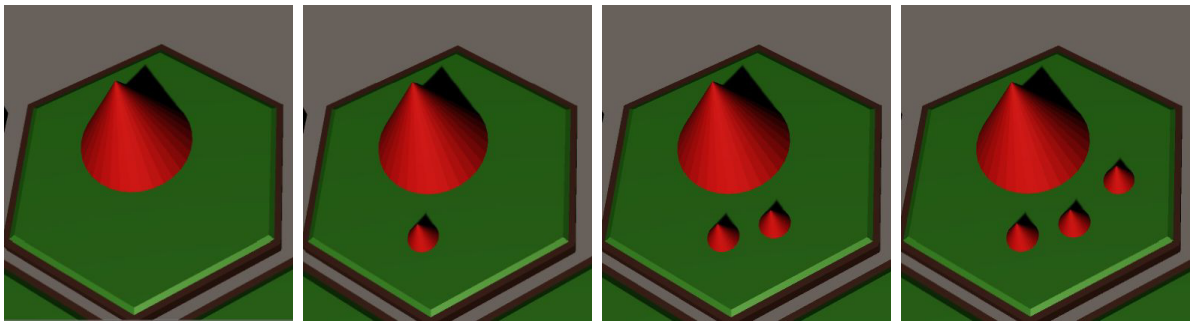
The zoomed-in game world visualization is shown in Figure 5.4. After the player focuses on a building by clicking on it, this visualization is shown. The building is visible on the left-hand-side of the screen. The right-hand-side of the screen shows the data panel with all building related information and manipulation possibilities.

Figure 5.4.: Game world view with focus on one building

Game world view when focused on one building. The viewport is zoomed-in on the building and the user interface with building details and manipulation opportunities are shown.

Each building has a certain level in order to make the game more complex, and provide the player with a different option on how to spend the resources gained. By spending a certain amount of resources, a building can be expanded. The different visualizations for the different building levels are shown in Figure 5.5. In the prototype, not every building has the same number of levels available.

Figure 5.5.: Building visualization



(a) Level 0 (b) Level 1 (c) Level 2 (d) Level 3

Building visualization of the same building type with different levels, starting with level zero and going up to level four.

5.6.2. User Interface

The user interface constitutes the second half of the game visualization. There are basically four different user interface elements present in the prototype, namely the top panel, the data panel, the feedback panel, and the screen overlay.

Figure 5.6 shows the top panel, the data panel, and the feedback panel. The top panel is located at the top of the screen, giving general information about the game state associated with the player logged in. It also gives access to the chat, the resource transfer menu, and the leaderboard. The data panel is located on the right-hand-side of the screen and is used for building-related data, the game chat, or the resource transfer mechanism. The feedback panel, at the bottom of the screen, is used for showing feedback to the user.

Figure 5.6.: User interface panels

This figure shows all three user interface panels, namely the top panel at the top, the data panel on the right, and the feedback panel at the bottom.

The data panel shows all building-relevant data when a building is focused on. There are three different panels the player can choose from, in this case, namely the general tab, the expansion tab, and the special tab. All three tab visualizations are shown in Figure 5.7.

In the general tab, the player can see the name, level, and description of the selected building. It offers the basic or general information for a selected building.

The expansion tab shows all information regarding the expansion of the selected building. This includes the next level to reach, the resource costs, and the building time. It also shows which buildings (including their levels) are required for expanding, and which are not allowed to be possessed (including their levels) before the building in question can be expanded. Also, the positive effects of the new building expansion are shown. The *Ind. Bonus* shows the number of individual points gained by creating

this building. *Pop. Bonus* describes the population growth as a factor when building this expansion. The last item, *Boni*, state the increase in the resource income as a factor after expanding this building. In this tab one can start the expansion by clicking on the *Expand Building* button.

The special tab shows building-related data and manipulation methods. In our example of the sawmill, the player can allocate workers to the different resource gathering sites, and change the working conditions of all gathering sites.

Figure 5.7.: Building data panel.

(a) General tab (b) Expansion tab (c) Special tab

Data panel visualization for buildings with its three different tabs, namely general, expansion, and special.

The screen overlay is the last user interface element discussed. It is shown in Figure 5.8 in its two states, namely showing the individual leaderboard and the team leaderboard. It can be activated by clicking the *Leaderboard* button on the top panel, see Figure 5.6. It can be closed again by clicking the *Close* button, or the content can be changed by clicking *Change Chart Type*.

Figure 5.8.: Screen overlay

(a) Individual ranking (b) Team ranking

This figure shows the screen overlay for the leaderboard. Once for the individual ranking and once for the team ranking.

5.6.3. Teamwork Components

Since the four game mechanics associated with the four teamwork components of the game design are of central interest, their visualization is shown in this section. This includes the game mechanics for the teamwork components: orientation, monitoring, adaptability, and communication.

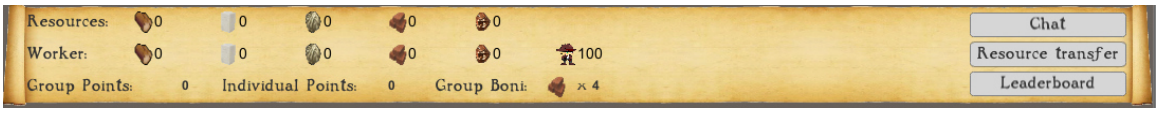
Orientation

For the orientation teamwork component, there are three important visualizations: the top panel, the expansion tab for buildings, and the resource transfer menu. All three visualizations are shown in Figure 5.9.

The top panel, Figure 5.9 (a) shows the group score and the individual score of the player. Additionally, these scores are shown on the leaderboard compared to the scores of the other teams and players, see Figure 5.8.

Individual points are gained by building or expanding certain buildings. For each building, the individual points gained are shown in the expansion tab of the data panel when the building is in focus. This is shown in Figure 5.9 (b).

Figure 5.9.: Orientation visualization



(a) Individual and team scoring

(b) Individual building points

(c) Resource transfer

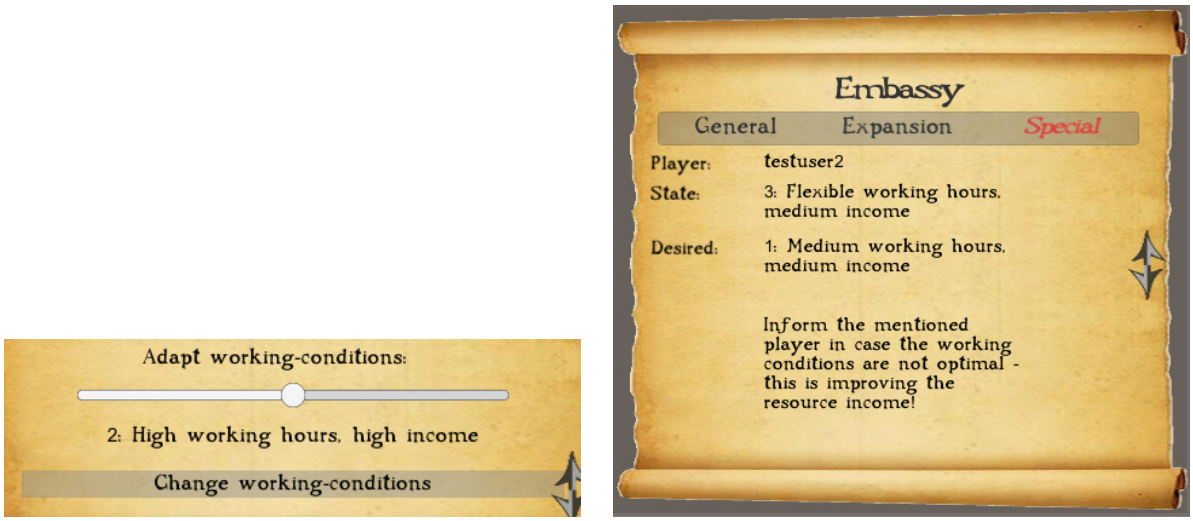
This figure shows the orientation visualization. In (a) the individual and team scores are shown. In (b) one can see the individual points gained by expanding a building. In (c) the resource transfer to the group account, which leads to group points, is shown.

Group points, which also count as individual points, are gained by transferring resources to the group account. This can be done at any time by opening the resource transfer menu from the top panel, see Figure 5.6. This menu is shown in Figure 5.9 (c).

Monitoring

The monitoring visualization includes two different views, shown in Figure 5.10. The first one is shows the current set working conditions for the player. This menu can be reached by selecting one site and navigating to the bottom of the special tab in the data panel. At this location the working conditions can also be adapted, see Figure 5.10 (a). The working condition of a team member can be seen at the embassy building with level 1 on the special tab, see Figure 5.10 (b).

Figure 5.10.: Monitoring visualization



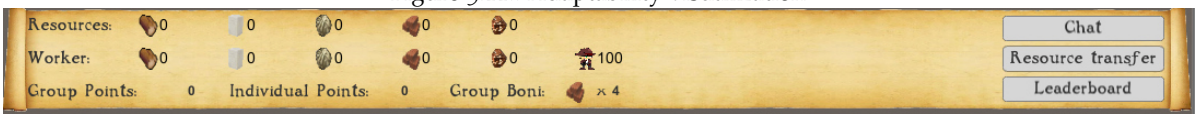
(a) Working conditions adaptation (b) Working conditions monitoring

This figure shows the monitoring visualization. The menu for adjusting one's working conditions is shown and the menu for requesting teammates' working conditions is shown.

