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Bachelor

Computer Science

The search for low-code development platforms that support serious games

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BACHELOR THESIS

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Abstract

Agile project management is taught to project teams by the means of serious games. Since it is a common practice for Agile coaches to offer serious games in physical settings, a problem for both parties arose during the coronavirus pandemic. Due to the many contact restrictions, Agile coaches are not able to offer serious games to project teams. While project teams are not able to receive any training, thereby lacking in acquiring the essential skills needed for Agile project management. This problem can be tackled by shifting the offering of serious games to a digital setting. In this thesis, Agile coaches are supported in finding the right software to realize this. Low-code development platforms seem to be the perfect tool to help Agile coaches in digitizing their training. Combining this, the research question that will be answered is: '*What are suitable low-code development platforms to build serious games for teams in a virtual world?*'. In doing so, requirements for serious games offered in digital settings and those of low-code development platforms were established. In addition, low-code development platforms were collected. The Analytical Hierarchy Process express method tested the platforms against the requirements, resulting in a ranking of best-fitted to least-fitted platforms in supporting the building of serious games. Mendix appeared to be the most suitable platform. After testing working in Mendix has proved to be challenging. This thesis provides a starting point in exploring new ways for future research on the relationship between low-code development platforms and serious games.

Contents

1 Introduction

In this section an introduction to the problem is addressed.

1.1 The problem

Working on a major collaborative project without Agile is almost impossible to imagine nowadays. Agile working helps to steer project management in the right direction by using an iterative approach. In this approach, project teams deliver small and consumable chunks of work that are continuously evaluated. Constant evaluation of these small chunks assures a quick and efficient mechanism to implement changes where needed.

Agile project management can be taught by the means of serious games [FRE+03] [DLS15]. These games are a fun and effective way for project teams to acquire the essential skills needed in Agile project management. These skills include, for example, communication, planning management, and decision-making [SODMS18]. Normally, serious games were offered by Agile coaches in physical settings, meaning face-to-face. However, due to the coronavirus pandemic and its many contact restrictions, this was not an option anymore. As a result, Agile coaches and project teams stood for a challenge. On the one hand, Agile coaches could not offer serious games to project teams, since they did not have the right resources to practice their jobs. On the other hand, project teams were not able to receive any training from the Agile coaches, resulting in a lack of acquiring the essential skills needed for Agile project management. In short, due to the outbreak of the pandemic, demand for different ways to offer and receive serious games has arisen.

A potential solution to this problem would be to shift the offering of serious games to a digital setting. By offering serious games in this way, Agile coaches can resume practicing their jobs, albeit in a digital setting. In addition, project teams are assured to receive training in acquiring the necessary skills in Agile project management, albeit remotely and individually. To offer serious games in a digital setting programming is required. It seems obvious for Agile coaches to outsource the programming of serious games to IT developers. However, this is not an ideal solution since there is a well-known lack of experienced IT personnel. As a result, higher costs and long waiting times might occur. While we are amid a global pandemic, having to contend with long waiting times is inconvenient. This is because people are expected to shift their work from physical to digital settings within a short amount of time. Another solution would be to provide Agile coaches with software in which they can implement and test the serious games themselves. It should be taken into consideration that Agile coaches have little to no programming experience, making it hard or even impossible to let them build serious games. This is where low-code development platforms (hereafter: LCDPs) jump in. LCDPs enable easy and rapid application development by building applications in a visual manner, contrary to traditional programming approaches [SIDRP20]. Since LCDPs are suitable for people with no programming experience, they seem to be the perfect tool for Agile coaches to shift the offering of serious games to a digital setting.

1.2 Thesis aim

This thesis aims to support Agile coaches in finding suitable LCDPs to help them shift the offering of serious games to a digital setting. Project teams will also benefit from this since they are assured to receive training in essential skills needed for Agile project management. First, the requirements of serious games offered in digital settings and those of LCDPs will be identified. Second, a selection of LCDPs will take place. In this selection, it will become apparent which LCDPs are suitable for building serious games. The selection will be performed by the means of the Analytical Hierarchy Process express method (hereafter: AHP-express method). This method takes into account the requirements that were previously identified. Third, a serious game will be built with, according to the AHP-express method, the most suitable LCDP in supporting the building of serious games. Putting this together, the research question that will be answered in this thesis is:

"What are suitable low-code development platforms to build serious games for teams in a virtual world?"

1.3 Thesis overview

This section contains the introduction and problem statement of this thesis; Section 2 discusses the background that has led to creating this thesis; Section 3 describes the application of the research methods used in this thesis; Section 4 describes the results of this thesis; Section 5 discusses the conclusions of this thesis followed by suggesting future work.

2 Background

In this section the background that has led to creating this thesis is discussed.

2.1 Serious games

2.1.1 A definition

The term 'serious games' is defined in many ways. A definition that can be given is that serious games are games used for purposes other than mere entertainment [SJB07]. Another definition that can be given is "*The application of gaming technology, process, and design to the solution of problems faced by businesses and other organizations. Serious games promote the transfer and cross-fertilization of game development knowledge and techniques in traditionally non-game markets such as training, product design, sales, marketing, etc.*" [MC06]. Despite there being so many definitions available of the term, no fixed definition of the concept exists. The part we can agree on is that serious games are involved with gaming for purposes other than entertainment or fun. The exact purposes however may vary depending on different interests and perspectives.

2.1.2 Serious games versus entertainment games

To which extent serious games (roughly) differ from games that focus on entertainment is elaborated in Table 1. This comparison was the result of a study [MC06] conducted by Michael and Chen. Based on a design- and development perspective, they compared serious games to entertainment games [MC06]. The main differences are the following. Entertainment games aim to provide gamers the richest possible experience from their games, while serious games aim to provide a simulation that can be used to solve a certain problem [MC06]. Further, entertainment games are designed to let gamers focus on fun parts. In addition, gamers are allowed to simplify the simulation process [MC06], meaning gamers are allowed to, for example, perform random movements. In serious games, however, learning is central, and more careful decisions need to be made by the gamers [MC06]. This is because workable simulations in which problems are tried to be solved need to be pursued. To learn the right types of skills, the movements necessary for creating workable simulations must be correct [MC06]. Therefore gamers performing random movements is not desired in serious games. Lastly, entertainment games provide perfect communication, meaning no delays or misconceptions do occur, while in serious games communication is rarely perfect [MC06].

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

Table 1: Differences between serious games and entertainment games [MC06].

2.1.3 Importance in Agile project management

Serious games are applied in many fields such as education [DGBB14], health [Dan16], military [Mac02], and software development [Sch13]. Despite them being applied in many fields, little is known about how serious games are applied to teach Agile project management. Recall that in Agile project management project teams organize and execute consumable chunks of work or initiatives in an iterative manner. In addition, these initiatives are constantly assessed through feedback. Managing projects in this way has proven to be revolutionary in organizations that, for example, create new products and services [SH14]. The skills that are needed in Agile project management can be taught by the means of serious games [FRE+03] [DLS15]. However, these days little is known about how serious games that teach Agile project management are offered to organisations in practice and what skills exactly can be acquired from them. Stettina et al. were one of the first to do research [SODMS18] on his. Through desk research, 26 serious games that focus on acquiring Agile skills were analysed. In addition, interviews were taken with Agile coaches, business consultants, and game developers (hereafter: experts) to explore the way in which they offer serious games to project teams in practice. The analysis of the serious games showed that the following skills were addressed by the games: communication, project management, planning management, and time management, collaboration, organization management, requirements management, decision-making, and customer-orientation [SODMS18]. Next, the interviews showed that the experts divide their training, meaning the offering of serious games to project teams, into three parts. During pre-training, the experts emphasize the real problem or goal within the organisation and verify this with the project team [SODMS18]. During training, the serious game is practised and a reflection is done on the lessons learned through the game [SODMS18]. In addition, it is discussed which changes need to be made at work. During post-training, the outcome of the training is measured [SODMS18]. It is also discussed how the changes and lessons learned should be applied in practice, meaning at work.

Since acquiring skills in Agile project management is taught by the means of serious games, it is of great importance that during this coronavirus pandemic Agile coaches need to be helped in searching for different ways to offer such games. As the research [SODMS18] by Stettina et al. shows, project teams are to be taught crucial skills by practicing serious games, such as communication and time management. If project teams cannot receive any training, they will be missing out on acquiring these crucial skills.

2.1.4 Agile Portfolio Poker and Herding Cats

In the next paragraphs, two serious games will be elaborated on in which Agile project management is central. These are examples of typical games Agile coaches may offer to project teams to acquire the necessary skills in Agile project management.

Agile Portfolio Poker

Agile Portfolio Poker (hereafter: APP) is a serious game that helps project teams to facilitate decision-making using value propositions. In the game, project teams will estimate projects using poker cards. Project managers estimate projects based on their size and complexity, while project directors estimate projects based on the value they expect projects to yield. Both managers and directors are assigned different sets of cards as can be seen from Figure 1 (left). The project managers have the cards: 1, 2, 3, 5, 8, 13, 20, and so on, and the project directors have the cards: 0,

1, 2, 3, 5, 8, 13, 20, 40, and so on. Before the estimation process, the projects need to be assembled and reviewed by the project team. After the managers and directors have finished estimating the projects, they are placed on a canvas. On the canvas, the poker cards of the managers are plotted vertically, and the cards of the directors horizontally. Such canvas is shown in Figure 1 (right). The position a project occupies in the canvas is the manager's poker card (y-axis) against the director's (x-axis). Projects can be classified as: 'low value, small size', 'low value, large size', 'high value, small size', and 'high value, large size'. Based on how the projects are positioned on the canvas, a prioritized backlog is created. Such backlog is shown in Figure 1 (right). Projects that appear high in value and small in size are placed on top of the backlog, while projects that appear low in value and large in size are placed at the bottom. The order in which projects are in the backlog is the most efficient manner to execute the projects. In this way, APP helps project teams to facilitate decision-making, that is in what (efficient) order to perform which projects.

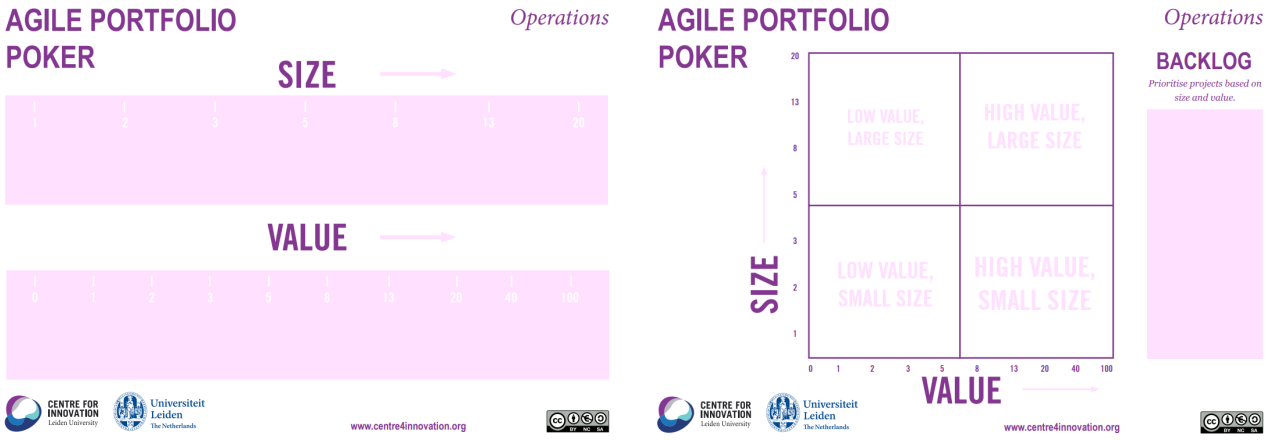

Figure 1: APP value propositions (left) and corresponding canvas (right) [Ste].

Herding Cats

Herding Cats (hereafter: HC) is a serious game that teaches project teams the differences between Agile projects and waterfall projects. Agile projects are projects that are iteratively executed in consumable chunks, while waterfall projects are executed sequentially, meaning from beginning to end sequentially. In addition, HC demonstrates how important it is to plan properly. In the game the portfolio board containing initiatives ('epics' and 'projects') is central. Such board is shown in Figure 2. Further, there are three roles in the game: a Product Owner (hereafter: PO), a Project Manager (hereafter: PM), and a Financial Controller (hereafter: FC). The initiatives should be dragged into the corresponding timelines (or swim lanes). The epics need to be prioritized and planned followed by dragging them into the Agile swim-lanes. This is the responsibility of the PO. The projects need to be dragged into the Waterfall swim lanes. This is the responsibility of the PM. In addition, the rule is that the values of the epics can be booked after each month, while the values of the projects can be booked after completing an entire project. As a FC you need to calculate and book these values in the Return on Investment (ROI) table. While playing HC, it will become apparent that Agile projects compared to Waterfall projects bring many advantages, such as yielding values faster, less risk, and easy planning management.

