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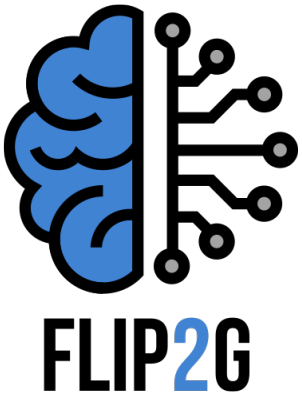

Deliverable 1.2

Requirements for gaming environments in education and training

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Version-Status:	**V1 - Final**
Submission date:	**30/09/2019**
Dissemination level:	**PU**

This project has been funded with the support of the **Erasmus+ programme** of the European Union

Deliverable factsheet

Project Number:	**601190-EPP-1-2018-1-DK-EPPKA2-KA**
Project Acronym:	**FLIP2G**
Project Title:	**Enhancing education and training through data-driven adaptable games in flipped classrooms (FLIP2G)**

Title of Deliverable:	**D1.2 – Requirements for gaming environments in education and training**
Work package:	**WP1 – Serious games for education and training**
Due date according to contract:	**30/09/2019**

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Abstract: This deliverable deals with the technical and user requirements, which need to be fulfilled in the FLIP2G project. It presents various learning models and gamification uses, and derives recommendations on the next steps of development from those. Finally, there is also a list of recommendations towards teachers, students and technical backgrounds with a special focus on learning analytics.

Keyword List: **Serious Games, Gamification, Game based learning, Training and Education**

Consortium

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

The following table presents the acronyms used in the deliverable in alphabetical order.

Abbreviation	*Description*
AI	Artificial Intelligence
AR	Augmented Reality
ARG	Alternate Reality Game
MaTHiSiS	Managing Affective-learning THrough Intelligent atoms and Smart InteractionS
MMO	Massively Multiplayer Game
PBL	Problem-based learning
PC	Personal Computer
RPGs	Role-Playing Games
RTS	Real-time strategy games
ToC	Table of Contents
VR	Virtual Reality

Executive Summary

This deliverable provides an overview of learning theories applied in video games, additional to the ones reviewed in D1.1, and gives an evaluation on which of those learning theories might be applicable in the context of FLIP2G.

A consortium-wide evaluation of pedagogy models associated serious and educational games and any overlaps between those two disciplines was conducted. It was determined that some of those models or aspects of models are more suited for educational digital games, especially in combination with a PBL and a Flipped Classroom model, while others are unsuited for this project.

Connectivism, a learning theory that utilizes the internet and considers learning a social effort instead of culminating knowledge in individuals, is a model, which is particularly ingrained in E-Learning.

Other models focus on certain aspects of learning and should also be taken into consideration when creating a Flipped Classroom learning program. Notable examples of this are *Andragogy*, methods of adult education, *Public Sphere Pedagogy*, a model that combines public discourse with learning, and *Reflective Practise*, a learning theory that considers the importance of applied learning and practice and is therefore particularly suited for Flipped Classroom methods where practice takes place in class as the central learning element.

An additional discussion about user requirements took place, where consortium partners, particularly those with an educational background, provided their insight on the outcomes students and teachers might expect from such a program. The main result of this discussion was a separation into teacher requirements and student requirements, as the interface, objectives and tasks of those two groups are very disparate.

The documentation of those analyses is provided in this deliverable, as well as an extensive reason analysis that was conducted associated to their outcomes.

Finally based on the user requirements a list of technical requirements was derived and is documented in this deliverable. For each feature, importance and developmental requirements were determined. The next step will be to evaluate resources and time needed for development of each feature and make a final decision about optional and necessary features.

1 Introduction

The focus of this deliverable is the collection and analysis of data on serious games, learning theories and technical backgrounds used for development of serious games. For this, sixteen serious games and multiple pedagogy theories were analysed. The findings are displayed in this paper.

As opposed to D1.1, this deliverable will deal with the actual analysis instead of the collection and connection of data. A conclusion about which learning theories and functions should be applied in development of this game will also be made.

1.1 Audience

The intended audience for this document is the FLIP2G consortium, the European Commission, and the public interested in investigating the Flipped Classroom (FC) model and applications of GBL to the FC or AL pedagogies.