Adaptability

The adaptability visualization is quite simple, and only consists of an image representing the current bonus. This is one of the five resources bringing four times the group points when transferred to the group account. This visualization is shown in the top panel, see Figure 5.11.

Figure 5.11.: Adaptability visualization

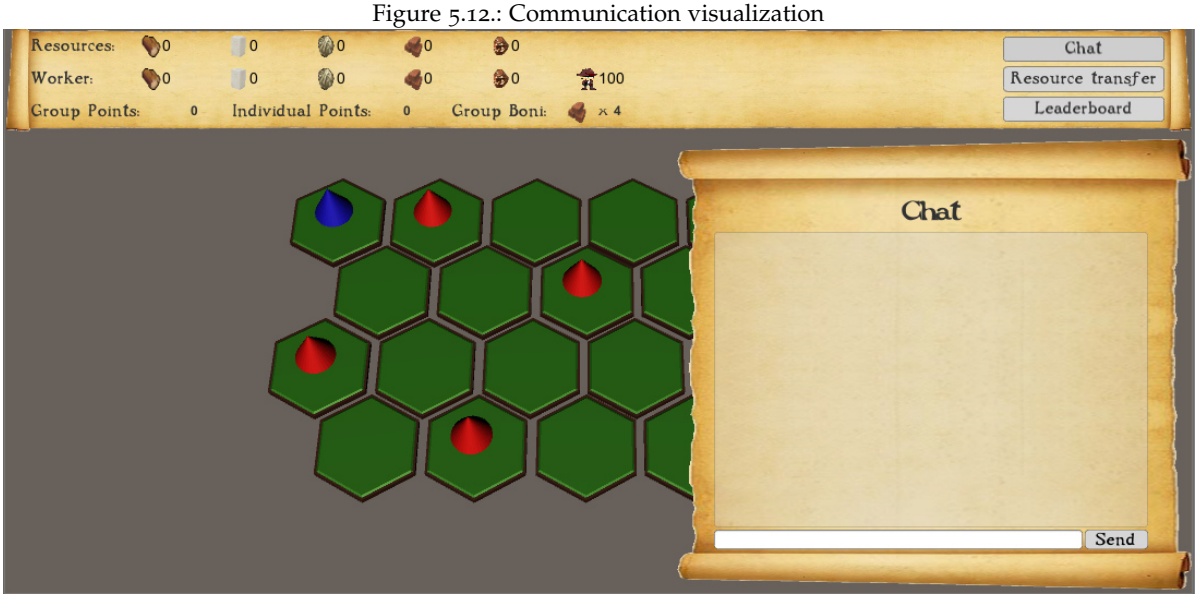


This figure shows the adaptability visualization in the form of the group bonus in the top panel. It is the symbol of a resource, which yields four times the group points of all other resources when transferred to the group account.

Communication

The communication visualization is seen in the form of the group chat. This chat, placed in the data panel, can be opened and closed using the *Chat* button on the top panel. It can be used to communicate with the other team members by sending messages. A screenshot of the chat is shown in Figure 5.12.

Figure 5.12.: Communication visualization



This figure shows the communication visualization in form of the chat window located in the data panel. It can be used to communicate with one's team members.

5.7. Limitations

Although this serious game prototype is built upon a solid theoretical basis, it has some limitations. These limitations can be divided into four main categories, namely visualization, functionality, game balancing, and storage. All of these four categories are discussed in the following.

Visualization
The first limitation mentioned, visualization, is quite obvious. The 3D graphics

used are very basic, consisting of geometrical figures. Different building types are represented by different colors, and different levels are represented by additional geometrical figures. Also, the 2D graphics used for the user interface are basic. The whole visualization can be described as functional, rather than appealing.

With good visualization as one of the most important features of a game, this prototype will probably lack the ability to engage the player fully in the game. An immersive game environment is essential to transfer the player to a perfect experience, as proposed when talking about the concept of flow. When a game lacks this ability, it is deprive of its number one reason for being used.

This prototype weakness was approved in advance, and is easy to compensate for in the future. The graphics need to be replaced, and the user interface re-designed. These design and work tasks have been omitted in order to be able to fit the extent related to a serious game implementation into this thesis. Additionally, those aspects are not the scope of this thesis.

Functionality
The second limitation mentioned, functionality, cannot be seen at first glance, but brings along similar disadvantages to visualization. The game mechanics associated with the four teamwork components are included in the game, but these account for nearly all of the game mechanics included. There are a few additional ones, such as building restrictions (not being allowed to have all the buildings at the same time), which encourage discussion among team members. It is clear that more of these game mechanics are needed to seriously challenge the players.

A game, such as this prototype, which is constructed too simply will not be able to engage players in the long term. A solution strategy might be found too easy or the game mechanics might not be challenging enough. The game might simply turns out to be too boring.

Game Balancing
The third limitation, game balancing, is a limitation which needs to be reduced consistently. It is not yet clear how the game mechanics work together and how teams can gain advantages by using them. One bonus gained by a certain behavior might outrun all others by far and make every discussion within the team unnecessary. To correct such phenomena, and weight the game mechanics so as to achieve a well-balanced game, needs time and a lot of playtesting in realistic environments.

This is a limitation each game faces at the beginning. In order to find a meaningful game balance, studies need to be conducted, game sessions need to be analyzed, and players' feedback needs to be collected and incorporated. This is a time-consuming process, but necessary for finding the desired game balance to engage the players.

Storage
The fourth and last limitation discussed here, storage, has no influence on the game itself. Right now a transient run-time storage is used, which means that all data is lost upon a stop of the system. This is not a big problem since the game server is intended to run all the time, and in only stopped at the end of the game session. All required data for the evaluation needs to be extracted first.

The only problem occurs when the system is not working as expected. A temporary break down of the game server would result in a reset of the game state. This might be a problem in a long running or even open-ended game session.

The transient storage was implemented in this prototype to reduce the programming effort. In order to overcome this limitation, the game state could be stored regularly to the hard drive, or the game state data could be stored directly to the hard drive, for example in a database.

5.8. Summary

In this chapter, a prototype is designed according to the serious game design developed in the last chapter. To begin with, the general idea and the requirements of the technical design is deduced. The used technologies are discussed and implementation details are outlined. In the end, the created software is shown and its limitations are discussed.

The prototype is based on the serious game design in the previous chapter. Most of the requirements are based on this fact. Furthermore, this prototype should enable the evaluation of the relationship between the concept of the game and teamwork. The user interface is another component whose structural setup can be tested. It is also possible to get an idea of how a fully fledged game based on the current serious game design would look.

The technical design includes multiple software components, which are located on either the server side or client side. The overall workflow is shown, including all components and their interplay. The JSON data format for the web socket message system is discussed, which connects the Node.js server with the C# Unity clients.

The four different areas of limitations are outlined along with their reasons, and possible solutions are reviewed. Visualization, functionality, game balancing, and the transient storage are all approved limitations, which can be overcome by spending more time on development and game testing.

The prototype designed in this chapter is the basis of the user study described in the next chapter.

6. Prototype Evaluation

In this chapter, the prototype evaluation will be planned and analyzed. The aim of the study, its setup, and the concrete procedure will be discussed. After that, the results will be collected, presented, and analyzed.

6.1. Study Design

The basis for research is validation. In the context of a serious game, there are many issues which need to be discussed, and assumptions which need to be validated. The biggest assumption in relation to serious games is probably the one that puts this e-learning approach before traditional approaches in terms of learning efficiency and user motivation during usage.

Evaluating learning efficiency and user motivation needs to be the long-term goal of the scientific efforts related to the proposed serious game design. At this stage, these evaluations seem to be premature since the presented prototype is in a very early stage. The two main reasons for this are the dull graphical representation, and the yet to be carried out game balancing.

To begin with, a simpler evaluation is required for serious game design that was created. This evaluation can be used to validate base assumptions of the serious game design, and allows for a game balancing, as well as an interpretation of tracking quantities in relation to the game mechanics within the game. It can also be used to guide the development of the next level prototype in terms of new features and a desirable game design.

6.1.1. Study Aim

The study, conducted in this thesis, aims to validate the relationship between the prototype and teamwork, as well as the layout of the user interface and the potential for a fully-fledged version of the game. The following section will give a justification for these three evaluation focuses.

The relationship between the prototype and teamwork is central to the learning efficiency of the serious game. If there is none, it seems very unlikely that learning about teamwork would be possible with this game. The player's perception of the game's relationship to teamwork is an approximation of the real relationship between teamwork and the game. Due to the very basic game mechanics and graphical

representation, this evaluated relationship could be a good indicator not only for the prototype, but also for the serious game design.

The second evaluation focus, the user interface, is intended to give feedback about the prototype. The arrangement of the panels and buttons, as well as the game world manipulation methods are a central aspect of a strategic game. The usage should be easy and quick to understand. The feedback can be used to guide the implementation of the next prototype.

Finally, the recognition of the prototype's game mechanics as being suitable for a fully-fledged game is interesting. If this potential has already been seen by non-involved players at this early stage when playing the game, this is a strong indicator for the game design's future success.

6.1.2. Study Related Evaluation Questions

Based on the research question **'How can a purely virtual serious game be designed to develop teamwork skills?'** and the outlined serious game design, implicit assumptions are made. One of them has already been discussed in the previous subsection, namely the relationship between teamwork and the prototype. Another one, often overlooked due to its triviality, is that the prototype usage is simple and intuitive, in short, it has good usability. Finally, the prototype's potential as a fully-fledged game is of great interest.

These assumptions are formulated as evaluation questions for the evaluation study and are stated in the following way:

[Q1] Is there a perceivable relationship to teamwork when playing the prototype game?

