Requirements for Competence Developing Games in the Environment of SE Competence Development

Philipp M. Zähl [1], Marcel Biewendt [2], Martin R. Wolf [3], Mathias Eggert [4],

Abstract: Many of today's factors make software development more and more complex, such as time pressure, new technologies, IT security risks, et cetera. Thus, a good preparation of current as well as future software developers in terms of a good software engineering education becomes progressively important. As current research shows, Competence Developing Games (CDGs) and Serious Games can offer a potential solution.

This paper identifies the necessary requirements for CDGs to be conducive in principle, but especially in software engineering (SE) education. For this purpose, the current state of research was summarized in the context of a literature review. Afterwards, some of the identified requirements as well as some additional requirements were evaluated by a survey in terms of subjective relevance.

Keywords: software engineering, requirements, competence developing games, systematic literature review

1 Introduction

With the start of the covid pandemic in 2019, many companies were forced to invest more in digitization [FRB21]. This has ensured strong growth in the German IT industry, but at the same time the current shortage of skilled workers is slowing down the covering of the associated needs for qualified employees [BPW22; Ge21]. As a result, demand exceeds supply, which means that the prices for software and IT service providers continue to rise [BPW22]. In order to remain competitive and to be prepared for future challenges and technologies, current and future software developers must be adequately trained [Sh00].

1 Lab for IT Organization and Management, Aachen University of Applied Sciences, Eupener Str. 70, 52066 Aachen, Germany; zaehl@fh-aachen.de, https://orcid.org/0000-0003-3302-4415

2 Institute for Digitization, Aachen University of Applied Sciences, Eupener Str. 70, 52066 Aachen, Germany; biewendt@fh-aachen.de, https://orcid.org/0000-0002-3410-7995

3 Institute for Digitization, Aachen University of Applied Sciences, Eupener Str. 70, 52066 Aachen, Germany; m.wolf@fh-aachen.de

4 Aachen University of Applied Sciences, Eupener Str. 70, 52066 Aachen, Germany; eggert@fh-aachen.de, https://orcid.org/0000-0002-3340-7873

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Especially with individual software, which may have to cover very special applications, good preparation for engineering-oriented work in the sense of good software engineering (SE) training is required. As current research shows, Competence Developing Games (CDGs) and Serious Games can offer a potential partial solution [WK17]. However, what are the necessary requirements for such a CDG?

1.1 The CODEGA Project

This paper is based on a thesis, which was developed in the research project CODEGA at the University of Applied Sciences Aachen [Zä22]. CODEGA (*Quality assurance of digital innovations through Competence Developing Games*) was launched in 2021 at the Institute for Digitization Aachen (IDA), in collaboration with the Lab for IT Organization & Management (ITOM) of the Department of Electrical & Information Engineering. The central goal of CODEGA was to investigate whether software quality can be improved by CDGs. This was based on findings from previous research, which demonstrated increased motivation even in more *boring* activities, such as software testing. The project was implemented through the development of an own CDG, on which necessary investigations were subsequently carried out. As a result, the ZeroDebt (ZD) game was created.

ZeroDebt is an online multiplayer deduction game developed as part of the CODEGA project. The gameplay and game setting are strongly based on the game Among Us by *Innersloth*, in which players can move freely in a spaceship. At the beginning of the game, the two roles Crewmate and Impostor are assigned. The task of the Crewmates, who make up the bulk of the group, is to solve the tasks distributed on the map or to identify all Impostors and eliminate them by majority vote. The unknown Impostors, in turn, must eliminate the Crewmates.

During the game, players cannot communicate with each other. Instead, they can discuss their observations or guesses about who the Impostor might be after a body is found or during called emergency meetings. If a majority can agree on a potential Impostor, that Impostor is thrown out of the spaceship. If all Impostors have been eliminated before they could kill enough Crewmates, the Crewmates have won. The Crewmates tasks are simple click or drag'n'drop tasks that can be completed within a few seconds. Even dead Crewmates can continue to complete them as ghosts, putting permanent pressure on the Impostor.

ZeroDebt (ZD) transforms the game in that the Crewmates' tasks are to be solved through software development. For this, a real software project of the players is read in and examined for problems/risks by a SonarQube instance. These identified problems are then introduced into the game environment as Crewmate tasks. Thus, while playing, a player can reduce the technical debt of his project and pave the way for further progress. While the Imposter in Among Us has a countdown after each kill in which he can't kill another player for the time being, in ZD he also has software problems to solve that unlock his ability.