1.2 Structure

The structure of the document is as follows:

- Section 2 presents a comparative analysis of Serious Games and learning theories
- Section 3 presents the user requirements for gaming in education and learning
- Section 4 presents the technical requirements for educational games
- Section 5 concludes on the specific requirements for the FLIP2G model

2 Comparative Analysis - Serious Games & Learning Theories

The following sections will deal with an analysis of learning theories applicable to E-Learning. As already outlined in D1.1, the Flipped Classroom Model and PBL are the driving theories FLIP2G is based on, but in evaluating other learning theories, added value will be created and implemented to the project. The objective of this analysis is to use its results to create a holistic approach to gamified learning.

Additionally, to the formerly in D1.1 researched games *Mathisis, Sharkworld, Fold.it, X-Plane* and *World without Oil*, eleven other serious games were analysed based on multiple variables. Their narrative, genres, topics and release platforms were information usually provided by the developer, and applied learning models, analytics, data collection and gamification methods were researched and analysed.

Those games were selected based on their objectives, content, target group and online and social functionalities.

It was ensured that the analysed games consisted of a diverse range of games but also included games comparable to what FLIP2G aims to create.

- Simport (Warmerdam et al., 2006)

  A construction simulation where players need to create a harbour. It is designed to teach construction and project management principles to adults.

  Consequently, it features a variety of learning theories centred around PBL and the necessity to constantly adapt playstyle and strategy. It is increasingly complex in its playthrough and is supposed to be played by professionals with a management or construction background as well as people without prior knowledge, so the former can support and teach the latter.

- Gaming through Government (Koza, n.d.)

  An educational game intended for middle school students which employs quizzes and mini-games to teach about American history and politics. To advance in the game, students need to learn and reproduce political and historical facts to eventually become the next American president.

Figure 1: Screenshot of Simport's Gameplay

They must utilize resources outside of the game, like school books and online resources. Good and bad decisions have a direct influence on the player score, and via frequent rewards a Positive Feedback Loop is generated. Through the individualization aspects of this game, the effect of the Positive Feedback Loop is heightened.

Figure 2 - One of the many minigames of Gaming Through Government (Koza, n.d.)

Kahoot! Is a platform for young pupils as well as business professionals used to create and fill out multiple choice quizzes. Individual performance in those games can be used by

teachers to assess their students. Additionally, competition among students is encouraged through leader boards and ratings.

Due to the efficient use of gamification methods and its success, this platform should be evaluated deeper in case a similar approach is envisioned.

Currently Kahoot! has more than 100 million MAUs (Kahoot!, 2018). In case of a later economic exploitation of the project, Kahoot! can also be considered a competitor.

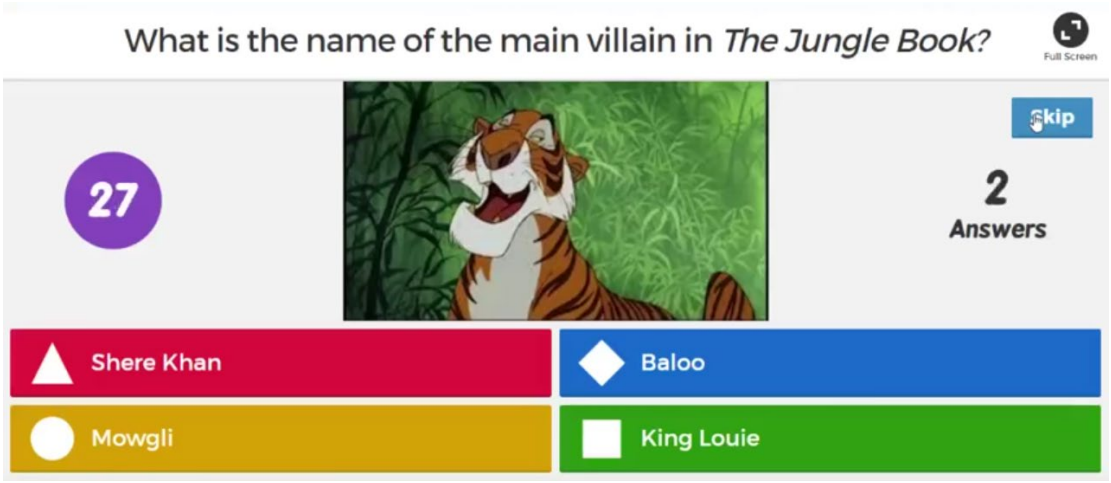

Figure 3 - Kahoot!'s browser-based gameplay (Brand et al., 2013)