- **[Q1.1]** Is there a perceived superficial relationship to teamwork when playing the prototype game?
- **[Q1.2]** Is there a perceived relationship to the four teamwork aspects (communication, orientation, adaptability, and monitoring) by means of their definitions when playing the prototype game?

[Q2] Does the game's user interface feature good usability?

[Q3] Is the game potential of this prototype recognized when playing the prototype game?

- **[Q3.1]** Can it be foreseen, that a fully-fledged game based on the presented prototype and its game mechanics could be an entertaining game?
- **[Q3.2]** Can it be foreseen, that a fully-fledged game based on the presented prototype and its game mechanics could be a game suitable for training in teamwork skills?

Below, the evaluation study is outlined in order to answer the questions **Q1** (via the questions **Q1.1** and **Q1.2**), **Q2**, and **Q3** (via questions **Q3.1** and **Q3.2**).

6.1.3. Study Setup

The study is divided into two parts, namely the expert evaluation and the user experience evaluation. The expert part of the study is intended to evaluate the pedagogical aspects of the prototype. The user experience part of the study is intended to evaluate aspects related to the potential for fun and handling of the prototype.

Within both parts of the study, each participant is asked to fill out questionnaires, watch a video, and try out the prototype. The required materials, such as the laptop and writing material are supplied by the study supervisor. The preparation on the laptop is also done by the supervisor.

Following the trial, the questionnaires are collected and bundled. The questionnaires are anonymous and cannot be traced back participants after the study has been conducted.

Expert Evaluation.
In the expert evaluation part of the study, experts are questioned about the pedagogical aspects of the prototype game. Due to the many scientific areas involved in the prototype construction, multiple experts are considered. This includes experts in the area of learning, computer games, and cognitive research.

Each trial of the expert evaluation will be conducted individually with each participant within a single session under supervision, and will take about one hour. The supervisor explains the study procedure to the participant before the start of the trial. He is also responsible to answer possible questions from the participant as long as they do not influence the study.

User Experience Evaluation.
In the user experience evaluation, potential users are questioned about game-relevant aspects of the prototype game. The field of potential users is wide, but in this study, the focus is on students betwenn the ages of twenty and thirty.

Each trial of the user experience evaluation will be conducted for four participants playing as a team within a single session under supervision, and will take about one hour. The supervisor explains the study procedure to the participant before the start of the trial. He is also responsible to answer possible questions from the participant as long as they do not influence the study.

6.1.4. Study Procedure and Motives

In the following, the procedure for both the expert evaluation and the user experience evaluation are outlined. Also, the motives for the chosen structure is given.

User Experience Evaluation

1) Fill out the demographic data questionnaire (3 questions), see Table A.1
2) Watch an explanatory video about the game and its features (7:45).

3) Play the game for 15 minutes in a team of four.
4) Fill out the SUS questionnaire (Brooke et al., 1996) (10 questions), see Table A.6.
5) Fill out the concept-specific player questionnaire (10 questions), see Table A.7.

In the introduction phase of the study, the participant watches an explanatory video and plays the game prototype. The video is intended to give the participants a quick overview of the game and its mechanics. During the short game session the participants can experience the prototype game and its features in a team of four.

In the evaluation phase, the participants feedback is collected by using the SUS questionnaire and a concept specific questionnaire. The SUS questionnaire gives insights into the usability capabilities of the prototype game for the evaluation question **Q2**. The concept specific player questionnaire examines the game's potential for the evaluation question **Q3.1**.

Expert Evaluation.

1) Fill out the demographic data questionnaire (3 questions), see Table A.1
2) Fill out the foreknowledge questionnaire (3 questions), see Table A.2.
3) Watch an explanatory video about the game and its features (7:45). It can be found here:
   https://www.dropbox.com/s/oq38zhn33apuv17/prototypeVideo.mp4?dl=0
4) Perform tasks in the game (8 tasks), see Table A.3.
5) Fill out the first part of the concept-specific expert questionnaire (10 questions), see Table A.4.
6) Fill out the second part of the concept-specific expert questionnaire (12 questions), see Table A.5.

In the introduction phase of the study, the participant fills out the foreknowledge questionnaire, watches an explanatory video, and executes tasks in the game. The foreknowledge questionnaire is intended to give better insights into the quality of the answers given in relation to one of the different areas, namely learning, computer games, or cognitive research. After that, the game is described in an explanatory video about the prototype. The game mechanics shown have to be used by the participant when performing tasks in the game in order to get a feel for the game.

In the evaluation phase, the participants' feedback is collected by using the concept-specific expert questionnaire, which is divided into two parts. The first part questions the participant about the game's learning/teaching potential for evaluation question **Q3.2** and about the perceived superficial relationship to teamwork for evaluation question **Q1.1**. The second part of the concept-specific expert questionnaire aims to examine the perceived relationship between the four teamwork aspects communication, adaptability, monitoring, and orientation for evaluation question **Q1.2**. For this purpose, the definitions for all four teamwork aspects are given.

6.2. Results

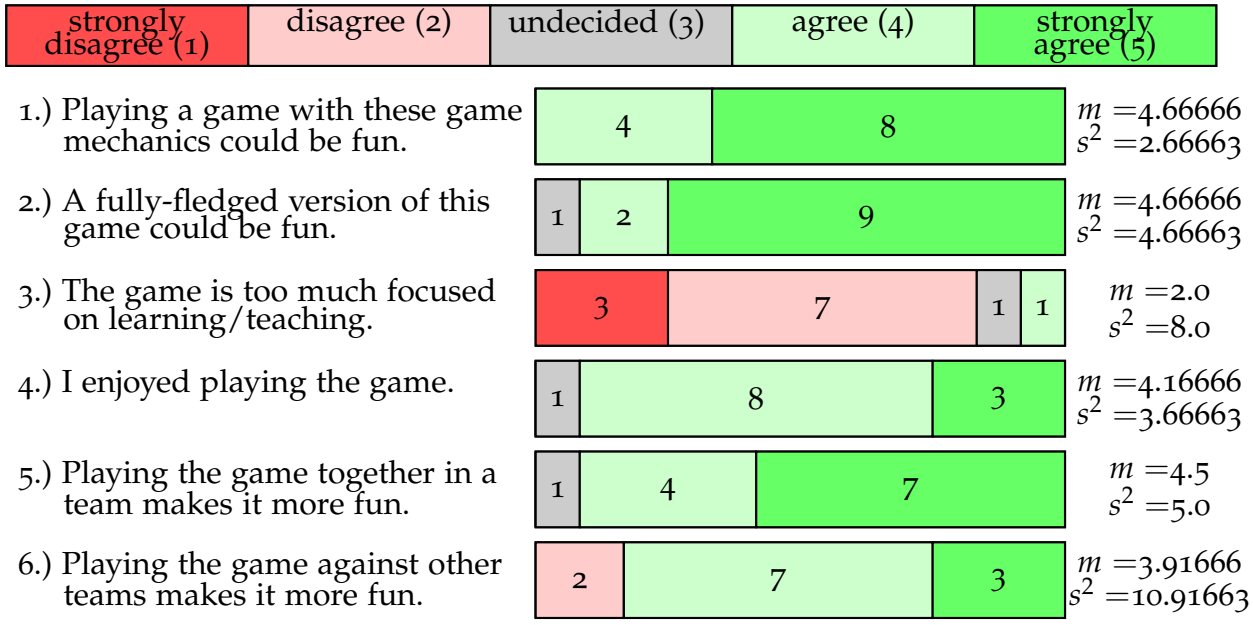
In this section, the results of the evaluation are shown. The full answers can be found in Appendix B.

6.2.1. User Experience Evaluation

For the user experience evaluation, three test runs were carried out with four participants for each test run. Four of the participants were in the $18-25$ age bracket, and eight were in the $26-30$ age bracket. The highest degree or level of schooling completed by the participants included five master's degrees, one bachelor's degree, five higher education certificates, and one secondary school certificate. There were two female and ten male participants.

The SUS scores of the eight participants can be found in the interval between 37.5 and 90 with a sample mean of 73.5 and a sample standard deviation of 14.4. This means that the software has good usability (Bangor, Kortum, & Miller, 2009). Assuming a normal distribution for the SUS score, the one-sided, 95% confidence interval is limited with the value 65.7.

Figure 6.1.: Result - Software Specific User Questionnaire, Likert-scale questions



Answers to the Likert-scale questions of the software-specific player questionnaire, see Table A.7. The values for m and s^2 represent the sample mean and variance, with *strongly disagree* encoded as 1, *disagree* encoded as 2, *undecided* encoded as 3, *agree* encoded as 4, and *strongly agree* encoded as 5.

When looking at the Likert-scale answers of the software-specific user questionnaire (see Figure 6.1), a score similar to the SUS score can be calculated. For each participant, the items get rated from zero to four, summed up, and multiplied by 25/6. This

yields a value in the range from zero to 100. Item three is rated as five minus the position of the ticked square from the left. All other items are rated as the position of the ticked square from the left minus one. This leads to scores which can be found in the interval between 58.3 and 91.7 with a sample mean of 83 and a sample standard deviation of 9.2.

The answers to the open questions of the software specific user questionnaire are listed in Table 6.1. They are only concerned with the game depth (7) and the usability (14) of the prototype.