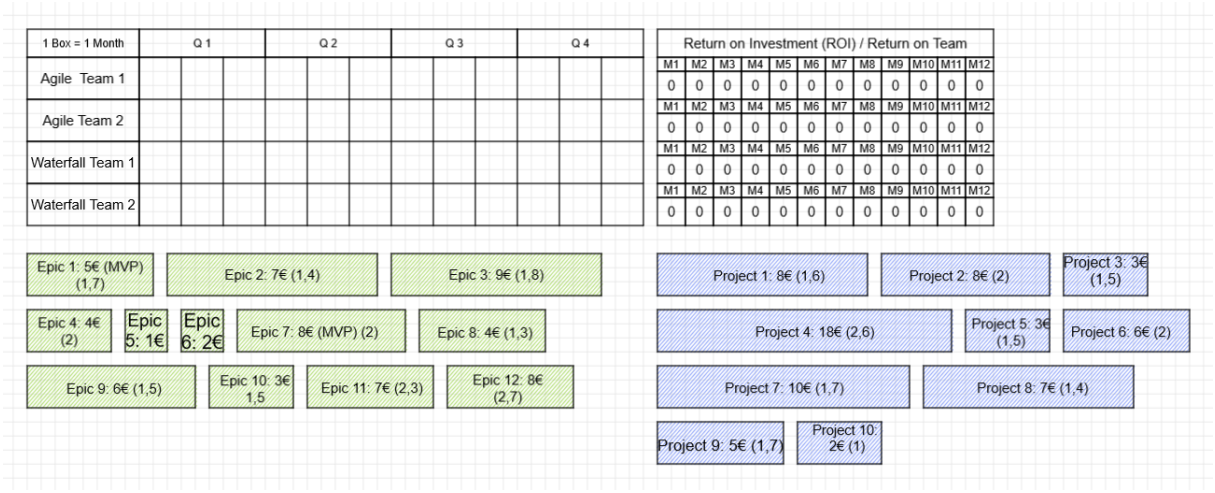

Figure 2: HC portfolio plan [Ste].

2.2 Low-code development platforms

2.2.1 A definition

Low-code development platforms (hereafter: LCDPs) are cloud-based development platforms that enable fast application development. Using a Graphical User Interface (hereafter: GUI) and visual abstractions, ready-for-production applications can be built in a visual manner [SIDRP20]. Simply the visual abstractions need to be placed into the platform, thereby eliminating the need for hand-coding. LCDPs are a good fit for people with little to no programming expertise, also called citizens, since the traditional programming approaches are largely bypassed. However, in low-code still, a bare minimum of hand-coding is required, hence the term 'low-code' and not 'no-code'.

2.2.2 Features

It should be emphasized that every LCDP is unique, meaning each platform contains its own set of features, functionalities, and services. In a technical study [SIDRP20] conducted by Sahay et al., the distinctive features of LCDPs are discussed. Figure 3 shows these distinctive features. The research shows that each LCDP contains at least a GUI, business logic specification mechanisms, and application build mechanisms. The GUI contains a group of features that together form the front-end of the LCDP. For example, drag-and-drop buttons, text fields, tables, and forms are part of the GUI. Recall that these are visual abstractions, meaning the LCDP has already programmed the features for us. In the GUI, applications are built visually by dragging and dropping the visual abstractions in the work field. Business logic specification mechanisms consist of ways to specify business logic. An example of such a way is API support, which ensures that one application can communicate with other applications. Application build mechanisms consist of ways how to build a specific application. For example, based on the (modeled) application, code must be generated and executed somewhere in the LCPD. In addition, each LCDP supports security, interoperability, and deployment of applications. Interoperability support refers to features that interact with external services, such as Dropbox or Office 365. Deployment support refers to features that ensure that (modeled) applications are being deployed. For example, when an application is build, the

application is published in the app stores. LCDPs may differ in supporting (online or offline) collaboration, reusability, and scalability. For further details on these features, a reference is made to [SIDRP20].

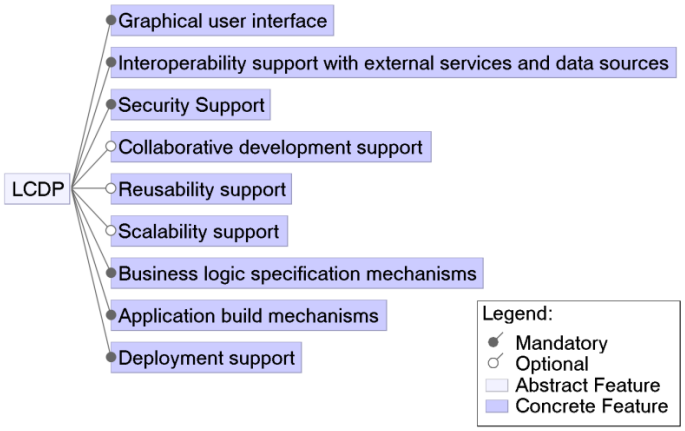

Figure 3: Distinctive features of LCDPs [SIDRP20].

2.2.3 Benefits of low-code

Research [Leh18] conducted by 451 Research showed that LCDPs (in the research referred to as Digital Automation Platforms or 'DAPs') bring many benefits. LCDPs contribute to speeding up the development process of applications significantly. By using LCDPs, applications are realised about 50-90% faster compared to using traditional programming approaches [Leh18]. Simply less time is taken to implement, test and launch applications for production. In addition, LCDPs accelerate innovation and lower the cost of human resources [Leh18]. Since employees without programming background can arm oneself with LCDPs, they can (continuously) test and refine their suspicions while working, thereby avoiding potential IT bottlenecks.

Since LCDPs bring along so many benefits, they seem to be the right tool for Agile coaches to help them shift the offering of serious games to a digital setting. LCDPs are investigated in particular because they enable rapid application development. In addition, they are suited for people with a lacking IT background. Combining this, LCDPs might help Agile coaches to digitize their training more quickly, which is very desirable in times of a global pandemic.

3 Methodology

In this section the research methods that were applied are discussed.

3.1 Research approach

A study of mixed methods, in which quantitative and qualitative research methods were applied, was performed to find out what LCDPs are suitable for Agile coaches to shift the offering of serious games to a digital setting.

3.2 Identifying requirements

In the first part of this thesis, the requirements of serious games offered in digital settings were identified. To identify these requirements, two existing digital serious games were analyzed and the method of co-design was applied. In addition, the requirements of LCDPs were identified. These requirements were put together by the means of co-design as well. Identifying the requirements of serious games offered in digital settings and those of LCDPs was necessary to understand what it takes to build serious games in a LCDP, which is our digital setting.

3.2.1 Co-design

Both requirements of serious games offered in digital settings and LCDPs were identified by the means of co-design. In co-design, diverse experts come together to collaborate creatively [SMK11]. Experts, in this case, are referred to as researchers and developers, but also users (of a certain product). Co-design is known to provide specific benefits which help to realize specific goals within projects [SMK11]. For example, by involving users in projects such as IT system design, higher quality of the system and the system requirements are ensured. In addition, a better fit between the system and its users is realized [Kuj03].

3.2.2 Analysis of digital serious games

The requirements of serious games offered in digital settings were in addition to co-design also identified by the analysis of two digital serious games. The games that were analyzed are APP and HC. Recall that these games are described in Section 2.1.4. The data of both games were collected and reviewed, followed by co-design to identify the needed requirements for serious games offered in digital settings.

Data collection
The following data of the serious games were collected and reviewed:

- The game rules of APP. They are shown in Section 2.1.4 and Appendix D Section D.1.
- A demo of APP. Some screenshots of the demo are shown in Appendix D Section D.2. The demo was already in my possession since it was the result of Leiden University's Computer Science (hereafter: LIACS) Software Engineering course from 2019-2020.
- The game rules of HC. They are shown in Section 2.1.4 and Appendix D Section D.3.

- A sample game of HC. They are shown in Section 2.1.4 and Appendix D Section D.4.

3.3 Selecting low-code development platforms

In the second part of this thesis, a LCDP selection was performed. In the selection, LCDPs were evaluated to which extent they meet the requirements identified in Section 3.2. Recalling the aim of this thesis, the selection aims to find out to which extent LCDPs are suitable for building serious games. First, a set of LCDPs (hereafter: test set) was obtained, followed by testing the set against the requirements. The tool that was used in this test is called the AHP-express method.

3.3.1 Obtaining the test set

Before obtaining the test set, a base list containing LCDPs that will undergo the three-criteria test was created. The platforms in this list were extracted from a report [Inc20] published by IT consultancy firm Gartner. In this report, Gartner provided an overview of the most popular LCDPs of 2020. The report also shows what platforms outperform other platforms. In addition, my supervisor (hereafter: Stettina) insisted to add a LCDP with which he is familiar in the base list.

The formation of the test set was based on three criteria. Only when a LCDP from the base list meets all criteria, it will be included in the test set and will be tested with the AHP-express method.

Three-criteria

1. *A LCDP needs to be advanced and large-scale.* It has been assumed that LCDPs that are advanced and large-scale have many technical and non-technical features at their disposal. By choosing advanced and large-scale LCDPs, the risk of platforms lacking certain (technical) features to build serious games is reduced. As a result, LCDPs are chosen that are capable of building a wide range of applications. In addition, the platforms (most likely) have a high chance of being able to build serious games.

2. *A LCDP should provide any form of free accessibility.* A LCDP should at least offer a free demo or trial, or in the best case be open-source (free to use). Later in this thesis, an experiment will take place and there should be no costs involved. By choosing only the platforms that are freely accessible the risk of costly experiments is avoided.

3. *The associated website of a LCDP should provide a good user experience (UX).* Website UX includes, for example, navigation, usability, and impression. The associated website of a LCDP will probably be consulted often by users. For example, when a user does not know how to use a certain tool in the LCDP, it is convenient to consult the community forum or watch tutorials on the website to find a correct solution. By assessing the websites against UX, only the websites that provided a positive experience were chosen.

The sequence in which the LCDPs from the base list was tested against the three criteria is as follows. First, the LCDPs were investigated to whether they meet the criteria of being advanced and large-scale. In doing so, the report by Gartner [Inc20] was used. Second, the LCDPs were investigated to whether they meet the criteria of being available in any free form. In doing so, the associated (or original) websites of the platforms were explored. In particular, the homepages of

the websites were searched for a button or tab indicating how to request a free demo or trial for that platform. Last, the associated websites were explored again to investigate whether the LCDPs meet the criteria of providing a good website UX. The websites were scanned for purposes such as navigation, impression, design, usability, and so on. It is important to emphasize that this choice was based on personal assessment.

3.3.2 Applying the AHP-express method

The AHP-express method was used to decide to which extent the LCDPs from the test set are suitable for building serious games. The method is derived from the standard Analytical Hierarchy Process method (hereafter: AHP method) founded by Saaty. The AHP method is a multi-criteria decision-making tool that is used in many fields such as economics, politics, and software [Lea20]. Despite its wide applicability, the method suffers from a major drawback. This is because many comparisons between elements are required to make a (final) decision [Lea20]. To save time and reduce complexity, a simplified version of the method, called the AHP-express method, was introduced. In the AHP-express method, the number of comparisons is reduced by only comparing a single element to all other elements. This single element is referred to as the 'element of apparent greater importance' or best element.

The AHP-express method generates a decision for a problem in the following manner. The method starts by creating a tree structure to view the decision-making process. At the root or objective level, the main goal of the problem is defined. At the criteria level of the tree, partial objectives that meet the main goal are defined. At a lower level of the tree, or sub-criteria level, partial objectives might be defined but only if necessary. At each level of the tree, the set of partial objectives must meet the objective or parent node. The lowest level of the tree consists of the alternatives. These are the elements from which the method will make its final decision. Figure 4 shows a general tree structure of a certain decision problem.