- Cell Lab: Evolution Sandbox (Säterskog, 2015)

  This mobile game features a digital petri dish on which players can plant organisms, resources and other microscopic matters to watch them interact with each other and learn microbiological fundamentals. It features a very steep learning curve, but balances this out with an extensive tutorial that explains both the game mechanics and the underlying scientific principles in increasing complexity. Throughout the game it also points out that the tutorial needs to be followed precisely in order to understand the game mechanics and play the game.

- Hazmat: Hotzone (Schell, 2002)

  A game teaching first aiders how to interact with hazardous and chemical emergencies in a real-life context. Instructors can effortlessly create their own scenarios in pre-built physical

life-sized models. As this game is only intended for training of firefighters and first aiders, it is an excellent example of *Situated Learning*.

It is also notable that this game contains an AI, which evaluates the performance of players.

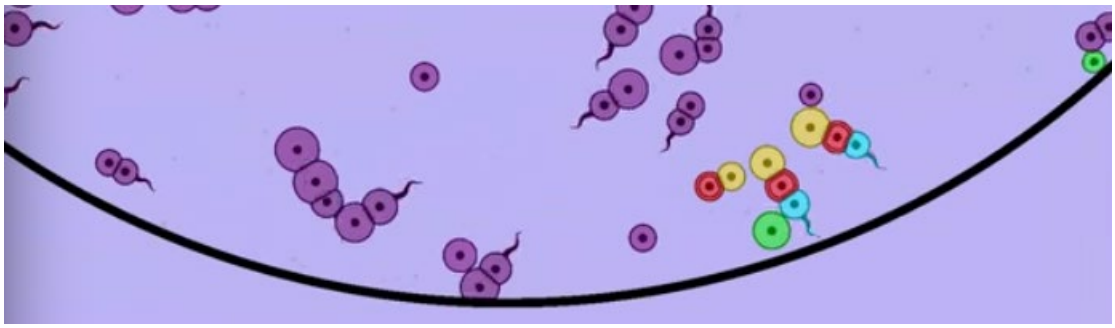

Figure 4 - Cell Lab Gameplay showing multiple cells and evolutions with different functions (Säterskog, 2015)

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  A special focus was put on programming learning games, as they are one of the aspects of STEM disciplines and this focus provides a frame to compare how different techniques can be used to reach a similar goal.

- Code Combat (CodeCombat, 2013)

  A unique game regarding to how it links its narrative to the educational content. It teaches coding by requiring students to program their avatar to progress through a dungeon and defeat monsters. This game is a good example of game-based learning as opposed to gamification, since it completely redesigns the process of learning to code and adds

incentives especially in the early tutorials where students of programming are often discouraged by a lack of positive feedback or progression.