Table 6.1.: Result - Software Specific User Questionnaire, open questions

I'd like to see the following game mechanics added to the game to make it more fun:
more buildings maybe; cheats; mehr gebäude bauen können; einkaufen; mehr ressourcen; create products from resources; more buildings levels/buildings; more buildings like market, that maybe have special powers; chat: mehrzeilige Nachrichten und "Entfehrnen" sollte möglich sein; Spielfeld Reize ausbauen (vlt. "richtige" Häuser oder Arbeiter); Noch mehr Funktionen, Gebäude höher ausbauen; Im Prinzip Prototypen ausbauen
I suggest the following improvements:
interface improvments; doesn't have to zoom in on the buildings that much; resource transfer: number always reload*; chatfenster immer öffnen können; show how much assignment of workers is exhausted ("30 workers assigned too much"); make it possible to play against other teams; Das Spiel war von der Geschwindigkeit eher schnell. Eventuell Gebäude länger ausbauen lassen etc.; Anderes Wort für Punkte
The following game features need to be improved:
chat:multiline; save game stats; zoomen; closing button for pop-ups/tabs (e.g. chat, buildings) "Enter" for chat $->$ sending message; easy recognition of different resource buildings; chat: multiline support; chat; sliders; chat; assigning workers cumbersome; only three expansion levels so far; Kommunikation mit dem Team: unterschiedliche Möglichkeit der Kommunikation; Einfach mehr Funktionen Gruppenkonto mit den Punkten nicht gut umgesetzt weil zB Ressourcen ans Konto übergehen dort dann aufeinmal weg sind
I found the following bugs:
resource transfer: see above *(see: *)*; no multiline chat messages changing from building menu to chat not possible; Chat funktioniert nur Einzeilig; Geschwindigkeit vom Spiel zu schnell; keine Pausen der Arbeiter

Answers to the open questions of the software specific player questionnaire, see Table A.7.

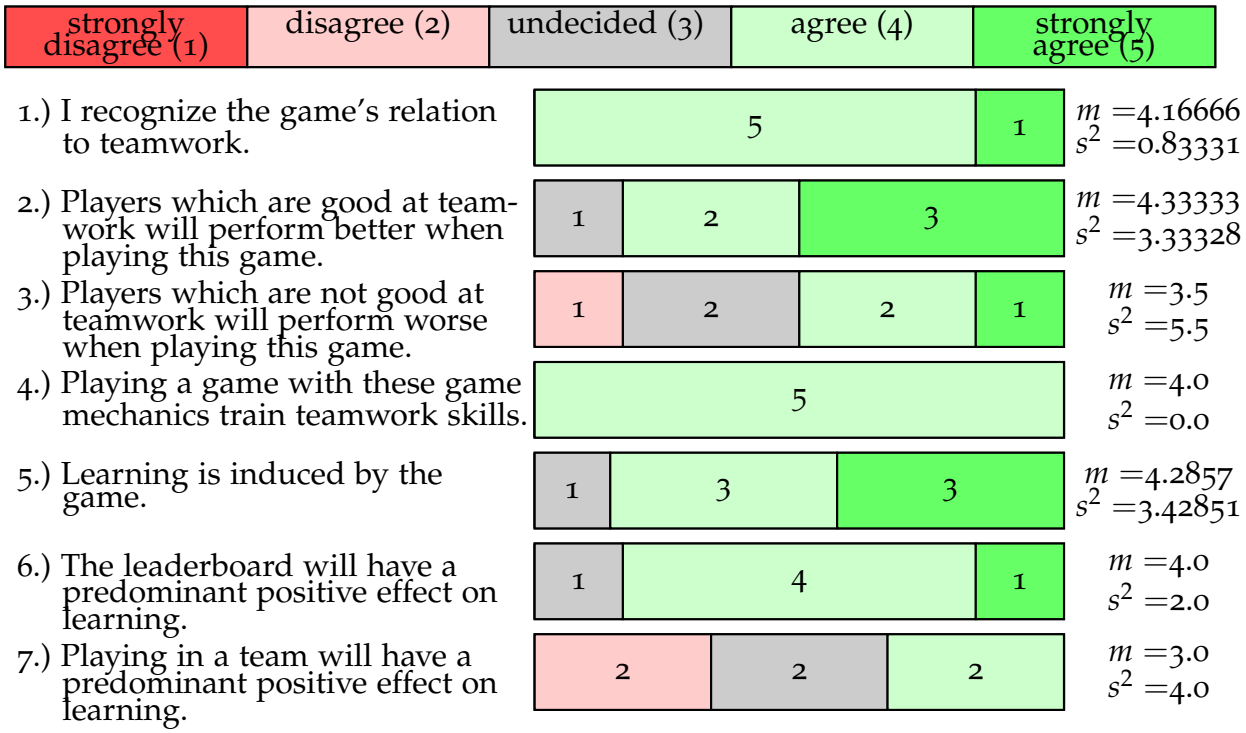
6.2.2. Expert Evaluation

For the expert evaluation, six test runs were carried out. Each test run included one expert. At least two of them were experts for teaching/learning, at least two of them were computer game experts, and at least two of them were cognitive science experts. Four of them were in the $26-30$ age bracket, one in the $36-40$ age bracket, and one in the $41-50$ age bracket. The highest degree or level of schooling completed by the

participants were four master's degrees and two doctorate degrees. There were two female and four male participants.

When looking at the Likert-scale answers of the software-specific expert questionnaire, part 1 (see Figure 6.2), a score similar to the SUS score can be calculated. This can be done to calculate a teamwork score (items 1, 2, 3, 4) and a learning score (items 4, 5, 6, 7). For each participant, the items get rated from zero to four, summed up, and multiplied by 25/4. This yields a value in the range of zero to 100. All items are rated as the position of the ticked square from the left minus one. This leads to teamwork result scores, which can be found in the interval between 62.5 and 87.5 with a sample mean of 75, and a sample standard deviation of 11.2. The learning result scores can be found in the interval between 62.5 and 75 with a sample mean of 67.7, and a sample standard deviation of 4.7.

Figure 6.2.: Result - Software Specific Expert Questionnaire, Part 1, Likert-scale Questions



Answers to the Likert-scale questions of the software-specific expert questionnaire, see Table A.4. The values for m and s^2 represent the sample mean and variance, with *strongly disagree* encoded as 1, *disagree* encoded as 2, *undecided* encoded as 3, *agree* encoded as 4, and *strongly agree* encoded as 5.

The answers to the open questions of the software-specific expert questionnaire, part 1, are listed in Table 6.2. They are concerned with the prototype's game depth, usability, and suggestions for teamwork improvement.

The results of the rating questions of the software-specific expert questionnaire, part 2, are given in Table 6.3. The resulting means for the representation of the specific teamwork dimensions are between 5.8 and 7.2, where 1 stands for a low representation and 10 stands for a high representation.

Table 6.2.: Result - Software Specific Expert Questionnaire, Part 1, open questions

I'd like to note the following concerning learning with this game:
I am not sure if a leaderboard will improve learning; Es kann die Kooperation zu anderen fördern um ein gewünschtes, gemeinsames Ziel zu erreichen. Es können Strategien erlernt werden, die dazu dienen, gemeinsame/kollektive und auch individuelle Ziele, erreichen zu können. Soziales Lernen: "geben und nehmen" in Bezug auf die Verteilung der Rohstoffe. Gegenseitiges Helfen = stärkt das Team und das Individuum. Das Spiel kann teilweise einen Hinweis darauf geben, ob eine Person "teamfähig" ist oder eher ein Einzelkämpfer ist. Die SpielerInnen erhalten durch dieses Spiel auch die Möglichkeit zu lernen, ihre persönliche Bedürfnisse und die ihrerArbeiterInnen, in verständlicher und wohlwollender Form, den anderen SpielerInnen mitzuteilen. Es können auch Kommunikationsformen entwickelt werden, die es erlauben, dass das Team noch effektiver arbeiten kann.; i would add more functionality to include conflicts of interest for individual players (e.g. betrayal), more incentives for promoting cooperation; quantitative positive feedback is provided, if the player applies teamwork; in addition to teamwork, the game definitely also provides great training on strategy thinking skills
I'd like to note the following concerning the teamwork relation of this game:
I think a leaderboard could improve teamwork; Kommunikation als Medium, um eine Teamaufgabe erfolgreich bewältigen zu können. Umgang und effektiver Nutzen von vorhandenen Ressourcen sowie der Aufbau von neuen Ressourcen (als Individual- und Teamleistung). Kooperation mit anderen Teammitgliedern, um ein gewünschtes Ziel erreichen zu können.; The individual aspects about teamworking could be made more explicit and clear; I would have been able to recognize the relation to teamwork even) better, if there would have been more other players (virtual ones, or even better - real ones)
I'd suggest the following to enhance the game's usefulness:
Improve design (I know, it is a prototype); Ev. Könnte man das Spiel erweitern, so, dass beispielsweise zum Ausbau eines Hauses Teamwork gefragt ist oder so, dass gewisse Rohstoffe neu durch Teamwork zugänglich werden. Man könnte auch eine Funktion einbauen, also eine Aufgabe, die unterucht, wie Teamfähig die SpielerInnen sind → nach dem Dissonanzprinzip.; usability improvements (e.g. how workers are assigned), better visual clues on changes (e.g. group bonus change), and some sort of achievement notification (general impression: it's hard to fell something happening/changing); Relation between individual and group leaderboard should be more clear (goal of the game; maybe some theoretical explanation on teamwork skills and optional self-assessment on those skills (would enable even pre- post assessment after playing the time for a while))

Answers to the open questions of the software-specific expert questionnaire, part 1, see Table A.4.

Table 6.4 lists the answers to the open questions of the software specific expert questionnaire, part 2.