Each completed problem lets him kill one person.

ZeroDebt represents a kind of platform on which many more investigations will be possible. Besides the original goal of improving code quality, the development towards a software engineering CDG is also promising. For this reason, a requirements elicitation is essential for the further development steps.

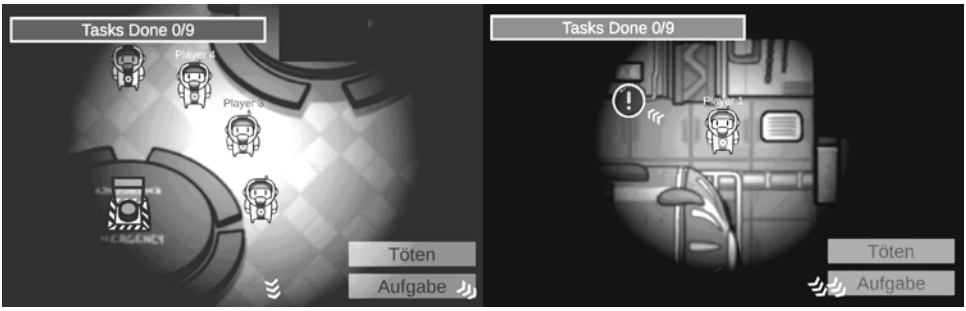

Fig. 1: Screenshots from ZeroDebt

2 Research Method

In order to determine the requirements of a CDG for competence development in the SE environment, a literature research is to be carried out first. Afterwards, some of the identified requirements as well as some additional requirements will be evaluated according to their subjective relevance within the scope of a survey.

3 Systematic Literature Review

3.1 Methodology

The methodological procedure of this research is divided into the three phases *Planning the review, Execution and Analysis* [Ga19; Mc13]. In order to select the literature appropriately and to prevent arbitrariness in the selection of literature, search criteria should be established and the search sources used should be defined [Br15]. The resulting search process is shown in Figure 2. The literature search was conducted in January 2022.

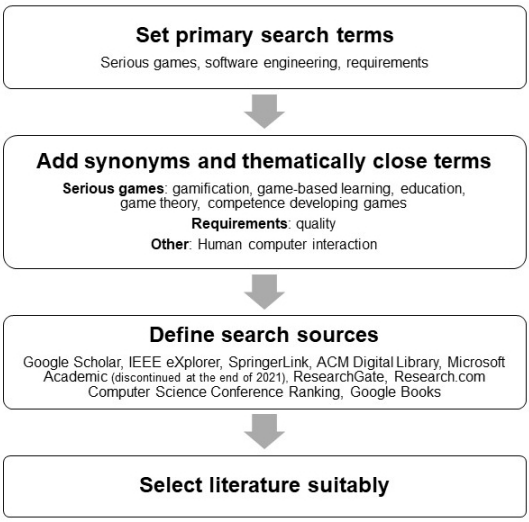

Fig. 2: Search process of the literature review

Studies with collected primary data as well as publications consisting of summaries of secondary literature should be included in the literature search. Thus, it should be ensured that continued research approaches and discovered correlations are not neglected. Furthermore, the following exclusion criteria are established: (1) no full text available; (2) non-English, Dutch or German language studies; (3) publications that only present a self-created learning game without evaluating it with primary data or justifying its success based on similarities to studies from secondary literature.

3.2 Results

The literature review included 19 publications, which include different perspectives, such as psychological or game theoretical perspectives, and different game definitions of Competence Developing Games. Thereby, the literature comes from different years of the last two decades (see Figure 3).