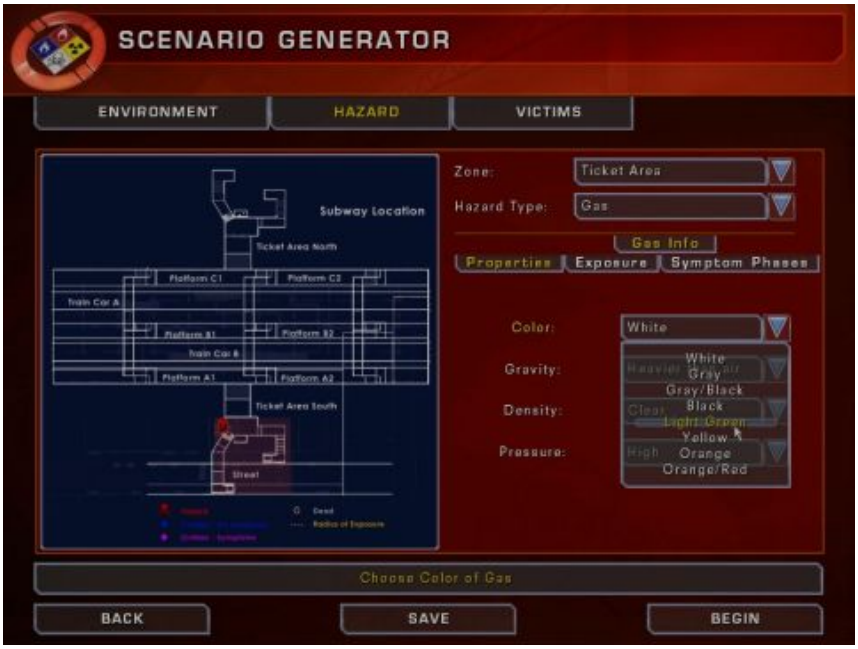

Figure 5 - Hazmat:Hotzone User Interface for the Supervisor (Shell, 2002)

Figure 6 - Gameplay of Code Combat (CodeCombat, 2013)

- Lightbot (Lightbot Inc., 2017)

A Puzzle Platformer where students must drag and drop code snippets to create functions for a robot in order to reach his goal in each level. It is in many ways comparable to Code Combat, except the focus of the game, which does not lie on fighting, but on creating solutions for logic puzzles. This demonstrates very well how game-based learning of the same content can go two completely different ways.

Figure 7 shows that the difference in mood and mechanics is apparent, but the underlying principles are the same for 2 games, code combat and Lightbot.

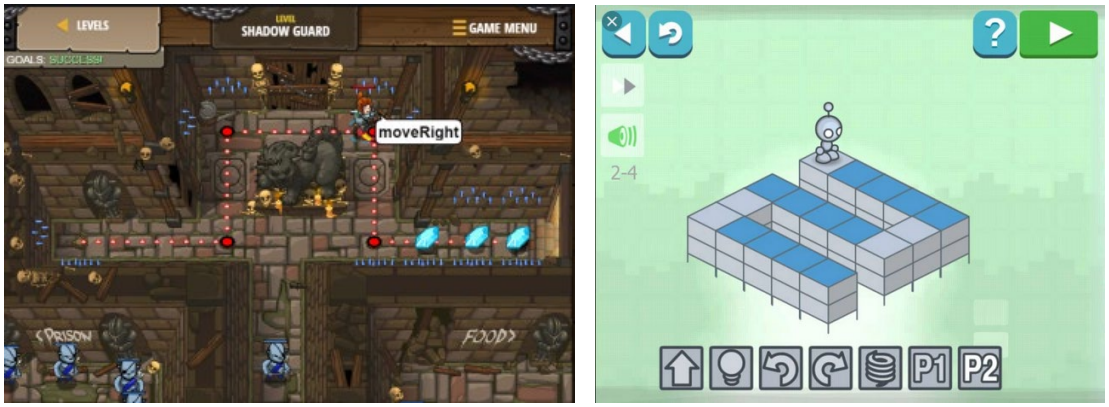

Figure 7 - Screenshots of Code Combat (left) (CodeCombat, 2013) and Lightbot (Lightbot Inc., 2017)

- Human Resource Machine (Tomorrow Corporation, 2015) and 7 Billion Humans (Tomorrow Corporation, 2018)

  Those games were developed by the same studio and are comparable in many regards. Both are puzzle games where players drag and drop increasingly complex functions to proceed in-game, like in Lightbot. They follow models of Guided Learning, Transformative Learning and Andragogy.

- Screeps (Chivchalov et al., 201

  In this MMO RTS, players need to write real JavaScript code for their units. As its target group are players who are already versed in programming, and due to its competitive nature, this makes its market potential very niche.