6.3. Discussion

In this section, the study and the results gathered from it are discussed in regard to the evaluation questions introduced at the beginning of this chapter. For this task, it

Table 6.3.: Result - Software-Specific Expert Questionnaire, Part 2, rating questions

How strong is the particular aspect of teamwork represented in the game prototype on a scale from 1 to 10 (1 - low representation, 10 - high representation):			
Communication	10, 4, 8, 9, 5, 6	mean= 7,	sd= 2.4
Orientation	8, 7, 5, 8, 7, 8	mean= 7.2,	sd= 1.2
Monitoring	9, 2, 8, 8, 6, 8	mean= 6.8,	sd= 2.6
Adaptability	7, 4, 6, 7, 6, 5	mean= 5.8,	sd= 1.2

Answers to the rating questions of the software-specific expert questionnaire, part 2, see Table A.5. The ratings for the four teamwork aspects, as well, as the mean and the standard deviation of the ratings is shown.

is important to consider the study setting, and how it differs from the anticipated game setting. Also, the state of the game prototype needs to be considered. Each of these three points will now be examined.

A big difference in the test setup of the user experience evaluation in comparison to the anticipated game setting is the game duration. The users tested the prototype for 10 to 15 minutes, whereas the anticipated game setting is to use the game several times for short intervals over a long periode of time. This influenced the gaming experience, since the resource costs of buildings and game times, such as building times and the times after which a change of bonuses occurred, were adapted.

Another big difference in the test setup in comparison to the anticipated game setting is the number of teams involved. The motivational aspect of the competition was ruled out by only having one team involved. The only sense of competition might have been perceived when comparing scores within the team.

The state of the game prototype is another limiting situational condition. Only the very basic game mechanics are included, which generates a lack of game depth. Also, the visualization of the prototype can be considered poor.

We will now discuss the evaluation questions based on the study conducted, as well as the answers to the open questions from the conducted study.

6.3.1. Expert Evaluation

[Q1.1] *Is there a perceived superficial relationship to teamwork when playing the prototype game?*

This can be answered with yes based on the answers to the relevant items $(1, 2, 3, 4)$ listed in Figure 6.2. Most of the items' aggregated ratings show a value between *agree* and *strongly agree* (items $1, 2, 4$). Only item 3 (Players which are not good at teamwork will perform worse when playing this game) has an aggregated *undecided* rating. With a calculation method similar to that of the SUS score, the overall result score was computed from the relevant items as 75.

Table 6.4.: Result - Software-Specific Expert Questionnaire, Part 2, open questions

I found the communication aspect of teamwork in the following game mechanics:
chat; chat; embassy & working condition exchange + strategy for specifying on certain resources; chat, embassy; chat, group score; possibility to communicate with team members
I like to note the following regarding communication in the game:
multiline chat messages should be supported; Die Kommunikation ist durch den Chat gut möglich. Für die Untersuchung dieses Konstrukts in Bezug auf teamwork aber noch ausbaufähig.; there could be more scenarios where team players are forced to share information; The receiver of a message should have a button to acknowledge the message; it would be good to have opportunity to contact individual team members directly, would be good to see whether team member has read/received message
I found the orientation aspect of teamwork in the following game mechanics:
leaderboard, chat; Berücksichtigung der Rohstoffvergabe in der Gruppe; Verteilung der Ressourcen auf andere SpielerInnen; Mitteilung der Bedürfnisse der ArbeiterInnen; group leaderboard and group point transfer; embassy; (group score), embassy, donate points to group; collecting team points and group points
I like to note the following regarding orientation in the game:
interactions between users should be improved; Ist schon gut eingebaut; spannend wäre hier auch, eine Aussage darüber zu treffen, welche SpielerInnen "teamplayer" in Bezug auf dieses Konstrukt sind und welche eher Einzelziele verfolgen.; it might be interesting to have a look at which players access the information about individual contribution to team performance - and to investigate the correlation with teamwork skills and individual achievement orientation.
I found the monitoring aspect of teamwork in the following game mechanics:
embassy (if upgraded to level 1); Dieser Part ist nur in Bezug auf die Mitteilung der Bedürfnisse der ArbeiterInnen erfüllt.; embassy and working condition; leaderboard, embassy; group score, embassy; seeing immediate changes/updates in resource points, − but also possibility to communicate with team members about changes, provide feedback etc.
I like to note the following regarding monitoring in the game:
Um dieses Konstrukt noch valider untersuchen zu können, könnte man einen "teamhead" einbauen. Achtung: Was macht das aber dann mit der Gruppendynamik.; I would be interested in the actions of the team members; it might be useful to activate a notice/hint, if some other player has taken an action
I found the adaptability aspect of teamwork in the following game mechanics:
Dieses Konstrukt wird durch den Gruppenbonus beim Transfer der Rohstoffe ausgedrückt.; group bonus & changing working conditions; group bonus; assigning resources to group based on bonus; updates on resources, points; possibility to communicate with others about changes, possibility to change working conditions
I like to note the following regarding adaptability in the game:
changes are very subtle at the moment → make them more visible; maybe some kind of history of actions (and their effect) would be helpful?

Answers to the open questions of the software-specific expert questionnaire, part 2, see Table A.5.

[Q1.2] *Is there a perceived relationship to the four teamwork aspects (communication,orientation, adaptability, and monitoring) by means of their definitions when playing the prototype game?*

All four teamwork aspects were perceived by the experts when playing the game, see Table 6.3. The mean values for the rating between 1 (low representation of the aspect in the prototype) and 10 (high representation of the aspect in the prototype) range from 5.8 to 7.2.

[Q3.2] *Can it be foreseen, that a fully-fledged game based on the presented prototype and its game mechanics could be a game suitable for training in teamwork skills?*

The answers to the relevant items (4, 5, 6, 7) from Figure 6.2 indicate that the answer to this question is yes. All but one of the items' aggregated ratings show a value between *agree* and *strongly agree* (items 4, 5, 6). Item 7 (Playing in a team will have a predominant positive effect on learning) has an aggregated *undecided* rating. With a calculation method similar to that of the SUS score, the overall result score was computed from the relevant items as 67.7.

6.3.2. User Experience Evaluation

[Q2] *Does the game's user interface feature good usability?*

This can be answered with yes based on the high SUS scores, with a mean of 73.5, although many answers to this open question (see Table 6.1) suggest that there is still a lot to do. They were mainly concerned with the chat, which should always be operable, feature multi-line support, and should send messages by pressing enter. Also, the assignment of the workers/resources should be improved, as well as the zoom feature of the game when clicking a tile.

[Q3.1] *Can it be foreseen, that a fully-fledged game based on the presented prototype and its game mechanics could be an entertaining game?*

This question can also be answered with yes when looking at Table 6.1. With a calculation method similar to that of the SUS score, the mean result score was computed from the relevant items as 83. All item ratings were similarly positive; however, items three (The game is too much focused on learning/teaching) and six (Playing the game against other teams makes it more fun) are a little bit lower. They are still rated with nearly the second best option out of five options.

6.3.3. Answers from Open Questions

The open questions from both studies delivered a series of answers on how to improve the game. The answers from the user experience evaluation, see Table A.7, were mainly directed towards the usability and the game depth of the prototype. The answers from the expert evaluation, see Table A.4 and Table A.5, are also concerned with the improvement of the teamwork training functionality of the prototype. These answers will now be discussed in detail.

Usability and game depth are the areas of concern for the user experience evaluation. This is no surprise since the study was aiming for these two areas, and the prototype's focus was not on one of these two areas. There is a lot of work to do in this direction. The fact that errors are not prevented before they happen was an especially big issue. For example, the sliders for assigning workers could be stopped when trying to assign too many workers. There are many more examples, especially when it comes to game depth, but since this is not the work's focus, we will continue with the remarks from the expert evaluation.

The expert evaluation remarks focus on how to improve or enhance the teamwork training functionality of the prototype. There are three extremely valuable suggestions among them. The first talks about different scenarios for the game, the second recommends the introduction of teamwork activities to unlock buildings or resources. The last suggests explicitly talking about the different teamwork aspects. These three possible improvements will now be examined.

The first suggestion (different scenarios), is especially helpful in situations where learners play the game very often. The need to find a strategy and discuss possible problem solving strategies vanishes after playing this game a few times. By introducing different scenarios that brings along different building costs, different goals, and different in-game possibilities, players are again forced to discuss a common strategy.

The second suggestion (including teamwork activities to unlock buildings or resources) can be used to directly enhance the teamwork training capabilities of the game. These activities can be incorporated as mini-games or mini-challenges to unlock in-game advantages. They can be realized as single player activities or even as multiplayer activities.

The last suggestion (to talk explicitly about teamwork) is interesting but needs to be discussed critically. Although this approach could raise the teamwork training capabilities of the game, it might also transform it to a great extent from a fun game into learning software. As this depends very strongly on the concrete implementation and the subjective perception of the players, tests need to be carried out to evaluate this approach.

6.3.4. Consequences for the Research Questions

Based on the implementation and the study's results, conclusions will be drawn in response to the research questions.

SRQ1 *How suitable is the experiential learning cycle for integration into a teamwork training game from the perspective of learning and teaching?*
This question cannot be answered in general. For the game design realized during this thesis, the experiential learning cycle was incorporated in a satisfying manner. Also, the result related to evaluation question **Q3.2** indicates that the realized approach, properly expanded, is suitable for teamwork training. It is not clear whether this directly depends on the experiential learning cycle, but since the teaching approach of this game design mostly builds upon it, it is a strong indicator for its usefulness.