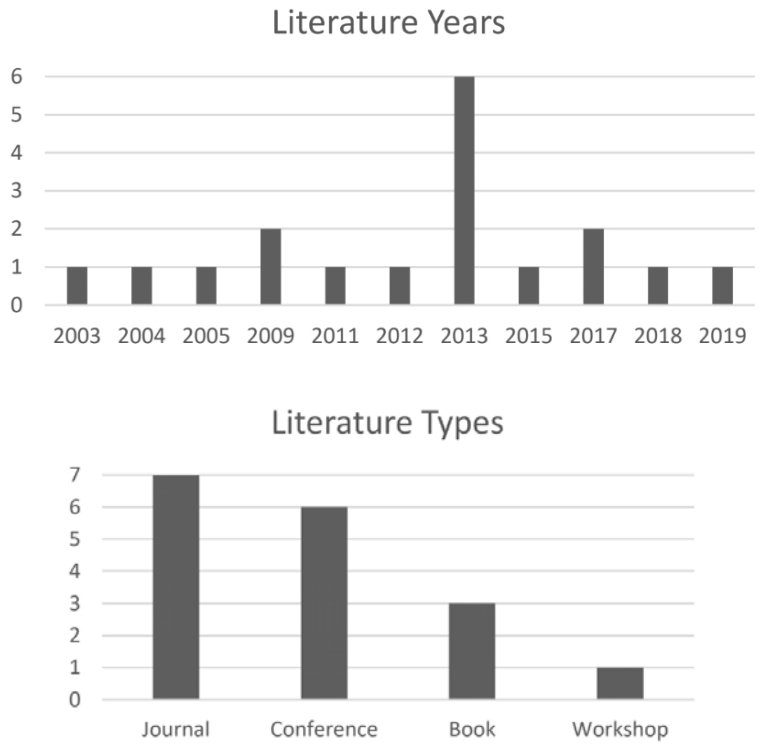

Fig. 3: Statistics on the selected literature

For the sake of clarity, the requirements identified are grouped by category.

Theories of Game Design and common aspects

Games have goals defined according to the SMART principle, or clear, step-by-step, and concise goals [AM18; Ga19; THE09; We13] that appropriately relate learning and business objectives to user interests [We13]. To describe these user interests or needs, different models exist, such as Mark LeBlanc's Taxonomy of Game Pleasures [LHZ04]. According to this, different experience factors or game forms are defined that can be enjoyable for players:

- Sensation (aesthetics, good sound, or tactile pleasure)
- Fantasy (immersion in the fictional world and suspension of disbelief)

- Narrative (suspense or a sequence of events)
- Challenge (by requiring effort through tasks or puzzles)
- Fellowship (feelings of joy, friendship, or community)
- Discovery (exploration, uncovering what is hidden, variety, or strategy)
- Expression (self-expression, creativity, and change)
- Submission (game structures, surrender, and forgetting reality)

It should be noted that players prefer certain game forms [Te16]. Therefore, to reach a broad target group, several of these should be considered in the game design.

Furthermore, players should have the possibilities to achieve a *flow*. Flow refers to a state in which the player is completely immersed in the game and what they are doing. This would include "the feeling of energized concentration, full participation, and success in the process of an activity". However, this requires the game to have a well-chosen level of difficulty and perceived challenges that neither over- nor under-challenge the player. [BT13; Cs01]

Resources

CDGs require a large financial investment. In addition, teachers need "computers with *gaming specification* (usually high-end devices), technical support, familiarity with game-based learning (GBL) content, adequate preparation time, and a suitable group of participants." [THE09] According to [SWM15], time-related factors must also be considered in CDGs. Furthermore, a dilemma exists between the formal framework and the minimum time to generate motivation. The limited time has to be used efficiently accordingly, which requires a suitable integration of the curriculum. [THE09] A game duration of about two hours with a game frequency of once a week is recommended - thus the game motivation is the highest [SC13]. Repetition of the game is essential, since playing once is hardly more effective than conventional learning - only through repetition higher learning successes can be achieved [Wo13].

Learning and environment

The introduction of new teaching methods is often difficult because a strong culture of formal, traditional learning has been established [BT13]. Thus, in the transition phase towards learning by Competence Developing Game, it must be taken into account that old patterns

and other influences can strongly influence learning behavior.

A Competence Developing Game has to be introduced into the curriculum step by step in order to accustom the learners slowly to the new learning environment. A too fast change leads to a "cognitive overload", which can manifest itself in confusion or frustration - thus it is no longer guaranteed that the participants can fully understand and enjoy the game [AM18; BT13]. Furthermore, the game should not be mixed with other teaching methods or forms of teaching, as this reduces motivation and complicates the learning process. "The students would be distracted by the new rules, elements, and learning methods," which would "blurring the learning experience as a whole" [AM18; Wo13]. Thus, it can also prevent participants from seeing the game "as an unnecessary obstacle" [BT13]. At the same time, they should have a possibility knowledge outside of the game, so that they can fill gaps in their knowledge if necessary.

Within the game, skill building should be achieved through situational learning, exploratory learning or learning through failure should be made possible [GS09]. At the same time, motivation, as the most important factor for learning, must always be maintained [Ge03; THE09]: "When motivation dies, learning dies and playing stops. Since good games are highly motivating to a great many people, we can learn from them how motivation is created and sustained" [Ge03]. In the school or university learning environment, after the introduction of a CDGs, participants should not be given complete autonomy over their learning, as this has a negative impact on learning success [BT13].