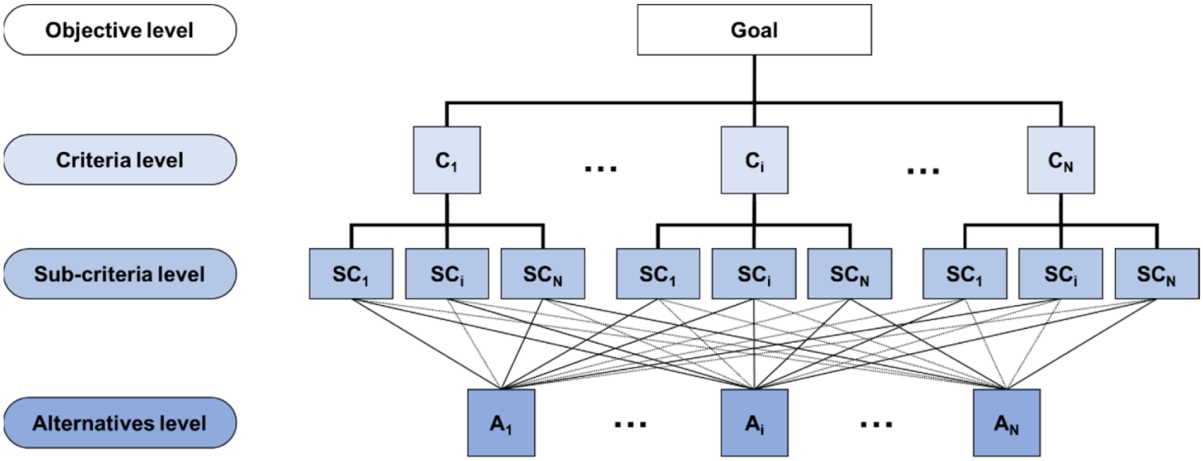

Figure 4: The tree-structure of the AHP-express model [PAC+22].

After creating the tree structure of the problem, the elements in the tree are compared pairwise according to their contribution to reaching each objective or parent node. The comparisons are

performed from the lowest level of the tree (e.g. alternatives) to the root (e.g. main goal). Based on the contributions of the elements in their objective, the best element is chosen and assigned a score of 1. Subsequently, all the other elements are compared to the best element. The scores for the other elements depend on how much they differ in contribution compared to that of the best element. The scores are based on the fundamental scale of Saaty, shown in Figure 5. After all the elements are assigned a score, calculations are performed that result in the priorities of the elements in the objective. Comparing elements in this way, along with some math, is performed until the root of the tree is reached, meaning the method calculated its final decision.

Numerical Values	Definition	Explanation
1	Equal	Two elements contribute equally to the objective
3	Moderate	Experience and judgment slightly favor one aspect over another
5	Strongly	Experience and judgment strongly or essentially favor one aspect over another
7	Very strongly	An aspect is strongly favored over another and its dominance demonstrated in practice
9	Extremely	The evidence favoring one aspect over another is of the highest degree possible for affirmation
2, 4, 6, 8	Intermediate values	Used to represent a compromise between preferences listed above

Figure 5: The fundamental scale of Saaty [CB15].

3.4 Building Herding Cats

In the third part of this thesis, an experiment was conducted with the best-fitted LCDP according to the AHP-express method. In this experiment an attempt was made to build a serious game, thereby validating the outcome of the AHP-express method and the identified requirements. It should be emphasized that this experiment was based on trial-and-error, meaning there will be repeated attempts to build the serious game, until either the game was built successfully or building the game was stopped at some point (e.g. due to errors or time limit). Recalling Section 2.1.4, the serious game that was tried out to be built is HC.

4 Results

In this section the research results will be discussed.

4.1 Requirements

This section describes how both the requirements of serious games offered in digital settings and LCDPs were established. In addition, the requirements are listed and provided with a brief explanation.

4.1.1 Low-code development platforms

The requirements of LCDPs were identified by the means of co-design. Recalling Section 3.2.1, co-design was accomplished through collaboration with Stettina, who is a professional in advising organizations with (co-)designing and (co-)implementing business agility subjects. In addition, he is the founder of the website [Ste] in which (non-)digital serious games are provided. In this thesis, Stettina will be named as a professional in IT from now on. Through informal and semi-structured online meetings in Microsoft Teams, the professional in IT broadened their understanding of important factors that new users (e.g. Agile coaches) should take into consideration before buying unknown software (e.g. LCDPs). During the meetings, minutes were taken in real-time. This data was reviewed during our last meeting. After brainstorming with each other, and taking into consideration the data, the definite requirements of the LCDPs were identified.

An overview of the requirements of LCDPs is provided below.

1. *Easiness of programming.* To determine the 'easiness of programming' of applications, three instances of the LCDP were considered. The *Integrated Development Environment* (hereafter: IDE) is an application within the platform that provides a single interface containing all programming needs such as a code editor, compiler, and debugger. *Mouse interaction* makes it possible to place visual abstractions (e.g. widgets) into the IDE. A drag-and-drop interface enhances the user experience by permitting to drag all the items involved in making an application, while a point-and-click interface by pointing and clicking at the items [SIDRP20]. In LCDPs users are allowed to add custom code. This code must be defined using a *programming language.*

2. *Support.* To determine the support offer, two types of support of the LCDP were considered. A *community forum* is an online meeting space in which users of the platform can ask questions, share knowledge, and debate with each other. A *help-desk* is the department that helps users to solve (technical) problems that occurred while working on the platform. A help desk consists of experts who are people who are employed by the platform.

3. *Supported platforms.* To determine the supported platforms, two system requirements of the LCDP were considered. They include *operating systems* and *web-browsers.*

4. *Training.* To determine the training offer, four types of training of the LCDP were considered. They include *documentation*, *free training* offer, *paid training* offer, and *certification.*

5. *Pricing*. Pricing includes the cost of a LCDP. Usually, the platform offers various subscriptions based on the size and wishes (of the organizations or users).

4.1.2 Serious games offered in digital settings

The requirements of serious games offered in digital settings were identified by the means of co-design in combination with the analysis of APP and HC. Recalling Section 3.2.2, the collected data of both APP and HC was reviewed by thoroughly examining the rules of the games. In addition, the sample game of HC was downloaded and tested through trial-and-error of the game. The demo of APP was viewed to recall the content of APP (the project that was worked on at LIACS). Through co-design, the understanding of important factors of building APP and HC was broadened. These games are also provided on the website [Ste] owned by the professional in IT. During the meetings, minutes were taken in real-time. As a result of the co-design process, programmable functionalities of serious games were established. They were formed in such a way that they apply to any serious game (and therefore not only applicable to APP and HC). The programmable functionalities are referred to as the definitive requirements for serious games provided in digital settings. In addition, two more requirements were established during collaboration with the professional in IT. The professional advised adding these two requirements as well, although they are not necessarily characteristic of serious games. However, the functionalities are handy tools to polish the appearance of such games and therefore are important to include as well.

An overview of the requirements of serious games offered in digital settings is provided below.

1. *Real-time collaboration*. Real-time collaboration is a technology that allows two or more users to collaborate concurrently on the specification of the same application. Conflicts between users are managed at run-time [SIDRP20].

2. *Synchronous multiplayer*. Synchronous multiplayer is a mode that allows two or more users to use the same application in real-time or simultaneously.

3. *Web-based*. Web-based application development is a type of application development that allows applications to run on a web browser.

4. *User registration*. User registration is a mechanism that allows users to register and log in to applications. Usually, the user must specify a username and password.

5. *User roles*. User roles are collections of permissions that determine the actions users can take. In addition, it determines what data users have access to.

6. *Animation*. Animation is a feature that manipulates images into moving images to generate user interaction and to make applications more fun.

7. *Freehand graphics*. Freehand graphics is a feature that allows drawing without the use of drawing tools (e.g rulers or shapes). They have the same benefits as animation.

8. *Standard UI elements*. Standard UI elements are elements that ensure interactions between an application and its users. The three standard interactions allow users to input information, (e.g. input fields or buttons), help them navigate (e.g. tags and pagination), share information (e.g. message boxes), and hold together all content (e.g. containers).

4.2 Selection of low-code development platforms

This section describes the LCDP selection. This selection aimed to find out to which extent the LCDPs from the test set are suitable for building serious games. To do so, the set was tested against the requirements from Section 4.1 by using the AHP-express method.

4.2.1 Test set

Recalling Section 3.3.1, a base list of 19 LCDPs was created. The platforms in this list were extracted from this report [Inc20] in which Gartner has ranked the 18 most popular LCDPs of 2020. Figure 6 shows the ranking of the popular platforms. The LCDPs that were included in the base list are: *AgilePoint*, *Appian*, *AuraQuantic*, *Betty Blocks*, *Creatio*, *Kintone*, *Mendix*, *Microsoft Powerapps*, *Newgen*, *Oracle (APEX)*, *Oracle (visual builder)*, *Outsystems*, *Pega*, *ProntoForms*, *Quick Base*, *Salesforce*, *ServiceNow*, *TrackVia*, and *Zoho Creator*. In addition, the professional in IT insisted to add the platform *The Wick Editor* in the base list.

Recalling Section 3.3.1, based on the report [Inc20] by Gartner, 10 LCDPs from the base list were interpreted to be advanced and large-scale. These platforms include: *Appian*, *Mendix*, *Microsoft Powerapps*, *Outsystems*, *Salesforce*, *ServiceNow*, *Betty Blocks*, *Pega*, *Zoho Creator*, and *The Wick Editor*. *Appian*, *Mendix*, *Microsoft Powerapps*, *Outsystems*, *Salesforce*, and *ServiceNow* are considered as 'leaders' as shown in Figure 6. Leaders perform best compared to the other competing platforms. Therefore these platforms are assumed to be representative of advanced and large-scale. *Betty Blocks*, *Pega*, and *Zoho Creator* are positioned as 'visionaries. However, they are positioned very close to the leaders. Therefore these platforms are assumed to be advanced and large-scale as well. *The Wick Editor* was added to the advanced and large-scale platforms at the insistence of the professional in IT. The other competing LCDPs were eliminated from the potential test set. In exploring the associated websites of the 10 LCDPs, it appeared that all platforms are available in a free form. *The Wick Editor* is the only open-source (free to use) platform, while the other LCDPs offer a demo or trial for a few weeks. In scanning the the associated websites of the 10 LCDPs, it appeared that *Mendix*, *Microsoft Powerapps*, *Outsystems*, *The Wick Editor*, and *Zoho Creator* provided the most pleasant website UX. The other platforms were eliminated from the potential test set. The associated websites of these platforms have in particular the least usability and design.

To conclude, the three-criteria test yielded a test set of five LCDPs: *Mendix*, *Microsoft Powerapps*, *Outsystems*, *The Wick Editor*, and *Zoho Creator*. Ultimately, this set will be tested with the AHP-express method to decide their suitability for building serious games.

4.2.2 Decision by the AHP-express method

Recalling Section 3.3.2, Figure 7 shows the tree-structure of the decision problem address in this thesis. At the root of the tree, the main goal which is to determine to which extent the LCDPs are suitable for building serious games is defined. At second-level, five criteria were defined. They include: *Network Interaction*, *User Management*, *User Interface*, *Easiness of development*, and *Pricing*. At third-level, 13 sub-criteria were defined. These are the 13 requirements that are elaborated in Section 4.1. *Network Interaction* includes the requirements: *Real-time collaboration*, *Synchronous multiplayer*, and *Web-based* application development. *User Management* includes the requirements:

Figure 6: A Gartner's Magic Quadrant (left) [Inc22] and the 2020 Gartner's Magic Quadrant for enterprise low-code application platforms (right) [Inc20].

User registration and *User roles*. *User Interface* includes the requirements: *Animation*, *Freehand graphics*, and *Standard UI elements*. *Easiness of development* includes the requirements: *Easiness of programming*, *Support*, *Supported platforms*, and *Training*. *Pricing* includes the single requirement *Pricing*. At the lowest level of the tree, five alternatives were defined. Recalling Section 4.2.1, the alternatives are equal to the test set. They include: *Mendix*, *Microsoft PowerApps*, *Outsystems*, *The Wick Editor*, and *Zoho Creator*.

The pairwise comparisons are presented in Appendix A. Recalling the tree structure and Section 3.3.2, the comparisons were performed from the lowest level of the tree to its root: LCDPs in each requirement, requirements in each criterion, LCDPs in each criterion, criteria in the main goal, and LCDPs in the main goal. The contributions of the elements in the objectives were determined based on data collection followed by personal assessment and co-design. How this was done is worked out step-by-step in Appendix A as well. Based on the contributions to the objectives, each element was assigned a score from the scale of Saaty (shown in Figure 5). Based on these scores, the priorities of the elements in the objectives were calculated, ultimately resulting in the priorities of the LCDPs in the main goal.