SRQ2 *How suitable is a competitive and cooperative approach in combination with a strategy game for creating a teamwork training game?*
This question can also not be answered directly using the findings of this thesis since there are a lot of factors influencing the answer. Judging from evaluation questions **Q1.1** and **Q3.1**, the game has a perceivable relationship to teamwork and the potential to become an entertaining game when turned into a fully-fledged game.

RQ *How can a purely virtual serious game be designed to develop teamwork skills?*
Clearly, there are multiple appropriate ways to design a purely virtual serious game for teamwork training. Each of these approaches has its own advantages and disadvantages. Judging from the evaluation results, the experiential learning cycle and a fused competitive/cooperative approach in combination with a strategy game are appropriate game mechanisms to design such a game.

6.3.5. Recapitulation

Summing up, the prototype offers a good basis for a teamwork training game. All evaluation questions have been answered in favor of the implementation. The biggest issues for the users were the usability and the game depth of the prototype. The expert evaluation shows different approaches on how to extend the prototype further. The small sample size of the study (18 participants) limits this positive result.

6.4. Summary

In this chapter, a study including a user experience evaluation and an expert evaluation was planned and analyzed. This study tried to evaluate the implemented prototype following the serious game design that was developed.

The evaluation questions, based on the research question was the starting point for the study. There were mainly three questions to be answered. The first is directed towards the relationship of the prototype to teamwork. The second question tries to assess the prototype's usability. The last one is concerned with the potential of the prototype to make a good teamwork training game.

It was found that all evaluation questions can be answered in favor of the implementation. That means, that the participants recognized a relationship between teamwork and the prototype. Furthermore, the usability of the prototype was rated good. Finally, the prototype has the potential to be extended into a fully-fledged teamwork training game.

The next chapter shows the lessons learned while undertaking this thesis.

7. Lessons Learned

In this section, my own views will be given regarding the presented work. They are divided into three sections, namely the literature review, the implementation of the prototype, and the study.

7.1. Literature

The literature review turned out to be challenging, mainly due to three reasons. The first reason is the vague definition of the terms involved, such as 'serious game' and 'game'. The second reason is that there are multiple research areas involved when considering a teamwork training game. The third and last reason is the quite high number of serious games introduced for team research purposes which are not constructed as learning games. These three reasons will now be explained in more detail.

The terms involved, such as serious game and game, are vaguely defined. Considering our serious game working definition as a **digital game with an explicit and carefully thought-out purpose other than entertainment**, this is obvious. When, for example, investigating a given game, one might not be able to understand the game mechanisms and the intentions of the game creator. These might be difficult to identify or the realization may not have worked as expected. A well-thought-out purpose other than entertainment might only be clear if supportive literature gives insights into the creator's approach. Another crucial question is 'Who decides what well-thought-out means?'

Some of the uncertainty involved in relation to the serious game definition can also be explained by the vague definition of a game. Which features make a game? There is no clear universal answer: in most cases this depends on the perception of the person involved. In a similar way, as adding another meter to a hill does not make it a mountain, there is a vague subjective perception of which features need to come together in order to yield a game.

A teamwork training game is related to multiple research areas, including team research, game research, and learning research. Each of these scientific areas needs to be considered, which makes the literature review an extensive undertaking. In addition, there is also the literature directly focusing on the intersections of two or even all three of the areas included. The overlap of game research and learning research can be considered as extremely important for the underlying task. The overlap of two

other areas, namely the team research and the game research is discussed separately in the next paragraph.

Team research authors introduced a high number of serious games which are not learning games. These games are used, as described in the literature, to investigate certain aspects of teamwork during the gameplay. Of course, learning about the topic involved could happen in these games as well, but this is true for each and every activity. Dealing with a topic might always trigger learning. The one thing missing here is the well thought-out learning purpose. It is probably hard to prove that there is none, but based on the game description in the literature, this well-thought-out learning purpose is missing.

7.2. Implementation and Game Design

When it comes to game design for a teamwork training game, one has to consider three different research areas. This also means combining different findings and theories, which might also be contradicting in some way. For example, a learning game needs to be fun and it needs to convey knowledge. This does not necessarily need to be contradictory, but finding the right balance between learning software and a leisure game for as many people as possible is a challenging task. This is especially true if there are other restrictions, such as those related to the content, which needs to be related to teamwork.

An analogy which often crossed my mind when working on this topic is the one of the perfect car. We are able to build the fastest cars, we are able to build the most economical car, as well, as the cheapest car, but building a car, which is the fastest, cheapest, and most economical is just not possible. In the context of a teamwork training game, this can be interpreted to mean that it is not possible to include the 'best' theory (assuming there is such a theory) from every scientific area involved. If, as a consequence, the 'second best' theory (assuming there is such a theory) in one field is used, the chosen game design is considered to be flawed. This, of course, is a simplified point of view.

Apart from the game design, the implementation also leaves a lot of room for discussion. Developing a game prototype without appropriate visualization could be considered a mindless undertaking. During this process, I discovered that there is indeed value in this approach, since a lot of experience can be gained concerning the game structure and its mechanics. The longer I worked on the prototype, the stronger my confidence in the underlying game principals and the technologies used became. I reached a stage that made me believe that the creation of a fully-fledged version of the game is indeed a feasible and advantageous idea.

7.3. Study

There are two main points which need to be mentioned in relation to the study. The first is the fact that it was hard to find participants. The second concerns user feedback, which was directed towards the usability of the prototype. In the following, these two points are considered further.

It was extremely difficult to find participants for the study, especially in groups of four. The trials were rescheduled quite often before it was possible to gather all participants for them. This was a very time consuming and frustrating procedure for the user experience evaluation. The expert evaluation was, in this sense, much more pleasant, although some trials also needed to be rescheduled.

Besides the SUS questionnaire, a lot of the open questions were also in relation to the usability of the system. This was done, although it was explained that the focus should be on the game mechanics and the game idea. A lot of the system's known weaknesses were stated, but some new and helpful information was also gathered from the feedback concerning the user interface.

7.4. Summary

This chapter will discuss the lessons learned while while undertaking this thesis. This has been done for the literature review, the implementation, and the study conducted.

The literature review was made difficult by the huge focus area generated by the three research areas involved, namely team research, game research, and learning research. The area of team research, in particular, produced a large number of serious games that are not learning games, and this made the research even more difficult. The vague definitions of the terms involved also posed a handicap.

Not only the literature review but also the implementation was a difficult matter due to the different research areas involved. Not all concepts which are considered to be useful for a teamwork training game could be considered due to limited resources.

The study gave important insights, although a lot of the open question feedback was in regard to the user interface, which was not a priority of the prototype. Also, it was difficult to find keen participants.

In the next chapter, this thesis will be summarized and future work will be discussed.

8. Summary and Future Work

In this chapter, the conducted work will be summarized and future work will be discussed.

8.1. Summary

This work presents a purely virtual serious game design for training in teamwork skills based on scientifically well-founded teamwork- and learning-theory. It incorporates content design, learning design, and game design in an experiential learning cycle for teaching communication, orientation, monitoring, and adaptability. Cooperation within a four-player team and competition against other teams function as motivating factors.

The teamwork training game was designed as a strategy browser game that is played repeatedly over a given time period. This long playing period gives the players time to reflect about the in-game actions and their meaning in relation to teamwork. The chosen serious game design largely influences the technical implementation of the prototype.

A game prototype based on the serious game design was realized as two separate components: the game server and the game client. The Node.js game server holds the game logic and performs all game relevant actions. The Unity3D C# game client visualizes the players' game states and offers them manipulation methods. Communication between these two components is done by using sockets.

The prototype was evaluated by performing a user experience study and an expert study. It was shown, that there is a perceivable relationship between the prototype and teamwork. Furthermore, the usability of the prototype was rated as good. Finally, the prototype has the potential to be extended into a fully-fledged teamwork training game. Besides these findings, multiple ideas and approaches on how to extend the prototype, as well as the game design, were collected.

8.2. Future Work

Based on the study conducted, there are three areas to work on related to the serious game design that was developed, and the prototype that was created. First, the prototype needs to be developed further in order to constitute a solid playable game.

Second, the ability of the game to provide training in teamwork skills needs to be investigated. Additionally, team research needs to be conducted in order to extend the game further. These three future work areas will now be discussed in detail.

The first point mentioned, development of the prototype, may be the most important task since the others depend on it. The study has shown, that improvement of graphical representation, game depth, and usability are the first and foremost concern of the players. Furthermore, game balancing needs to be done to allow enjoyable gameplay. After all these game-related improvements are done, the game can be analyzed based on its teamwork training capabilities.

This brings us to the second point that was mentioned, the game's teamwork training functionality. This functionality is the main reason for the game and needs to be verified. This was already done on a superficial, meta-level by domain experts; however, a verification based on a user study needs to be conducted next.

Besides the validation of the game's teamwork training capabilities, the conducting of team research is a central point for the game's further development. This last point is especially important to identify indices for the teamwork dimensions and assign them with a meaning. As a basis, the indices from Chapter 4, Serious Game Design, can be used. These indices could then be used to analyze a player's performance during game play, provide feedback, and help with improving the player's performance and teamwork skills.

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Appendix

Appendix A.

Study - Questionnaires and Procedure

This appendix shows the study procedure used in this thesis. The study conducted follows the structure described below, and is divided into an expert evaluation and a user experience evaluation.

A.1. Expert Evaluation.