Game Art and Aesthetics

Participants learn significantly more when CDGs are played in a group [Wo13]. The thus possible competitive or collaborative game concepts as well as the "certain degree of social comparison" have a positive effect on learning behavior [Pi12; We13]. Furthermore, through collaborative multiplayer game concepts or debriefing, experiences can be discussed and solutions debated, e.g., whether there would have been a better way to master the task, thus "completing the learning experience" [Ga19; GS09; THE09]. Such concepts have already been proven in large commercial online games, where players operate in inhomogeneous teams, sharing knowledge and making the most of different skills. "In the process, they create distributed and dispersed knowledge within a community in ways that would please any contemporary high-tech, cross-functional-team-centered workplace." [Ge03]

A good CDG should correspond in its appearance to a professionally developed application or, in this case, a commercial game [BT13]. After all, participants have the same expectations when it comes to the design of CDGs as they do for usual games. If the design is not well chosen or sufficiently mature, this leads accordingly to "disappointment, which is reflected in less motivation and learning" [Wo13]. However, this is contrasted with the fact that common games are primarily designed for entertainment and thus may also show vio-

lent or sexual content, which is unsuitable for a CDG in an instructional setting [THE09]. Basically, CDGs should be designed following game theory and rules of game design to be seen as an appealing and motivating application [GS09]. The visuals of the game world/interface also influence learning behavior: While photorealistic, unrealistic, and cartoon-like representations do not produce a significant difference in motivation but have a negative impact on learning success, a CDG with schematic visuals, on the other hand, can achieve higher motivation without affecting learning [Wo13].

The game genre has received little attention in the selected literature with regard to motivation and learning success. However, it could be observed that "girls and women [prefer] other gaming platforms than men [...], such as also mobile and social games as well as predominantly casual games, simulation and role-playing games. Women often have different game motives than men, i.e. joy and fun, creativity, building up, playing together are in the foreground and less the competition or competitive elements. Men and women also differ in the preferred context of play: Women often play alone, while men often play in virtual communities and teams." Thus, the gender of the intended target audience should be considered when choosing the game genre before developing a CDG. Game intensity is identical for both genders. [Ha17]

In the case of adventure and role-playing games, it must be noted that the game story has a very high influence on engagement and motivation [Wo13]. Furthermore it can be used to impart knowledge [THE09]. In the game world, participants should have the freedom to interact through a set of defined actions to interact in the game world [THE09]. These actions must be obvious and the mechanisms/tools needed to perform them must be understandable and clearly identifiable [Ga19; We13]. To avoid participants receiving relevant information without context or too early, information should be delivered just-in-time. Good games bring information into the game worlds that players move through in such a way that there is always a reference and the meaning is clear. [Ge03]

Game Design, mechanics and concepts

First of all, participants in CDGs should not be only consumers, as in schools, but also producers of their knowledge and curriculum [Ge03]. Thus, CDGs require bringing producers and consumers together to build a dynamic ecosystem [PvC16].

CDGs should include an appropriate game intro. The game intro is tasked with "confronting players in the early stages of the game with problems [that] are specifically designed to allow them to form good generalizations about what will work well later when they are confronted with more complex problems". In addition, the game intro is intended to be a hidden tutorial, that is, a game-like instruction manual where essential game mechanics are explained and tried out. [Ge03]

The protagonist of the game has a separate role in CDGs, as personal identification with

the game character is strongly related to the motivation to play: “The more a player can manipulate a game character and make decisions that impact on the character, the more the player invests in the character and the game at a deep level. This investment appears to be the deepest foundation of a players motivation in sticking with and eventually mastering a game.” - [Ge03] The identification with the character is even more important for women than for men [Ha17].

A CDG should provide a lot of feedback to the participants [GS09; THE09; We13]. In addition, reward systems are necessary, such as badges or a hall of fame where the best players are presented. The prerequisites/performance requirements for such rewards must be known and progress should be visible. Furthermore, in school and university contexts, it is a good idea to link such rewards to grade bonuses or comparable benefits [So17].

Game content specifically for software projects

Basically, the best possible representation of reality must be created. On the one hand, tools from the real world (such as development environments or technologies) can be used in the CDG for this purpose; in addition, simulation modeling should be implemented hybridly by means of Discrete-Event Simulation (DES) and System Dynamics (SD) [Pi12]. Furthermore, norms, industry standards, and other environmental factors should be considered in the CDG [Pi12; THE09].