	Mendix	Microsoft PowerApps	Outsystems	The Wick Editor	Zoho Creator
PA	0,257	0,228	0,186	0,178	0,152
(%)	25,7%	22,8%	18,6%	17,8%	15,2%

Table 2: The final decision made by the AHP-express method.

Table 2 shows the final priorities of the pairwise comparisons. This is the final decision made by the AHP-express method that expresses to which extent the LCDPs from the test set are suitable for

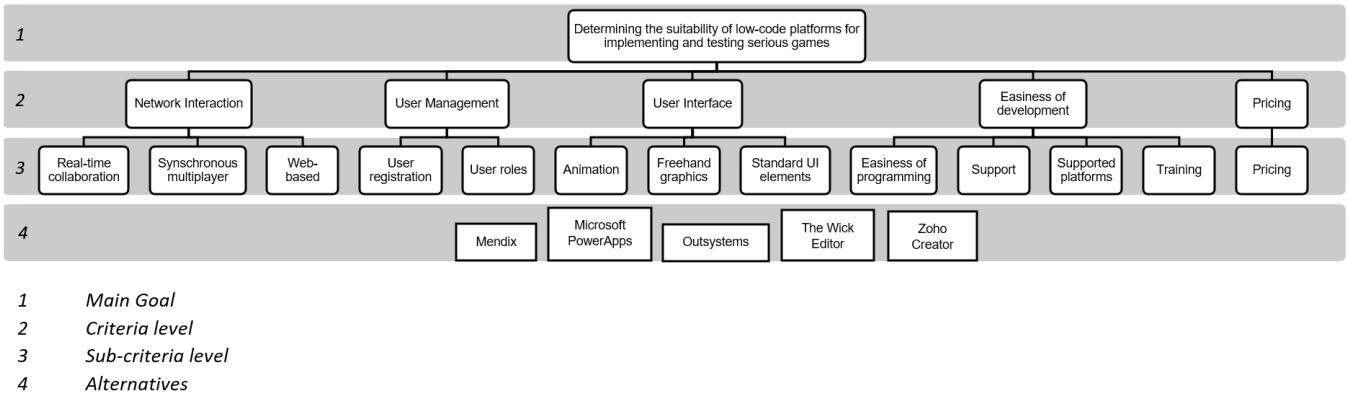

Figure 7: The tree-structure of the AHP-express model.

building serious games. On the one hand, *Mendix* appears to be the best-fitted LCDP for building serious games. With a difference of only 3%, *Microsoft PowerApps* appears to be the second best. On the other hand, *Zoho Creator* turns out to be the least-fitted LCDP. *Outsystems* and *The Wick Editor* are moderately suitable and ended in places three and four, respectively. Based on this ranking, *Mendix* is our candidate for the experiment in which HC will try to be built.

4.3 Building of Herding Cats in *Mendix*

This section describes the outcome of the trial-and-error experiment in *Mendix*. Before building HC, the free demo was requested, a free account was created, and `Mendix Studio Pro version 9.15.0` was downloaded. After logging in to the platform, the path to create a blank web application was followed.

4.3.1 IDE overview

Figure 8 shows the environment of Studio Pro version 9.15.0 or the IDE of *Mendix*. All programming needs are included, such as widgets, building blocks, automatic tester, debugger, and the blank web application also called a 'page'. Figure 8 is captured in `Design mode`. Design mode is the mode in which elements from the toolbox or building blocks can be dragged and dropped into the page. In addition, the design mode shows what the application will look like when it is published.

4.3.2 Building steps of Herding Cats

Recalling Section 2.1.3, the portfolio in HC contains two tables: the table with the Agile and Waterfall swim lanes and the ROI table. In addition, initiatives (epics and projects) are presented in the portfolio. In the first part of the experiment, these tables and initiatives were tried to mimic. As a first step, the `Layout grid` widget containing two columns was dragged and dropped into the page. Thereafter, in each column the `Table` widget containing a 5×5 table was dragged-and-dropped. In the left table (hereafter: the table containing the swim lanes), skipping the first row and first column, the `Table` widget containing a 3×1 table was dragged and dropped into the cells. Next,

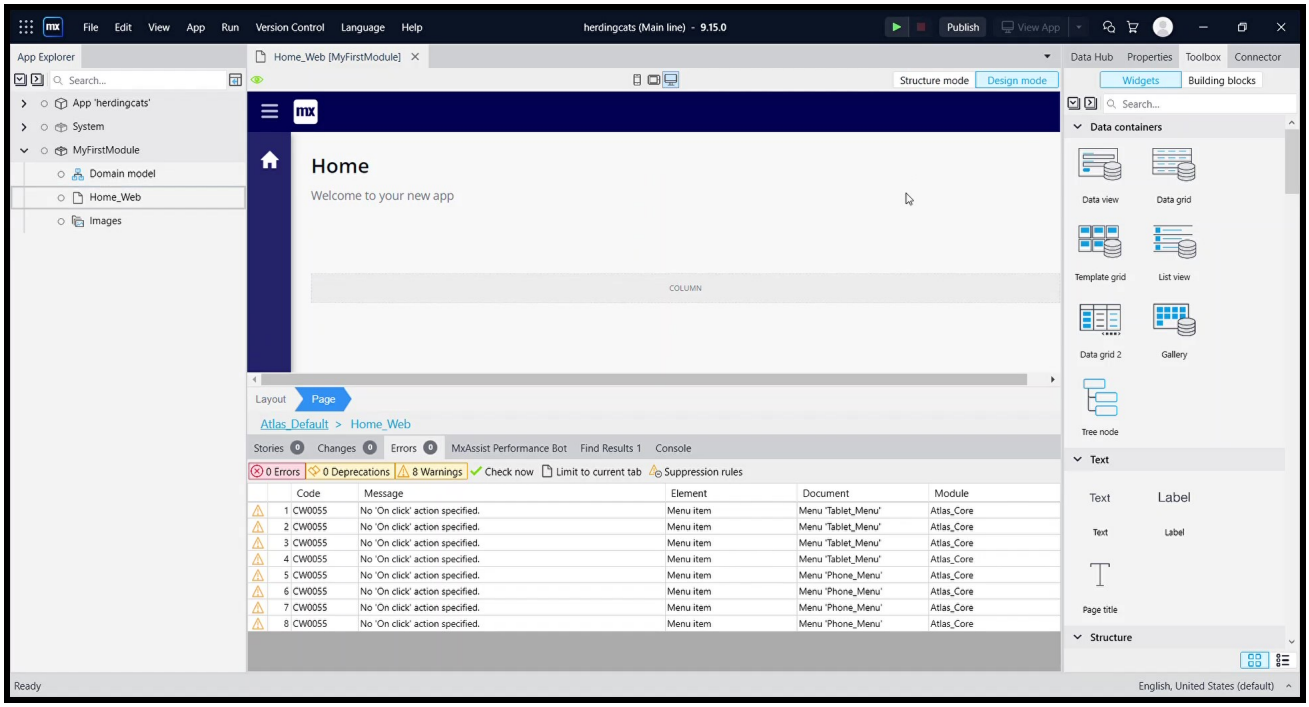

Figure 8: Studio Pro version 9.15.0.

the cells of the first row and first column of that table were assigned names. In doing so, the `Text` widget containing the corresponding names was dragged and dropped into these cells. The table containing the swim lanes has taken its shape. The creation of this table is shown in Figure 9. To create the shape of the right table (hereafter: ROI table) similar steps need to be performed.

Subsequently, the outlines of the table containing the swim lanes were drawn. This involved coding in CSS, in which the width and the style of the outlines had to be specified. In addition, it was found out that classes can be called upon. The class `table-bordered` ensures all cells in a certain table are automatically outlined with the same style and width. To add the CSS code a switch had to be made to `Structure mode`. In structure mode, the logical relationship between widgets is provided. In structure mode, the appearance of widgets can be adjusted as well. After the outlines were drawn, the application was tested, thereafter visiting the application in my web browser, which is Google Chrome. The `application root URL` was extracted via `Settings`. In this case, the application contains the following URL: `http://localhost:8080/`. The drawing of the outlines and the testing of the application are shown in Figure 10. To outline the ROI table, similar steps need to be performed.

Thereafter, the initiatives were tried to implement. The characteristic of the projects and epics is that they need to be draggable, meaning they allow being dragged in droppable widgets. The cells in the table containing the swim-lanes and ROI table need to be droppable, meaning they allow being dropped on by draggable widgets. Unfortunately, making the initiatives draggable and cells in the tables droppable could not be realized. Trial-and-error did not resolve the errors that occurred, meaning the building of HC in *Mendix* had to be stopped.

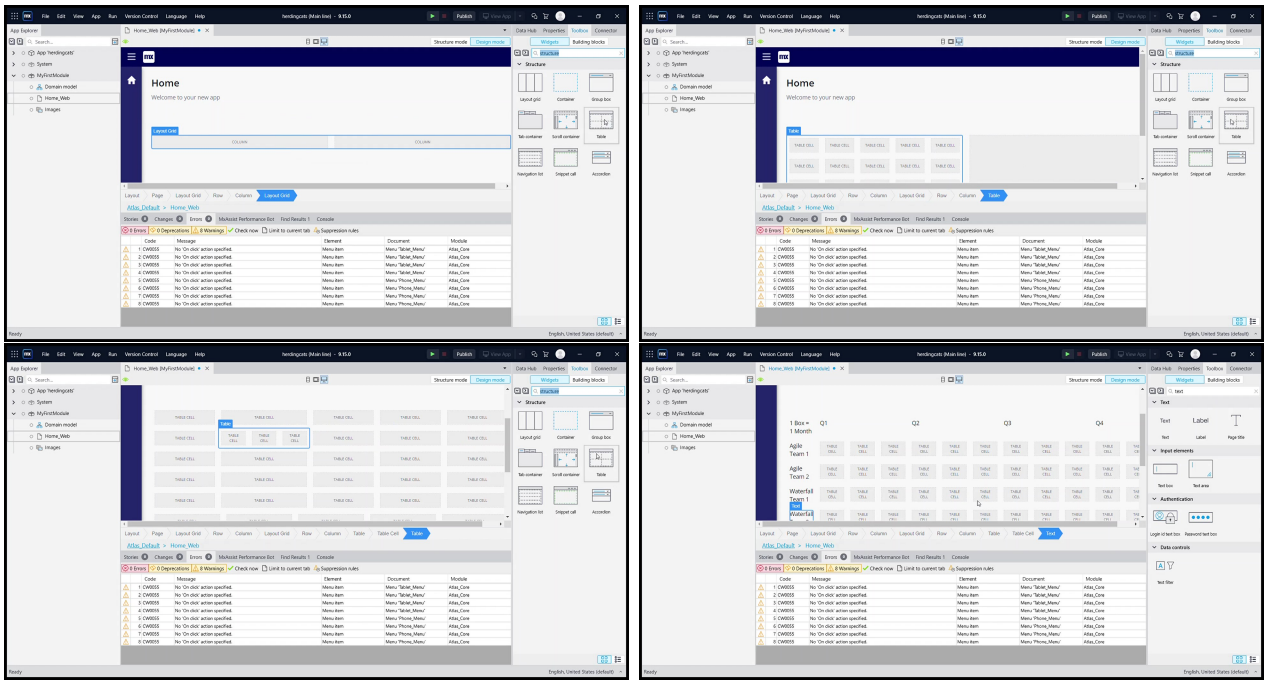

Figure 9: The creation of a table containing sub-tables.

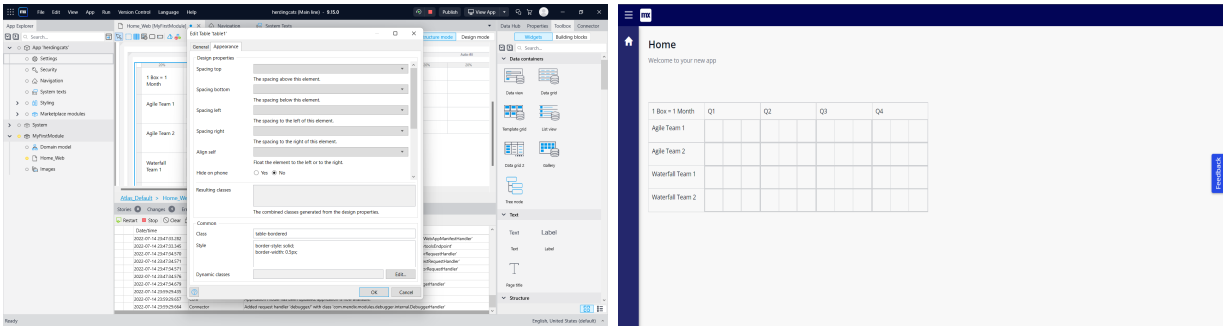

Figure 10: Drawing the outlines of a table (left) and testing the application (right).