1) Fill out the demographic data questionnaire (3 questions), see Table A.1
2) Fill out the foreknowledge questionnaire (3 questions), see Table A.2.
3) Watch an explanatory video about the game and its features (7:45).
4) Perform tasks in the game (8 tasks), see Table A.3.
5) Fill out the first part of the concept specific expert questionnaire (10 questions), see Table A.4.
6) Fill out the second part of the concept specific expert questionnaire (12 questions), see Table A.5.

Table A.1.: Demographic Data Questionnaire

Answer the following questions.

1.	What is your age?	☐ <18	☐ 18-25	☐ 26-30	☐ 31-35
		☐ 36-40	☐ 41-50	☐ 51-60	☐ >60
2.	What is the highest degree or level of school you have completed?	☐ No schooling completed		☐ Secondary school certificate	
		☐ Higher school certificate		☐ Bachelor's degree	
		☐ Master's degree		☐ Doctorate degree	
3.	What is your gender?	☐ Female	☐ Male	☐ Not listed	

This questionnaire is used to gather the demographic data of the participants.

Table A.2.: Foreknowledge Questionnaire

Rate your experience in the following categories.

	very low	low	moderate	high	very high
1. Learning/Teaching	☐	☐	☐	☐	☐
2. Computer Games	☐	☐	☐	☐	☐
3. Cognitive Research	☐	☐	☐	☐	☐

This questionnaire is used to determine the foreknowledge of the participants in relation to learning/teaching, computer games, and cognitive research.

Table A.3.: Evaluation Tasks

Perform the following tasks.

1. Assign an arbitrary number of workers to any site.
2. Expand any gathering site to level one.
3. Reach a team score of 200.
4. Inform a team member of his working condition.
5. Change your own working condition to any state.
6. Collect individual building points
7. Check the individual leaderboard.
8. Collect group bonus points.

The eight tasks which are performed by the participant during the study using the prototype.

A.2. User Experience Evaluation.

1) Fill out the demographic data questionnaire (3 questions), see Table A.1
2) Watch an explanatory video about the game and its features (7:45). It can be found here:
   https://www.dropbox.com/s/oq38zhn33apuv17/prototypeVideo.mp4?dl=0
3) Play the game for 15 minutes in a team of four.
4) Fill out the SUS questionnaire (Brooke et al., 1996) (10 questions), see Table A.6.
5) Fill out the concept specific player questionnaire (10 questions), see Table A.7.

Table A.4.: Software-Specific Expert Questionnaire, Part 1

Rate how much you agree with the following statements based on your experience.

	strongly disagree	disagree	undecided	agree	strongly agree
1. I recognize the game's relation to teamwork.	☐	☐	☐	☐	☐
2. Players which are good at teamwork will perform better when playing this game.	☐	☐	☐	☐	☐
3. Players which are not good at teamwork will perform worse when playing this game.	☐	☐	☐	☐	☐
4. Playing a game with these game mechanics train teamwork skills.	☐	☐	☐	☐	☐
5. Learning is induced by the game.	☐	☐	☐	☐	☐
6. The leaderboard will have a predominant positive effect on learning.	☐	☐	☐	☐	☐
7. Playing in a team will have a predominant positive effect on learning.	☐	☐	☐	☐	☐

8. I'd like to note the following concerning learning with this game:

_____

_____

9. I'd like to note the following concerning the teamwork relation of this game:

_____

_____

10. I'd suggest the following to enhance the game's usefulness:

_____

_____

Game-specific expert questions for evaluating the perceived superficial relationship between the game and teamwork, as well as the learning/teaching potential of the game.

Table A.5.: Software Specific Expert Questionnaire, Part 2

Read the following definitions and answer the related questions.

*Closed-loop **communication** is characterized by the exchange of information between a sender and a receiver irrespective of the medium. Behavioural makers of closed-loop communication are: • Following up with team members to ensure a message was received. • Acknowledging that a message was received. • Clarifying with the sender of the message that the message received is the same as the intended message.*

1. How strong is the communication aspect of teamwork represented in the game prototype on a scale from 1 to 10 (1 - low representation, 10 - high representation): _____
2. I found the communication aspect of teamwork in the following game mechanics:

---

3. I like to note the following regarding communication in the game:

---

*Team **orientation** is defined by the propensity to take other's behavior into account during group interaction and the belief in the importance of team goal's over individual members' goals. Behavioural makers of team orientation are: • Taking into account alternative solutions provided by teammates and appraising that input to determine what is most correct. • Increased task involvement, information sharing, strategizing, and participatory goal setting.*

4. How strong is the orientation aspect of teamwork represented in the game prototype on a scale from 1 to 10 (1 - low representation, 10 - high representation): _____
5. I found the orientation aspect of teamwork in the following game mechanics:

---

6. I like to note the following regarding orientation in the game:

---

*Mutual performance **monitoring** is defined by the ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor teammate performance. Behavioural makers of mutual performance monitoring are: • Identifying mistakes and lapses in other team members' actions. • Providing feedback regarding team member actions to facilitate self-correction.*

7. How strong is the monitoring aspect of teamwork represented in the game prototype on a scale from 1 to 10 (1-low representation, 10-high representation): _____
8. I found the monitoring aspect of teamwork in the following game mechanics:

---

9. I like to note the following regarding monitoring in the game:

***Adaptability** is defined by the ability to adjust strategies based on information gathered from the environment and reallocation of intrateam resources. Altering a course of action or team repertoire in response to changing conditions (internal or external). Behavioural makers of adaptability are: • Identify cues that a change has occurred, assign meaning to that change, and develop a new plan to deal with the changes.• Identify opportunities for improvement and innovation for habitual or routine practices.• Remain vigilant to changes in the internal and external environment of the team.*

10. How strong is the adaptability aspect of teamwork represented in the game prototype on a scale from 1 to 10 (1 - low representation, 10 - high representation): _____
11. I found the adaptability aspect of teamwork in the following game mechanics:

---

12. I like to note the following regarding adaptability in the game:

Game-specific expert questions for evaluating representation of the teamwork aspects in the prototype.

Table A.6.: SUS Questionnaire

		strongly disagree	disagree	undecided	agree	strongly agree
1.	I think that I would like to use this system frequently	☐	☐	☐	☐	☐
2.	I found the system unnecessarily complex	☐	☐	☐	☐	☐
3.	I thought the system was easy to use	☐	☐	☐	☐	☐
4.	I think that I would need the support of a technical person to be able to use this system	☐	☐	☐	☐	☐
5.	I found the various functions in this system were well integrated	☐	☐	☐	☐	☐
6.	I thought there was too much inconsistency in this system	☐	☐	☐	☐	☐
7.	I would imagine that most people would learn to use this system very quickly	☐	☐	☐	☐	☐
8.	I found the system very cumbersome to use	☐	☐	☐	☐	☐
9.	I felt very confident using the system	☐	☐	☐	☐	☐
10.	I needed to learn a lot of things before I could get going with this system	☐	☐	☐	☐	☐

The SUS questionnaire for evaluating the game and its user interface (Brooke et al., 1996).

Table A.7.: Software-Specific Player Questionnaire

Rate how much you agree with the following statements based on your experience.

	strongly disagree	disagree	undecided	agree	strongly agree
1. Playing a game with these game mechanics could be fun.	☐	☐	☐	☐	☐
2. A fully-fledged version of this game could be fun.	☐	☐	☐	☐	☐
3. The game is too much focused on learning/teaching.	☐	☐	☐	☐	☐
4. I enjoyed playing the game.	☐	☐	☐	☐	☐
5. Playing the game together in a team makes it more fun.	☐	☐	☐	☐	☐
6. Playing the game against other team makes it more fun.	☐	☐	☐	☐	☐

7. I'd like to see the following game mechanics added to the game to make it more fun:

_____

_____

8. I suggest the following improvements:

_____

_____

9. The following game features need to be improved:

_____

_____

10. I found the following bugs:

_____

_____

Game-specific player questions for evaluating the game's potential as an enjoyable computer game.

Appendix B.

Study - Raw Data

In this appendix, the study results are displayed. This is done in a very compact way to save space. Answers are separated by the sign |, Questionnaires are separated by the || sign. The ||| sign indicates that data from a new user is shown. An empty or unanswered question is marked by the sign −. Likert-scale answers are encoded as numbers, starting from one for the left-most square, two for the second square from the left, and so on.

For the user experience evaluation, first the date of the trial is shown, then the answers of the demographic data questionnaire (Table A.1), followed by the answers to the SUS questionnaire (Table A.6), and lastly the software-specific player questionnaire (Table A.7).

For the expert evaluation, first the date of the trial is shown, then the answers of the demographic data questionnaire (Table A.1) and the foreknowledge questionnaire (table A.2), followed by the answers to first software-specific expert questionnaire (Table A.4), and lastly the second software-specific expert questionnaire (Table A.5).