Tasks

The decisive attribute of a task or its challenge is its difficulty and its further progression through the game progress. Dealing with tasks or challenges can be represented by an expertise cycle, where players are repeatedly confronted with similar problems at the beginning “until the players reach a routine, self-evident mastery of certain skills. Then the game confronts the players with a new problem, such as a new type of enemy or a boss, which forces the players to forcing them to rethink the mastery they have come to take for granted, and to integrate their old skills with new ones. This cycle repeats itself throughout the entire game” [Ge03]. A CDG thus has to find a middle ground where the tasks are challenging enough for the participants, but easy enough that the tasks are manageable within a foreseeable period of time. Tasks that are too difficult and almost impossible to master will result in that fewer people want to play the game - the right level of difficulty, in turn leads to increased motivation: “Since games are often challenging, but doable, they are often also pleasantly frustrating, which is a very motivating state for people. To achieve this, good games allow players to adapt the game to their own abilities and learning styles” [Ge03]. It has been found helpful to consider the background, prior knowledge, and previously gained skills of the participants [Ga19; SWM15; THE09]. In addition, the tasks must become more difficult as the game progresses, so as to accommodate the improved skills of

the players [Ga19; Ge03; We13]. Thus, CDGs can consistently "operate at the extreme and growing edge of a player's competence of a player" and "remain challenging but doable, while schools often must operate at the lowest common denominator" [Ge03]. As a result participants have "a sense of immersion" and can "engage with maximum motivation to actively concentrate". This moment is also referred to as the flow state [BT13; GLE14], which also has a comparable meaning in colloquial language (cf. meaning "I am in the flow").

Essential for a well-balanced level of difficulty are the explanations or tasks associated with the task. In addition to good comprehensibility [SWM15], tasks with active as well as passive instructions should be equally given [Wo13]. In general, care should be taken to ensure that participants receive sufficient guidance and instruction [GS09] and that help or hints are available when needed. In addition to in-game explanations, additional resources should be provided, as presented earlier [Wo13]. Participants can fall back on these if the in-game explanations are not sufficient for them. Especially in Competence Developing Games, tasks should be able to be implemented by clear, standardized solutions, with which a sample solution can be provided after completion of a task [Ga19]. Thereby, sample solution as well as the achieved score should be comprehensible or supplemented by explanations [GS09]. Last, tasks should cover different perspectives and levels of abstraction [Pi12]. Furthermore, the duration of the task should be indicated or at least recognizable [Ga19].

Technical aspects

The game should be highly scalable to "allow for the simultaneous training of a large number of learners" [THE09]. A modular/component-based architecture through web technologies would not only satisfy scalability, but is platform-independent, so that participants can ideally play the CDG on their smartphones [Pi12]. In addition, the game must be adaptable to accommodate future changes or different usage scenarios [SWM15]. The performance of the player and the game must be measurable and the possible interactions must be intentional or planned [We13].

4 Primary Data: Survey

It has been shown which requirements a good Competence Developing Game should fulfill according to the secondary literature. For this purpose, selection criteria were first defined, after which then literature was searched and selected. By means of a uniform examination scheme the requirements were extracted and grouped. To complement the research, a survey was conducted. The scientific findings of this paper are not based on the results of the survey, yet they reaffirm the relevance of the topic.

A total of 130 people from the IT environment (Among others: trainees, students and employees) participated, with an average age of 25. Just under 100 of them are studying a subject related to IT. Of the IT employees, about 58 % work in software development. Using Likert scales, the participants were able to evaluate already mentioned, but also further requirements.

As figure 4 shows, the factors *Good design, Intuitive operation* as well as *Persistent game progress* received the highest approval. On the other hand, *character creation and customization*, the *choice of when to solve which task* and *comparison with others* also received approval, but also many dissenting votes.

Using free text fields, the participants could name game components that are perceived as particularly demotivating:

- Paid content
- punishments for supposedly wasted time
- time pressure
- daily “login compulsion”
- punishing respawn mechanics e.g. by long ways to the previous location/ progress.

In the last section of the survey, participants were presented with a possible concept whereby the ZeroDebt CDG could function as a software engineering CDG. 72 % of the participants were in favor of such a concept. At the same time, however, it was noted that not all SE processes might be suitable or that the prerequisites of these processes, such as communication, might be limited.

A correlation analysis was used to test whether a person’s frequency of play affects the requirements queried. A two-sided T-test was performed to test significance, with a significance level of 5 %. Transitive dependencies were tested for significance without findings.