5 Conclusions and Discussion

In this section the conclusions and future work will be discussed.

5.1 Conclusions

The aim of answering the research question is to help Agile coaches, amid the coronavirus pandemic, in finding suitable LCDPs to shift their training, which is the offering of serious games, to a digital setting. Project teams will also benefit from this as they are assured to receive training in acquiring essential skills needed for Agile project management.

The research question is answered by the means of mixed methods in which qualitative and quantitative research methods were applied. Which methods, or combinations thereof, varied per part of the research. The research question is as follows:

"What are suitable low-code development platforms to build serious games for teams in a virtual world?"

In the first part of the research, requirements of serious games offered in digital settings and those of LCDPs were established. In the second part, a set containing LCDPs was obtained. The AHP-express method combined these two results by testing the set of platforms against the requirements. As a result, the AHP-express method determined the extent to which the LCDPs are suitable to build serious games. The outcome of the AHP-express method is the answer to the research question. The outcome was verified by building a serious game with the best-fitted LCDP. The steps and analyzes that were performed to arrive at the outcome of the AHP-express method are as follows:

1. Identifying the requirements of LCDPs.
2. Identifying the requirements of serious games offered in digital settings.
3. Obtaining the test set containing LCDPs.
4. Applying the AHP-express method.
5. Building HC with the best suitable LCDP.

5.1.1 Summary of the research results

A total of five requirements of LCDPs were identified. These requirements are based on important factors that Agile coaches should take into account when purchasing a LCDP. They include: *Easiness of programming*, *Support*, *Supported platforms*, *Training*, and *Pricing*.

A total of eight requirements of serious games offered in digital settings were identified. Six out of the eight requirements entail programmable functionalities that apply to any digital serious game. They include: *Real-time collaboration*, *Synchronous multiplayer*, *Web-based* application development, *User registration*, *User roles*, and *Standard UI elements*. Two out of the eight requirements entail handy tools to polish the appearance of serious games. They include: *Animation* and *Freehand*

graphics.

A total of five LCDPs were included in the test set. The formation of the test set was based on three criteria. The LCDP had to be advanced and large-scale, be available in any free form, and the associated website of the LCDP had to provide a good experience (website UX). The platforms in the test set include: *Mendix*, *Microsoft Powerapps*, *Outsystems*, *The Wick Editor*, and *Zoho Creator*.

The AHP-express method started by creating a tree containing the LCDPs from the test set, requirements, criteria, and main goal. By performing pairwise comparisons between these elements, priorities of how the elements meet their objective (or parent node) were obtained. Priorities were calculated until the root of the tree was reached, meaning the AHP-express method arrived at the final priorities or the extent to which the LCDPs are suitable for building serious games. According to the AHP-express method, ***Mendix*** appears to be the best-fitted LCDP for building serious games. *Microsoft PowerApps* appears to be the second best. *Outsystems* and *The Wick Editor* are moderately suitable and ended in places three and four, respectively. *Zoho Creator* turns out to be the least-fitted LCDP. This ranking provides the answer to the research question.

The outcome of the AHP-method was validated with an experiment in *Mendix*. Building HC in *Mendix* appeared to be more difficult than expected. The tables that are characteristic of the game were quickly created by dragging-and-dropping widgets and some easy coding in CSS. However, making draggable and droppable widgets, the initiatives and cells of the tables of the game, appeared to be difficult. This was something unexpected, and could not be resolved through trial-and-error. The building of HC had to be stopped. The outcome of this experiment is at odds with the outcome of the AHP-express method. According to the AHP-express method, *Mendix* appeared to be the best suitable LCDP for Agile coaches to help them shift the offering of serious to a digital setting. However, the experiment has questioned this decision.

5.2 Discussion

The discussion is divided into improvements and future work.

5.2.1 Improvements

This research contains five areas for improvement.

1. An area for improvement could be to collaborate with multiple professionals in IT (instead of a single professional in IT) to obtain the requirements of serious games offered in digital settings and those of LCDPs. This may result in more or different sets of requirements.

2. An area for improvement could be to analyze more serious games (in addition to APP and HC) to ensure more requirements related to digital serious games are included in this research.

3. An area for improvement could be to compare the LCDPs that are ranked in Gartner's most recent report with the LCDPs that are ranked in the 2020 Gartner's Magic Quadrant for enterprise LCDPs report [Inc20]. Gartner is known for analyzing the low-code market

annually, meaning the rankings of the LCDPs (almost) change every year. By using Gartner's most recent report, different LCDPs might be selected in the base list and test set.

4. An area of improvement could be to come up with other criteria to form the test set of LCDPs. These criteria were based on personal input and the 2020 Gartner's Magic Quadrant for enterprise LCDPs report [Inc20]. By setting other criteria, different LCDPs might be selected in the base list and test set as well.

5. An area of improvement could be to collect data needed for the contributions of the LCDPs in each requirement by the means of questionnaires or interviews no matter in what form only. In doing so, uniform data collection is assured. The contributions of *Mendix* in each requirement were for the most part based on the questionnaire that was completed by Maas. For all other LCDPs, this was not the case since the employees of these LCDPs did not respond to the request to fill in the questionnaire.

5.2.2 Future work

Based on this research, the following work is recommended.

1. It is recommended to continue building HC in *Mendix*. In doing so, a better idea of the ease of use of *Mendix* will be obtained. In addition, it will be proven whether *Mendix* supports the building of serious games and that the requirements for serious games offered in digital settings and those of LCDPs are sufficient.

2. It is recommended to build HC in *Microsoft PowerApps* and *Outsystems* by the means of trial-and-error as well. In addition, the outcomes of these experiments can be compared with the outcome of the trial-and-error experiment in *Mendix* which was obtained in this research. By comparing the ease of use of the platforms and the degree to which there was a success to build HC, a better estimate can be made of which of these LCDPs will be most suitable for building serious games and Agile coaches.

3. It is recommended to investigate 'no-code' development platforms (hereafter: NCDPs) in the research. Based on the outcome of the trial-and-error experiment with *Mendix*, NCDPs may be a better fit for Agile coaches to build serious games.

4. It is recommended to analyze more digital serious games to inventory more requirements related to digital serious games. In this research, only APP and HC were analyzed, but analyzing digital serious games may lead to identifying more or others.

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A Pairwise comparisons of the AHP-express method

The pairwise comparisons of the AHP-express method were performed as follows. Based on the extent to which the elements contribute to the objective or parent node, scores were assigned. The extent of the contributions was determined in two ways: data collection followed by personal assessment and co-design. These ways are elaborated in Section A.2. The element that contributes the most to the objective is marked as the best element and therefore is assigned a score of 1. The contributions of all the other elements need to be compared to that of the best element. Based on these comparisons, all the other elements are assigned a score as well. Recalling Figure 5, the scores are based on the scale of Saaty. This is where the term 'pairwise comparisons' comes from: the best element pairs with every other element. After all the elements are assigned a score, some calculations are performed that will lead to the priorities of the elements in the objective. Ultimately, these calculations result in obtaining the final priorities or decision of the method. Roughly, five types of priorities were calculated:

1. Priorities of the LCDPs in each requirement.
2. Priorities of the requirements in each criterion.
3. Priorities of the LCDPs in each criterion.
4. Priorities of each criterion (in the main goal).
5. Final priorities of each LCDP (in the main goal).

A.1 Abbreviations

It was decided to abbreviate the elements that are pairwise compared with each other. Table 3 shows how the criteria, requirements, and LCDPs were named. Recalling Figure 7, the elements are extracted from the tree structure.

A.2 Determining the contributions

The extent to which the elements contribute to the objectives was based on data collection followed by personal assessment and co-design. The contributions of the following elements in their objective had to be determined:

1. Contributions of the LCDPs in each requirement.
2. Contributions of the requirements in each criterion.
3. Contributions of the criteria in the main goal.

A.2.1 Contributions of the LCDPs in each requirement

The contributions of the LCDPs in each requirement were based on data collection followed by a personal assessment. The data on how the LCDPs contribute to the requirements were collected in three ways: a questionnaire, associated websites of the LCDPs, and the paper by Sahay et

C1	Network Interaction
C2	User Management
C3	User Interface
C4	Easiness of development
C5	Pricing
SC11	Real-time collaboration
SC12	Synchronous multiplayer
SC13	Web-based (application development)
SC21	User registration
SC22	User roles
SC31	Animation
SC32	Freehand graphics
SC33	Standard UI elements
SC41	Easiness of programming
SC42	Support
SC43	Supported platforms
SC44	Training
SC51	Pricing
A1	Mendix
A2	Microsoft PowerApps
A3	Outsystems
A4	The Wick Editor
A5	Zoho Creator

Table 3: List of the abbreviated elements.

al. [SIDRP20]. Based on this data, the LCDPs were assessed using the scale of Saaty.

Table 27 of Appendix B shows how the data that was extracted from the questionnaire, associated websites of the LCDPs, and paper by Sahay et al. [SIDRP20] is structured. Table 27 is divided into five sub-tables. The first column and second row of each table present the requirements (SC11-SC51) and the LCDPs (A1-A5) respectively. The first row presents the criterion to which the requirements belong. How the platforms contribute to the requirements is noted in each cell.

The questionnaire aimed to obtain data from experts. In this case, experts refer to the employees of the support departments of the LCDPs. Based on the requirements from Section 4.1, the questionnaire was set up. The questionnaire consists of a set of 11 predetermined and open-ended questions. A reference is made to Appendix C for the questionnaire. The questionnaire was sent to the support departments by email with the request to fill out the questionnaire. Unfortunately, too few employees responded to the request, resulting in a lack of data. However, there was one single respondent. Her name is Claudine Maas (hereafter: Maas) and she works in the support department of *Mendix*. A reference is made to Appendix C for Maas' completed questionnaire.

To overcome the lack of data due to too few respondents, a switch was made to exploring the associated websites of the LCDPs and the paper by Sahay et al. [SIDRP20].

A.2.2 Contributions of the requirements in each criterion

The contributions of the requirements in each criterion were based on co-design. Recalling Section 3.2.1, based on the relationships between the requirements in their criterion and through collaboration with the professional in IT, scores were assigned. In particular, we brainstormed whether the requirements are of equal importance to meet the criterion. Based on our judgment, the requirements were assessed using the scale of Saaty.

A.2.3 Contributions of the criteria in the main goal

The contributions of the criteria in the main goal were established in the same way as in Section A.2.2.

A.3 Calculating priorities of the LCDPs in each requirement

In this step, the priorities of the LCDPs in each requirement were calculated. Recalling Section A.2.1, the scores assigned in the pairwise comparisons were based on Table 27 of Appendix B followed by a personal assessment. The comparisons in SC11 are the only ones elaborated on in detail, meaning the motivations for assigning the scores to the contributions of the LCDPs in each requirement are worked out. The calculations to arrive at the priorities of the LCDPs in SC11 are worked out as well. It was decided not to elaborate the pairwise comparisons in all other requirements since the priorities were obtained similarly.

A.3.1 Priorities in SC11 (detailed)

Motivations
Based on row 'SC11' from Table 27, the following scores were assigned. A1, A2, and A3 were chosen

as the best element because the research shows convincing evidence that all platforms support real-time collaboration. Recall only a single element can be chosen for the pairwise comparison. Based on numerical order, A1 will be chosen as the best element. Comparing A1 with A2 and A1 with A3 results in the same contribution to the objective real-time collaboration. This is because evidence shows that A2 and A3 also support real-time collaboration. Therefore, A2 and A3 were assigned a score of 1 as well. Comparing A1 with A4 and A1 with A5 does not result in the same contribution in the objective real-time collaboration. This is because no evidence for A4 and A5 was found supporting real-time collaboration. However, no hard evidence against it was found either. Therefore A4 and A5 were assigned a score of 7.