B.1. User Experience Evaluation

||| 20.07.2018 || 18-25 | secondary school certificate | male || 3 | 1 | 4 | 1 | 4 | 2 | 5 | 2 | 5 | 1 || 5 | 5 | 1 | 4 | 4 | 4 | − |interface improvements| − |− ||| 20.07.2018 || 26-30 | higher school certificate | male || 4 | 2 | 4 | 1 | 4 | 1 | 4 | 2 | 5 | 2 || 5 | 5 | 2 | 4 | 4 | 4 | more buildings maybe | doesn't have to zoom in on the buildings that much | − |− ||| 20.07.2018 || 18-25 | higher school certificate | male || 3 | 4 | 2 | 4 | 2 | 3 | 4 | 3 | 2 | 4 || 4 | 4 | 4 | 3 | 5 | 2 | cheats | resource transfer: number always reload | chat:multiline, save game stats | resource transfer: see above ||| 20.07.2018 || 18-25 | bachelor's degree | female || 4 | 2 | 3 | 2 | 4 | 2 | 4 | 3 | 4 | 1 || 5 | 4 | 2 | 4 | 5 | 5 | mehr gebäude bauen können, einkaufen, mehr ressourcen | chatfenster immer öffnen können | zoomen |− ||| 18.07.2018 || 26-30 | master's degree | male || 3 | 1 | 5 | 2 | 4 | 2 | 5 | 1 | 4 | 1 || 5 | 5 | 2 | 4 | 3 | 5 | − | − | closing button for pop-ups/tabs (e.g. chat, buildings) "Enter" for chat → sending message, easy recognition of different resource buildings |− ||| 1.07.2018 || 26-30 | master's degree | male | 4 | 1 | 4 | 1 | 3 | 2 | 4 | 2 | 2 | 4 || 4 | 5 | 2 | 4 | 5 | 2 | − | show how much assignment of workers is exhausted ("30 workers assigned too much") | chat: multiline support | no multiline

chat messages ||| 18.07.2018 || 26-30 | master's degree | male || 3 | 4 | 5 | 3 | 3 | 2 | 3 | 4 | 4 | 2 || 4 | 3 | 2 | 4 | 5 | 5 | – | – | – |– ||| 18.07.2018 || 26-30 | higher school certificate | male || 4 | 1 | 4 | 1 | 4 | 1 | 5 | 1 | 5 | 2 || 5 | 5 | 2 | 4 | 5 | 4 | create products from resources, more buildings levels/buildings | – | chat, sliders |– ||| 09.08.2018 || 26-30 | master's degree | male || 3 | 1 | 4 | 3 | 4 | 2 | 4 | 2 | 5 | 2 || 5 | 5 | 1 | 5 | 4 | 4 | more buildings like market, that maybe have special powers. | make it possible to play against other teams | chat, Assigning workers cumbersome, only three expansion levels so far | changing from building menu to chat not possible ||| 09.08.2018 || 26-30 | master's degree | female || 4 | 1 | 5 | 4 | 5 | 2 | 5 | 2 | 2 | 1 || 5 | 5 | 1 | 4 | 5 | 4 | chat: mehrzeilige Nachrichten und "Entfehrnen" sollte möglich sein. Spielfeld Reize ausbauen (vlt. "richtige" Häuser oder Arbeiter) | – | Kommunikation mit dem Team: unterschiedliche Möglichkeit der Kommunikation | – ||| 09.08.2018 || 26-30 | higher school certificate | male || 1 | 1 | 5 | 2 | 4 | 1 | 5 | 1 | 5 | 3 || 5 | 5 | 2 | 5 | 4 | 4 | Noch mehr Funktionen, Gebäude höher ausbauen. Im Prinzip Prototypen ausbauen | Das Spiel war von der Geschwindigkeit eher schnell. Eventuell Gebäude länger ausbauen lassen etc. | infach mehr Funktionen | Chat funktioniert nur Einzeilig | 09.08.2018 || 18-25 | higher school certificate | male || 4 | 2 | 3 | 4 | 5 | 1 | 4 | 3 | 5 | 2 || 4 | 5 | 3 | 5 | 5 | 4 | – | Anderes Wort für Punkte | Gruppenkonto mit den Punkten nicht gut umgesetzt weil zB Ressourcen ans Konto übergehen dort dann aufeinmal weg sind | Geschwindigkeit vom Spiel zu schnell, keine Pausen der Arbeiter

B.2. Expert Evaluation

||| 17.07.2018 || 26-30 | master's degree | male || 5 | 2 | 1 || 4 | 5 | 3 | 4 | 5 | 2 | 3 | I am not sure if a leaderboard will improve learning | I think a leaderboard could improve teamwork | Improve design (Iknow, it is a prototype) || 10 | chat | multiline chat messages should be supported | 8 | leaderboard, chat | interactions between users should be improved | 9 | embassy (if upgraded to level 1) | – | 7 | – | – ||| 09.08.2018 || 26-30 | master's degree | female || 5 | 3 | 3 | 4 | 3 | 3 | 4 | 4 | 2 | 5 | Es kann die Kooperation zu anderen fördern um ein gewünschtes, gemeinsames Ziel zu erreichen. Es können Strategien erlernt werden, die dazu dienen, gemeinsame/kollektive und auch individuelle Ziele, erreichen zu können. Soziales Lernen: "geben und nehmen" in Bezug auf die Verteilung der Rohstoffe. Gegenseitiges Helfen = stärkt das Team und das Individuum. Das Spiel kann teilweise einen Hinweis darauf geben, ob eine Person "teamfähig" ist oder eher ein Einzelkämpfer ist. Die SpielerInnen erhalten durch dieses Spiel auch die Möglichkeit zu lernen, ihre persönliche Bedürfnisse und die ihrer ArbeiterInnen, in verständlicher und wohlwollender Form, den anderen SpielerInnen mitzuteilen. Es können auch Kommunikationsformen entwickelt werden, die es erlauben, dass das Team noch effektiver arbeiten kann. | Kommunikation als Medium, um eine Teamaufgabe erfolgreich bewältigen zu können. Umgang und effektiver Nutzen von vorhandenen Ressourcen sowie der Aufbau von neuen Ressourcen (als Individual- und Teamleistung). Kooperation mit anderen Teammitgliedern, um ein gewünschtes Ziel erreichen zu können. | Ev. Könnte man das Spiel erweitern, so, dass beispielsweise zum Ausbau eines Hauses Teamwork gefragt

ist oder so, dass gewisse Rohstoffe neu durch Teamwork zugänglich werden. Man könnte auch eine Funktion einbauen, also eine Aufgabe, die unterucht, wie Teamfähig die SpielerInnen sind → nach dem Dissonanzprinzip. || 4 | Chat | Die Kommunikation ist durch den Chat gut möglich. Für die Untersuchung dieses Konstrukts in Bezug auf teamwork aber noch ausbaufähig. | 7 | Berücksichtigung der Rohstoffvergabe in der Gruppe; Verteilung der Ressourcen auf andere SpielerInnen; Mitteilung der Bedürfnisse der ArbeiterInnen Ist schon gut eingebaut; spannend wäre hier auch, eine Aussage darüber zu treffen, welche SpielerInnen "teamplayer" in Bezug auf dieses Konstrukt sind und welche eher Einzelziele verfolgen. | 2 | Dieser Part ist nur in Bezug auf die Mitteilung der Bedürfnisse der ArbeiterInnen erfüllt. Um dieses Konstrukt noch valider untersuchen zu können, könnte man einen "teamhead" einbauen. Achtung: Was macht das aber dann mit der Gruppendynamik. | 4 | Dieses Konstrukt wird durch den Gruppenbonus beim Transfer der Rohstoffe ausgedrückt. | – ||| 19.07.2018 || 26-30 | master's degree | male || 3 | 5 | 1 || 4 | 4 | 4 | 4 | 4 | 3 | 3 | i would add more functionality to include conflicts of interest for individual players (e.g. betrayal), more incentives for promoting cooperation | – | usability improvements (e.g. how workers are assigned), better visual clues on changes (e.g. group bonus change), and some sort of achievement notification (general impression: it's hard to fell something happening/changing) | 8 | embassy & working condition exchange + strategy for specifying on certain resources | there could be more scenarios where team players are forced to share information | 5 | group leaderboard and group point transfer | – | 8 | embassy and working condition | – | 6 | group bonus & changing working conditions | changes are very subtle at the moment make them more visible ||| 10.08.2018 || 26-30 | master's degree | male || 4 | 5 | 4 || 5 | 5 | 4 | 4 | 4 | 3 | 4 | – | – | – | 9 | chat, embassy | – | 8 | Embassy | – | 8 | Leaderboard, Embassy | – | 7 | Group bonus | – ||| 28.07.2018 || 41-50 | doctorate degree | male || 5 | 3 | 5 || 4 | 4 | 2 | 4 | 4 | 4v | 4 | quantitative positive feedback is provided, if the player applies teamwork | The individual aspects about teamworking could be made more explicit and clear | Relation between individual and group leaderboard should be more clear(goal of the game) || 5 | chat, group score The receiver of a message should have a button to acknowledge the message | 7 | (group score), embassy, donate points to group | – | 6 | group score, embassy | I would be interested in the actions of the team members | 6 | assigning resources to group based on bonus | – ||| 21.08.2018 || 36-40 | doctorate degree | female || 3 | 2 | 5 | 4 | 5 | 5 | 4 | 4 | 3 | 4 | in addition to teamwork, the game definitely also provides great training on strategy thinking skills | I would have been able to recognize the relation to teamwork even better, if there would have been more other players (virtual ones, or even better - real ones) | maybe some theoretical explanation on teamwork skills and optional self-assessment on those skills (would enable even pre- post assessment after playing the time for a while) || 6 | possibility to communicate with team members | it would be good to have opportunity to contact individual team members directly, would be good to see whether team member has read/received message | 8 | collecting team points and group points | it might be interesting to have a look at which players access the information about individual contribution to team performance - and to investigate the correlation with teamwork skills and individual achievement orientation. | 8 | seeing immediate changes/updates in resource points, - but also possibility to

communicate with team members about changes, provide feedback etc. | it might be useful to activate a notice/hint, if some other player has taken an action | 5 | updates on resources, points; possibility to communicate with others about changes, possibility to change working conditions | maybe some kind of history of actions (and their effect) would be helpful?