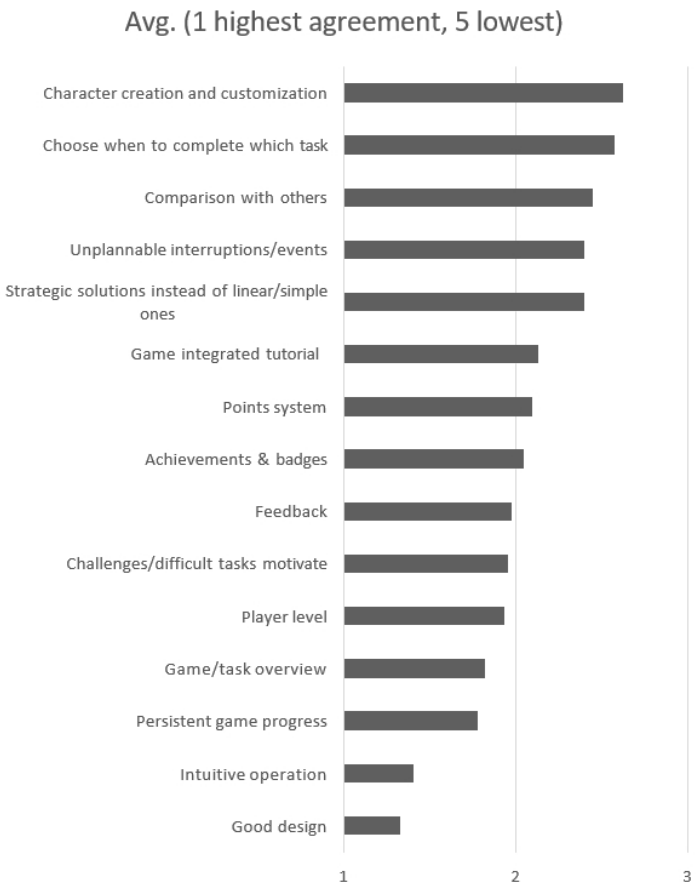

Fig. 4: Survey results [Zä22]

According to this, frequent gamers have the following variations of the requirements (cf. figure 5): The more often the players play, the...

- ...more they want to determine the task order themselves.
- ...more they want to be challenged by more difficult tasks.
- ...more they prefer a persistent game progress.
- ...less they need an integrated tutorial.
- ...shorter a task should take.

5 Discussion

When comparing the requirements determinations in the literature and primary data collection, contradictions can be found:

- *Leaderboard/comparison* with others is an important factor for CDGs according to the literature. However, the conducted survey revealed that this game component is not popular among all players - especially few players stated that the comparison is rather demotivating. This may be due to the fact that few players achieve poorer game results due to their lack of experience. This is because a leaderboard shows them, from their perspective during and after the game, that they did poorly compared to others. This negative rating could have a negative impact on game motivation.

- *Game Optics*: The literature review found that schematic game designs facilitate the highest learning success without having a significant negative impact on game motivation. However, in the survey, respondents indicated that schematic game designs were the least likely to be played. This can possibly be attributed to either an insufficient supply of such games or a lack of interest in playing such games. Thus, the inhibition to play a CDG in schematic design might be higher than for conventional games.

The listed contradictions should be verified by future investigations. Overall, however, it could be observed that the requirements from the literature predominantly coincide with the requirements of our own primary data collection.

Last, it was found that the existing literature for CDGs in the software engineering environment has so far neither formulated explicit requirements for the domain-specific content nor discovered any limitations.

6 Conclusion & Future Work

The intention of this paper was to identify requirements for Competence Developing Games in the software engineering environment. For this purpose, a literature research was conducted.

With regard to the problem statement, it can be stated that CDGs can certainly be used for the further education of students and employees, since previous studies as well as this work have reported positive results. However, it must be noted that such games have to fulfill a high number of requirements, which means that a great deal of effort must go into planning and conception. Otherwise, there is a risk that the game will not find sufficient acceptance or that the learning objectives will not be achieved.

As indicated in the previous section, some contradictions exist between the theoretically optimal as well as the desired requirements. These should be further evaluated in future studies. Furthermore, it is not yet known whether a CDG has to fulfill all requirements in order to be successful. A comparison with conventional computer games would be a promising approach for this.

Last, no domain-specific requirements for software engineering could be identified. Here, it would be useful to further differentiate through primary data.

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