Calculations
The priorities of the LCDPs in SC11 were calculated in the following way. Since A1 was assigned a score of 1, the scores that were assigned to the other LCDPs need to be divided by this score. The result of such a calculation is called the 'inverse'. The following inverses were calculated.

```
A1: 1/1 = 1,000
A2: 1/1 = 1,000
A3: 1/1 = 1,000
A4: 1/7 = 0,143
A5: 1/7 = 0,143
```

Subsequently, the inverses were added. The result of this calculation is called 'the sum of inverses'. The following sum of inverses was calculated.

```
Sum of inverses = 1,000 + 1,000 + 1,000 + 0,143 + 0,143 = 3,286
```

Last, the inverses are divided by the sum of inverses. The result of such calculation is called a 'priority'. The priorities of all LCDPs in SC11 form a priority vector. The following priorities (and thus priority vector) were calculated.

```
A1: 1,000/3,286 = 0,304
A2: 1,000/3,286 = 0,304
A3: 1,000/3,286 = 0,304
A4: 0,143/3,286 = 0,043
A5: 0,143/3,286 = 0,043
```

Interpretation
The priorities are presented as percentages (%). A1, A2, and A3 each have a priority of approximately 30% in SC11, while A4 and A5 each have a priority of approximately 4%.

SC11	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	1	7	7	
1/a	1,000	1,000	1,000	0,143	0,143	3,286
pr11	0,304	0,304	0,304	0,043	0,043	

Table 4: Priority vector of SC11.

A.3.2 Priorities in SC12-SC51

- A reference is made to Table 5 for the priorities of the LCDPs in SC12.
- A reference is made to Table 6 for the priorities of the LCDPs in SC13.
- A reference is made to Table 7for the priorities of the LCDPs in SC21.
- A reference is made to Table 8 for the priorities of the LCDPs in SC22.
- A reference is made to Table 9 for the priorities of the LCDPs in SC31.
- A reference is made to Table 10 for the priorities of the LCDPs in SC32.
- A reference is made to Table 11 for the priorities of the LCDPs in SC33.
- A reference is made to Table 12 for the priorities of the LCDPs in SC41.
- A reference is made to Table 13 for the priorities of the LCDPs in SC42.
- A reference is made to Table 14 for the priorities of the LCDPs in SC43.
- A reference is made to Table 15 for the priorities of the LCDPs in SC44.
- A reference is made to Table 16 for the priority of the LCDPs in SC51.

SC12	A1	A2	A3	A4	A5	Sum of inverses
A1	1	7	5	5	7	
1/a	1,000	0,143	0,200	0,200	0,143	1,686
pr12	0,593	0,085	0,119	0,119	0,085	

Table 5: Priority vector of SC12.

SC13	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	1	1	1	
1/a	1,000	1,000	1,000	1,000	1,000	5,000
pr13	0,200	0,200	0,200	0,200	0,200	

Table 6: Priority vector of SC13.

SC21	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	1	9	1	
1/a	1,000	1,000	1,000	0,111	1,000	4,111
pr21	0,243	0,243	0,243	0,027	0,243	

Table 7: Priority vector of SC21.

SC22	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	1	9	1	
1/a	1,000	1,000	1,000	0,111	1,000	4,111
pr22	0,243	0,243	0,243	0,027	0,243	

Table 8: Priority vector of SC22.

SC31	A1	A2	A3	A4	A5	Sum of inverses
A4	3	3	3	1	5	
1/a	0,333	0,333	0,333	1,000	0,200	2,200
pr31	0,152	0,152	0,152	0,455	0,091	

Table 9: Priority vector of SC31.

SC32	A1	A2	A3	A4	A5	Sum of inverses
A4	3	3	3	1	5	
1/a	0,333	0,333	0,333	1,000	0,200	2,200
pr32	0,152	0,152	0,152	0,455	0,091	

Table 10: Priority vector of SC32.

SC33	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	1	1	1	
1/a	1,000	1,000	1,000	1,000	1,000	5,000
pr33	0,200	0,200	0,200	0,200	0,200	

Table 11: Priority vector of SC33.

SC41	A1	A2	A3	A4	A5	Sum of inverses
A2	3	1	3	4	2	
1/a	0,333	1,000	0,333	0,250	0,500	2,417
pr41	0,138	0,414	0,138	0,103	0,207	

Table 12: Priority vector of SC41.

SC42	A1	A2	A3	A4	A5	Sum of inverses
A1	1	1	3	7	7	
1/a	1,000	1,000	0,333	0,143	0,143	2,619
pr42	0,382	0,382	0,127	0,055	0,055	

Table 13: Priority vector of SC42.

Matrix PASC

The priorities of the LCDPs in each requirement are shown in Table 17. This table of vectors is referred to as matrix PASC (Priorities of the Alternatives in each Sub-criteria). Matrix PASC will be used in a future step of the method.

SC43	A1	A2	A3	A4	A5	Sum of inverses
A1	1	7	7	1,5	5	
1/a	1,000	0,143	0,143	0,667	0,200	2,152
pr43	0,465	0,066	0,066	0,310	0,093	

Table 14: Priority vector of SC43.

SC44	A1	A2	A3	A4	A5	Sum of inverses
A2	3	1	3	5	5	
1/a	0,333	1,000	0,333	0,200	0,200	2,067
pr44	0,161	0,484	0,161	0,097	0,097	

Table 15: Priority vector of SC44.

SC51	A1	A2	A3	A4	A5	Sum of inverses
A4	5	3	5	1	4	
1/a	0,200	0,333	0,200	1,000	0,250	1,983
pr51	0,101	0,168	0,101	0,504	0,126	

Table 16: Priority vector of SC51.

	A1	A2	A3	A4	A5
pr11	0,304	0,304	0,304	0,043	0,043
pr12	0,593	0,085	0,119	0,119	0,085
pr13	0,200	0,200	0,200	0,200	0,200
pr21	0,243	0,243	0,243	0,027	0,243
pr22	0,243	0,243	0,243	0,027	0,243
pr31	0,152	0,152	0,152	0,455	0,091
pr32	0,152	0,152	0,152	0,455	0,091
pr33	0,200	0,200	0,200	0,200	0,200
pr41	0,138	0,414	0,138	0,103	0,207
pr42	0,382	0,382	0,127	0,055	0,055
pr43	0,465	0,066	0,066	0,310	0,093
pr44	0,161	0,484	0,161	0,097	0,097
pr51	0,101	0,168	0,101	0,504	0,126

Table 17: Matrix PASC.

A.4 Calculating priorities of the requirements in each criterion

In this step, the priorities of the requirements in each criterion were calculated. Recalling Section A.2.2, the scores assigned in the pairwise comparisons were based on co-design. The comparisons in C1 are the only ones elaborated on in detail. The calculations to arrive at the priorities of the requirements are not elaborated on since they are the same as in Section A.3.1.

A.4.1 Priorities in C1 (detailed)

Motivations
Based on the co-design process, the following scores were assigned. SC11, SC12, and SC13 were chosen as the best element since we believed that real-time time collaboration, synchronous multiplayer, and web-based application development are of equal importance in network interaction. All of them are indispensable features in realizing network interaction. Recall only a single element can be chosen for the pairwise comparison. Based on numerical order, SC11 was chosen as the best element. Comparing SC11 with SC12 and SC11 with SC13 results in the same contribution to the objective network Interaction. This is because both synchronous multiplayer and web-based application development are indispensable features as well. Therefore, SC12 and SC13 were assigned a score of 1. A reference is made to Table 18 for the priorities of the requirements in C1.

C1	SC11	SC12	SC13	Sum of inverses
SC11	1	1	1	
1/a	1	1	1	3
PSC1	0,333	0,333	0,333	

Table 18: Priority vector of C1.

A.4.2 Priorities in C2-C5

- A reference is made to Table 19 for the priorities of the requirements in C2.
- A reference is made to Table 20 for the priorities of the requirements in C3.
- A reference is made to Table 21 for the priorities of the requirements in C4.
- A reference is made to Table 22 for the priority of the requirement in C5.

C2	SC21	SC22	Sum of inverses
SC21	1	2	
1/a	1	0,5	1,5
PSC2	0,667	0,333	

Table 19: Priority vector of C2.

C3	SC31	SC32	SC33	Sum of inverses
SC33	3	2	1	
1/a	0,333	0,500	1	1,833
PSC3	0,182	0,273	0,545	

Table 20: Priority vector of C3.

Matrix PSC
The priorities of the requirements in each criterion are shown in Table 23. This table of vectors is referred to as matrix PSC (Priorities of the Sub-criteria in each Criterion). Matrix PSC will be used in the next step of the method.

C4	SC41	SC42	SC43	SC44	Sum of inverses
SC41	1	3	1,5	2	
1/a	1,000	0,333	0,667	0,500	2,500
PSC3	0,400	0,133	0,267	0,200	

Table 21: Priority vector of C4.

C5	SC51	Sum of inverses
SC51	1	
1/a	1	1
PSC5	1	

Table 22: Priority vector of C5.

	SC11	SC12	SC13	SC21	SC22	SC31	SC32	SC33	SC41	SC42	SC43	SC44	SC51
C1	0,333	0,333	0,333	0	0	0	0	0	0	0	0	0	0
C2	0	0	0	0,667	0,333	0	0	0	0	0	0	0	0
C3	0	0	0	0	0	0,182	0,273	0,545	0	0	0	0	0
C4	0	0	0	0	0	0	0	0	0,400	0,133	0,267	0,200	0
C5	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 23: Matrix PSC.

A.5 Calculating priorities of the LCDPs in each criterion

In this step, the priorities of the LCDPs in each criterion are calculated. The priorities have been calculated by multiplying matrix PSC (shown in Table 17) by matrix PASC (shown in Table 23). The result of this multiplication is matrix PAC (Priorities of the Alternatives in each Criterion). Matrix PAC is shown in Table 24 and will be used in a future step of the method.

	A1	A2	A3	A4	A5
C1	0,366	0,196	0,208	0,121	0,109
C2	0,243	0,243	0,243	0,027	0,243
C3	0,178	0,178	0,178	0,316	0,150
C4	0,242	0,359	0,128	0,136	0,134
C5	0,101	0,168	0,101	0,504	0,126

Table 24: Matrix PAC.

A.6 Calculating priorities of each criterion

In this step, the priorities of the criteria in the main goal were calculated. Recalling Section A.2.3, the scores in the pairwise comparisons were based on co-design as well.

The priorities of the criteria are shown in Table 23. This vector is referred to as matrix PC (Priorities of the Criteria). Matrix PC will be used in the next step of the method.

PC	C1	C2	C3	C4	C5	Sum of inverses
C1	1	1,5	2	2	3	
1/a	1,000	0,667	0,500	0,500	0,333	3,000
PC	0,333	0,222	0,167	0,167	0,111	

Table 25: Matrix PC.

A.7 Calculating final priorities of each low-code platform

In this step, the final priorities of the LCDPs in the main goal were calculated. The priorities have been calculated by multiplying matrix PC (shown in Table 25) by matrix PAC (shown in Table 24). The multiplication resulted in vector PA (Priorities of the Alternatives), which is shown in Table 26. The priorities indicate in percentage (%) to which extent the LCDPs are suitable for building serious games.

A1 has achieved the highest priority of approximately 26%. According to the method, this is the best-fitted LCDP for building serious games. A1 is followed by A2, A3, and A4. A5 has achieved the lowest priority of approximately 15%. According to the method this is the least-fitted LCDP.

	A1	A2	A3	A4	A5
PA	0,257	0,228	0,186	0,178	0,152

Table 26: Priority vector PA.

B Data collection

In this section, the data on how the LCDPs contribute to the requirements is presented. The data was collected in three ways: a questionnaire, associated websites of the LCDPs, and the paper by Sahal et al. [SIDRP20]. Table 27 is divided into five sub-tables. The first column and second row of each table present the requirements (SC11-SC51) and the LCDPs (A1-A5), respectively. The first row presents the criterion to which the requirements belong. In each cell, it is noted how the LCDPs contribute to the requirements.

C1					
	A1	*A2*	*A3*	*A4*	*A5*
SC11	Available [Maa21]	Available [Hea21]	Available [Outf]	Insufficient data	Insufficient data
SC12	Available [Maa21]	Insufficient data	Available [Out20]	Insufficient data	Insufficient data
SC13	Available [Maa21]	Available [Min22]	Available [Out22b]	Available [Wic20a]	Available [Ltd22a]

C2					
	A1	*A2*	*A3*	*A4*	*A5*
SC21	Available [Maa21]	Available [Mic22g]	Available [Sul21]	Insufficient data	Available [Ltd22b]
SC22	Available [Maa21]	Available [Sur17]	Available [Out22f]	Insufficient data	Available [Ltd22e]

C3					
	A1	*A2*	*A3*	*A4*	*A5*
SC31	Available [BV19a]	Available [Ano20]	Available [Out22a]	Available [Wic20b]	Available [Ltd19]
SC32	Available [BV19b]	Available [Mon22]	Available [Sal18]	Available [Wic20b]	Available [Ltd22l]
SC33	Available [Maa21]	Available [Wal22]	Available [Out22c]	Available [Wic20b]	Available [Ltd22c]

C4					
	A1	*A2*	*A3*	*A4*	*A5*
SC41 includes IDE (1), mouse interaction (2), and programming languages (3)					
SC41 (1)	Studio or Studio Pro, see *SC44 (2)*	PowerApps IDE (online instead of standalone), see *SC44 (2)*	Service Studio, see *SC44 (2)*	The Wick Editor, see *SC44 (2)*	App-IDE, see *SC44 (2)*
SC41 (2)	Drag-and-drop [SIDRP20]	Point-and-click [SIDRP20]	Drag-and-drop [SIDRP20]	Drag-and-drop [Wic20c]	Drag-and-drop [SIDRP20]
SC41 (3)	CSS, HTML, Java, JavaScript [Maa21]	Power Fx [Ano20]	CSS, HTML, JavaScript [Outc]	JavaScript [for20]	Deluge [Ltd22i]
SC42 includes forum activity (1) and help-desk (2)					
SC42 (1)	$>$ 35K questions with $\approx$ 30 posts a day [BV22d]	$>$ 350K questions with $\approx$ 40 posts a day [Mic22e]	$>$ 5K questions with $\approx$ 40 posts a day [Outd]	$<$ 1K questions with $\approx$ 5 posts a day [for]	$>$ 10K questions with $\approx$ 5 posts a day [Ltd22d]
SC42 (2)	Email, phone, live chat [BV22f]	Email, phone, live chat [Mic22d]	Email, phone [Outb]	Email [Wic20a]	Email, phone [Ltd22m]
SC43 includes operating systems (1) and web-browsers (2)					
SC43 (1)	Windows, MacOS, Linux [Maa21]	Windows [Del22]	Windows [Out22e]	Windows, MacOS, Linux [Ris18]	Windows, MacOS, Linux [Ltd22k]
SC43 (2)	Google Chrome, Microsoft Edge, Mozilla Firefox, Apple Safari [Maa21]	Google Chrome, Microsoft Edge, Mozilla Firefox, Apple Safari [Del22]	Google Chrome, Microsoft Edge, Mozilla Firefox, Apple Safari [Out22e]	Google Chrome, Mozilla Firefox, Apple Safari [Ris18]	Google Chrome, Mozilla Firefox, Apple Safari [Ltd22k]
SC44 includes documentation (1), free offer (2), paid offer (3), and certifications (4)					
SC44 (1)	Available [MTB22]	Available [Viv22]	Available [Outi]	Available [Ris18]	Available [Ltd22g]
SC44 (2)	49 learning paths [BV22a], 16 webinars [BV22b]	28 learning tracks [Mic22a], 105 modules [Mic22a]	13 learning paths [Oute], 93 courses [Outg]	17 tutorials [Wic20b], 10 example projects [Wic20b]	10 webinars [Ltd22f]
SC44 (3)	8 training courses [BV22a]	80 training courses [Mic22c]	7 training courses [Outa]	Not available [Wic20b]	5 training courses [Ltd22h]
SC44 (4)	4 programs [BV22c]	290 programs [Mic22b]	7 programs [Out22d]	Not available [Wic20b]	3 programs [Ltd22j]

C5					
	A1	*A2*	*A3*	*A4*	*A5*
SC51	Cheapest subscription starts at €50 per month per application, with multiple (5 in total) developers included, and most expensive subscription starts at €2000 per month for unlimited apps, multiple developers included [BV22e]	Cheapest subscription starts at €4,20 per month per application, single developer included, and most expensive subscription starts at €16,40 per month for unlimited apps, single developer included [Mic22f]	Cheapest subscription is a free version in which multiple small apps can be build, multiple developers included, and most expensive subscription starts at €1345 per month for unlimited apps, multiple developers included [Outh]	Open-source (free to use), but limited to a single developer [Wic20d]	Cheapest subscription starts at €25 per month per 5 apps, single developer included, and most expensive subscription starts at €400 per month for unlimited apps, multiple developers included [Ltd22n]

Table 27: The contributions of the LCDPs in the requirements.

C Questionnaire

In this section, the questionnaire is presented. The questionnaire consists of 11 predetermined and open-end questions. As mentioned previously, the questionnaire was completed by Maas only. She works in the support department of *Mendix*. The questionnaire was completed on 14-07-2021. Data extracted from her answers were included in Table 27 from Appendix B.

Q1. How many companies and developers use *Mendix*?
We currently have 200,000 active members on our platform. This however also includes people that use our platform to edit user stories in sprints etc. At https://developer.mendixcloud.com/link/people you can see more on who are developers on our platform. I would estimate the active developers based on our certification.
- 16135 are rapid certified,
- 1283 are advanced,
- 225 are experts.

Q2: What is the purpose of *Mendix*?
See https://www.mendix.com/evaluation-guide/mendix-vision/.

"Our fundamental belief is that software should not be something just for IT. Every company needs to become a software company to survive in a software-driven world. The whole organization needs to be collaborating on the lifeblood of the business, which is technology. The future of each company depends on it. The key to survival is experimentation and innovation by people that know the business domain."

In other words, why do companies/developers want to use Mendix? Or in which companies is Mendix used? See https://www.mendix.com/evaluation-guide/what-can-i-build/.

See What Types of Projects Are a Good Fit for Mendix?
Our client portfolio is immense and not really limited to specific industries. It is really applicable to all companies. From the HR system to the entire parcel sorting system at Post NL.

Q3: Is it possible to create multi-user (or multiplayer) applications?
Yes; several people can log into applications at the same time.

Q4: In Mendix is it possible to create applications in which several people can collaborate on an application at the same time (=real-time)? And is it possible to create applications in which people can participate in an application at the same time (=real-time)?

In principle it is possible and games have already been built with Mendix. I definitely know of some customers that have built Multiplayer games with Mendix, see https://www.youtube.com/watch?v=rNSKhP7LLXo. There are definitely some limitations. The thing is in Mendix you have standard functionality but you can extend it with a lot of custom java/javascript/HTML/CSS and external tools. This makes it possible to build everything you want. However, the more you build custom widgets/code to extend your Mendix application, the less you use the advantage of the

low-code Mendix platform. To get real-time data on your screen you have to build custom things (not standard low code functionality). For example, you could do this with a microflow timer in all supervisors (logged-in users). This will fetch live data from the server every few seconds, but you may run into performance limitations.

So; there are certainly possibilities; however, the benefits of Mendix do fall into the background. Google real-time Mendix or multiplayer games Mendix and you will find plenty of people who have done it successfully (for example time series).

Q5: In Mendix is it possible to build browser/web applications?
Yes, that's what it's made for next to mobile. See https://docs.Mendix.com/howto/general/setting-up-the-navigation-structure.

Q6: In Mendix is it possible for users to register themselves in an application ?
Yes, you can easily build this as follows.
- Build a page that anonymous users can access.
- Build a page where a user fills in some data.
- Build a micro-flow where an Account entity is created (default is in an empty app).

This will probably take you half an hour to assemble.

Q7: In Mendix is it possible to assign different roles to users in an application?
Yes, this is built into our platform and works out of the box (very easy to configure).
https://docs.mendix.com/refguide/user-roles
https://docs.mendix.com/studio/settings-security
https://docs.Mendix.com/howto/security/create-a-secure-app

Q8: In Mendix are these widgets available: drag-and-drop text areas, tables, buttons, user input fields, graphs?
Yes, see https://marketplace.mendix.com/link/component/116604.
Yes, see https://docs.Mendix.com/refguide/data-grid.
Yes, see https://docs.Mendix.com/refguide/button-widgets.
Yes, see https://docs.Mendix.com/refguide/text-box.
Yes, https://docs.Mendix.com/refguide/charts-configuration.

Q9: What web-browsers/operating systems are compatible with Mendix?
See https://docs.Mendix.com/refguide7/system-requirements.

Desktop Browsers
- Google Chrome
- Mozilla Firefox
- Apple Safari
- Microsoft Edge
- Microsoft Internet Explorer 11

Mobile Browsers
- iOS 9 and above (Safari)
- Android 5.0 and above
- Windows Phone 8 and above

Q10: Which IDE does Mendix have?
From our Studio and Studio Pro. These are systems that you install and can build in the applications.
https://docs.Mendix.com/studio/
https://docs.Mendix.com/refguide/

Q11: Which programming language (or languages) is used within Mendix?
It is basically low code, so no programming languages. You can extend it with Java, Javascript, HTML, and CSS. But you could even call python scripts via web services etc., so it's pretty unlimited.

D Data collection of Agile Portfolio Poker and Herding Cats

In this section, the data of APP and HC is presented. Recall that this data was used in Section 3.2.2.

D.1 APP game rules

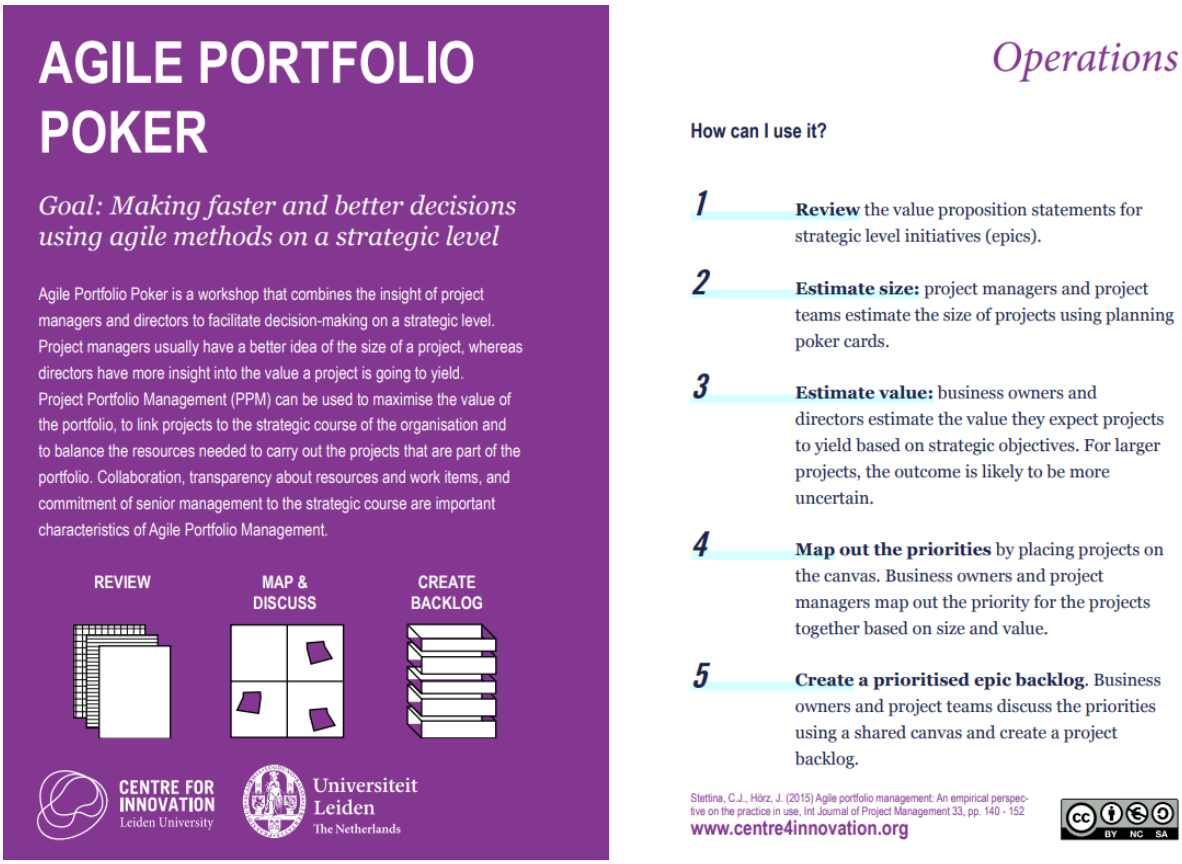
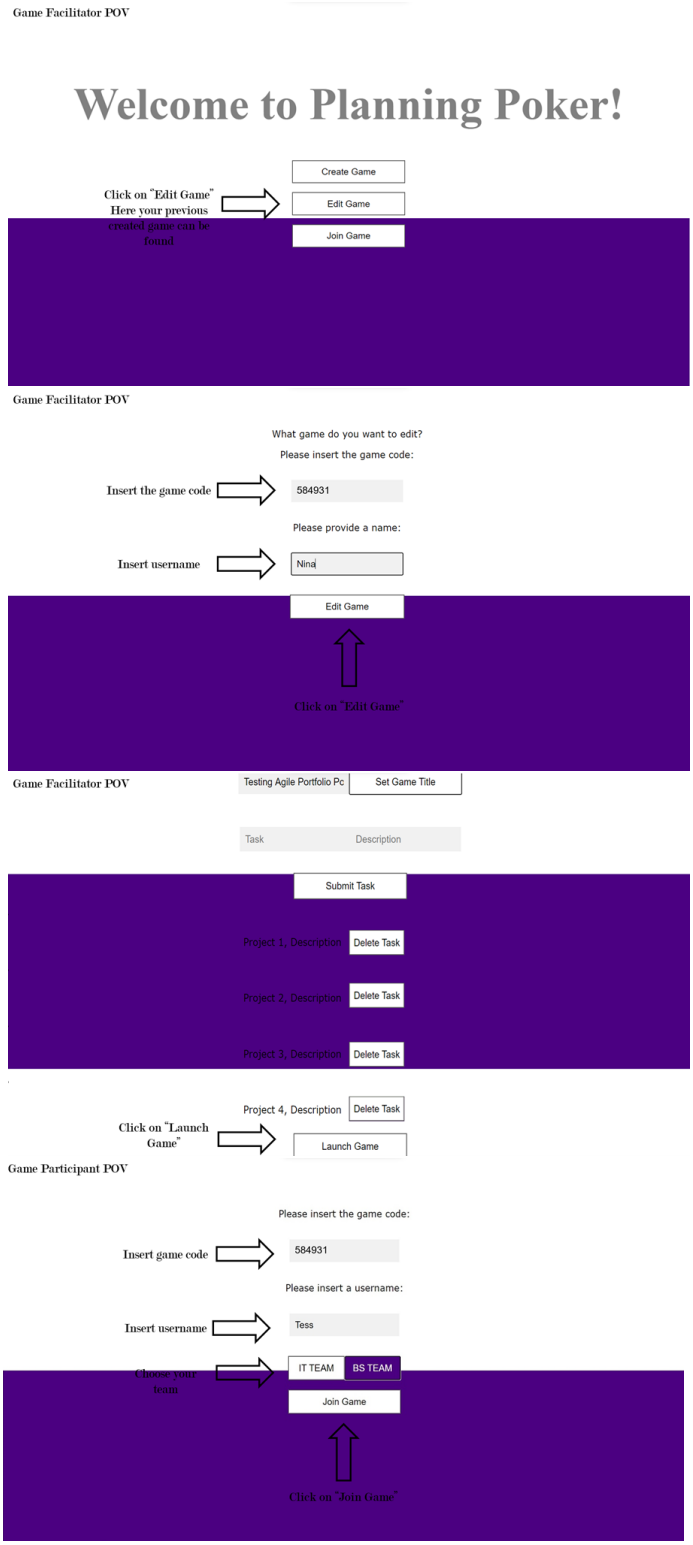
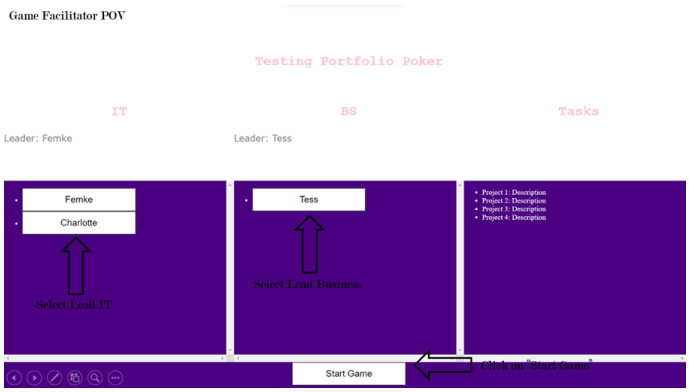
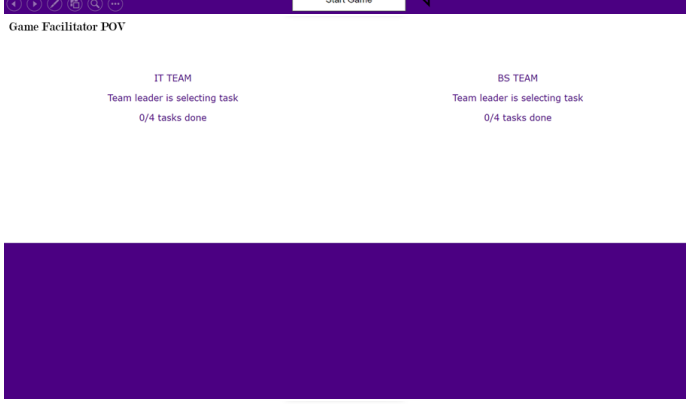


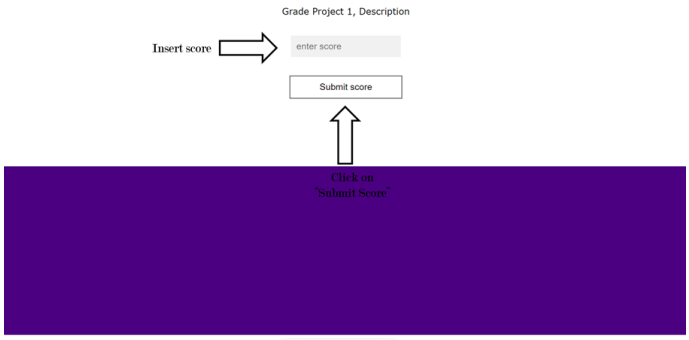
Figure 11: The game rules of Agile Portfolio Poker [Ste].

D.2 APP demo


Game Facilitator POV
Welcome to Planning Poker!
Click on "Edit Game" Here your previous created game can be found
Create Game
Edit Game
Join Game
Game Facilitator POV
What game do you want to edit?
Please insert the game code:
Insert the game code
584931
Please provide a name:
Insert username
Nina
Edit Game
Click on "Edit Game"
Game Facilitator POV
Testing Agile Portfolio Pc
Set Game Title
Task
Description
Submit Task
Project 1, Description
Delete Task
Project 2, Description
Delete Task
Project 3, Description
Delete Task
Project 4, Description
Delete Task
Click on "Launch Game"
Launch Game
Game Participant POV
Please insert the game code:
Insert game code
584931
Please insert a username:
Insert username
Tess
Choose your team
IT TEAM
BS TEAM
Join Game
Click on "Join Game"







- Project 2: 6.666666666666667 (IT: 3, BS: 20)
- Project 3: 0.7692307692307693 (IT: 13, BS: 10)
- Project 1: 0.36363636363636365 (IT: 11, BS: 4)
- Project 4: 0.10526315789473684 (IT: 19, BS: 2)

Figure 12: Screenshots of the demo of APP.

D.3 HC game rules

PREPARING THE GAME

1. Download the facilitator materials (Power Point deck, event cards, Excalidraw file)
2. Open the Herding Cats.excalidraw file from our facilitator materials and open it at excalidraw.com (or click here).
3. Set up a video call invite for all the participants through your preferred video conferencing tool (e.g. Microsoft Teams, Zoom).
4. Split your group up ideally into 4 teams of 3-5 participants per team.
5. Put each team into separate breakout rooms (some conferencing tools like Zoom, allow a direct splitting into breakout sessions, if your tool does not support this, you will need to set up additional breakout calls yourself).
6. In your browser open a new tab and go to Excalidraw.com (or click here), load the file "Herding Cats.excalidraw" from our facilitator materials and start a live collaboration, then share the link with the first team.
7. Repeat steps 6 and 7 for each of your participant teams.
8. Let the players play around with the drag and drop mechanics of the Excalidraw board for roughly 5 minutes and check in on their live sessions from time to time to answer any remaining questions. If the board should get messed up start a fresh live collaboration in a new tab and invite the team in question again.

PLAYING THE GAME

Introduction (10 Minutes):
Present the board, the projects and constraints to your participants and give the information, that all projects can be done by all teams in the limits of the given constraints, but don't tell them about the special events, the Agile and waterfall projects or explain the value/month.
Organize the team into the following roles:

- Portfolio Manager maintaining overview and providing feedback to individual Product Owners
- Product Owner for each of the teams to plan and prioritize the team's track within the portfolio
- Financial Controller to calculate the return per epic/project after each month.

Plan out initial portfolio (15 Minutes):

1. Let the players draw out an initial portfolio plan by dragging and dropping the various projects into the timelines of the Excalidraw board.
2. Now explain the difference between agile and waterfall projects. They can divide Agile projects for the value/quarter rounded down, meaning an 18 value Agile project taking 4 months can be split up into 4/9/13/18 points to represent they are delivering value the whole time.

Execute portfolio in monthly iterations (20-40 Minutes, 5 Minutes per month)

1. The players start executing the first month. The financial controller calculates the return on investment (ROI) for month X.
2. Facilitator picks one of the event cards, announces the event which might have an impact on the portfolio planning.
3. Give the teams 2 minutes to replan their portfolios if necessary.
4. Resume the game for another 4-8 months or until the time runs out and make sure to leave some time for a bit of discussion and reflection.

Figure 13: The game rules of HC [Ste].

D.4 HC sample game

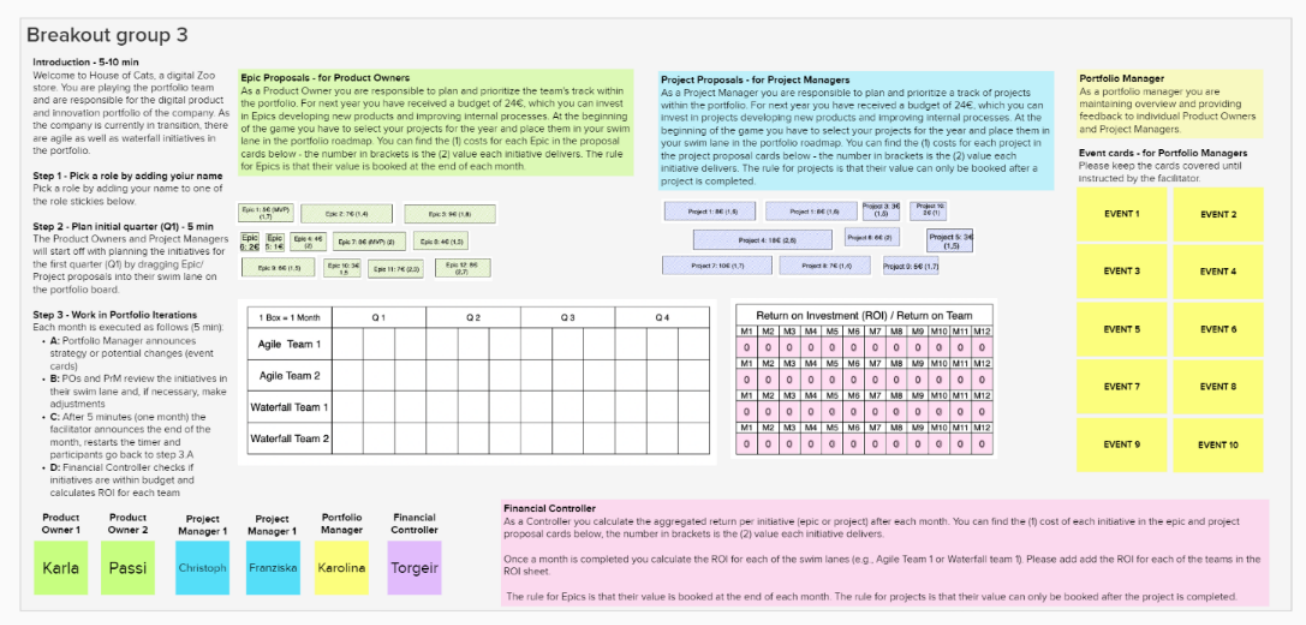


Figure 14: The sample game (and game rules) of HC [Ste].