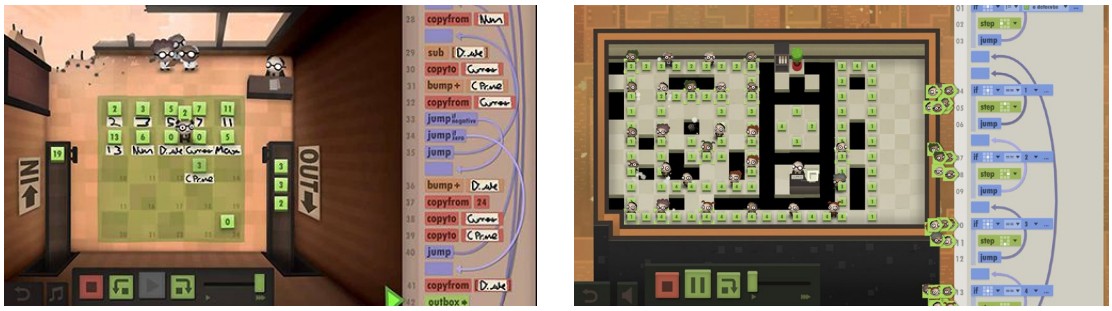

Figure 8 - Screenshots of Human Resource Machine (left) (Tomorrow Corporation, 2015) and 7 Billion Humans (Tomorrow Corporation, 2018)

All written code is usable in a functional context and therefore also works outside the game. As players can choose to stay in low level areas and progress at their own pace, this game utilizes the model of *Anchored Instruction*.

Figure 9 One Screeps area. Each area borders four others, which might be inhabited by other players (Chivchalov et al., 2014)

- CodinGame (Desmoulins et al., 2012)

  A browser-based shooter game, which requires players to write code in a coding language of their choosing. While the gameplay itself is purely single player, players collaborate in forums and social networks outside of the game to find and exchange solutions to known problems and hard levels.

Community challenges take place often, and, like in Fold.it, the winning code gets published on the website and in-game. As there are no pre-existing solutions to the challenges, players sometimes create revolutionary solutions, an added incentive for experienced coders to play this game. Unlike Screeps, CodinGame has tutorials for players without prior coding expertise.

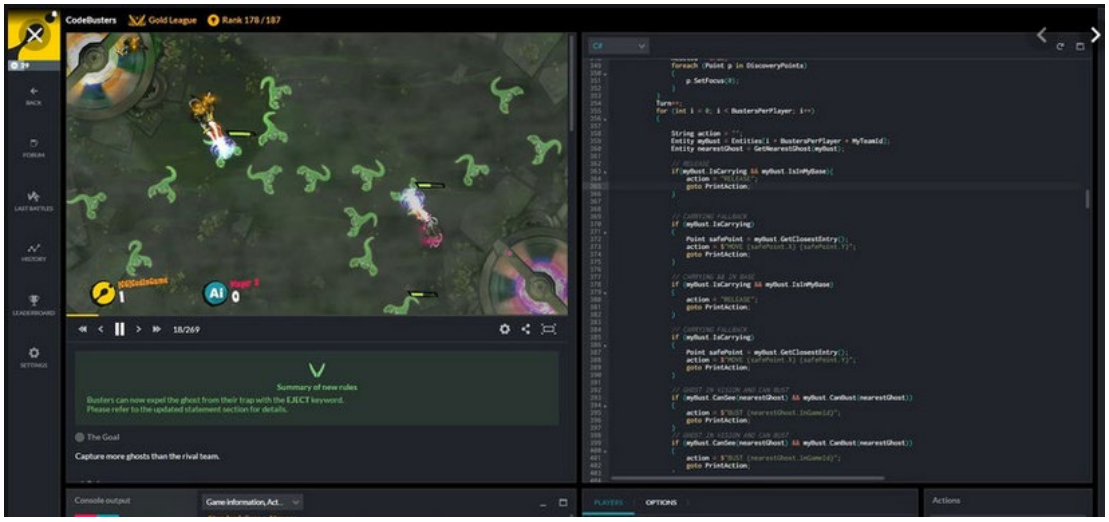

Figure 10 CodinGame Screenshot

Those programming learning games indicate very well how similar content can be communicated through different means. It also shows how multiple target groups are approached in different ways.

2.1 Learning Models

An analysis of serious games and applied learning theories was performed, based on the findings of D1.1 as well as the games introduced in the former section. A few of the introduced methods were already mentioned beforehand, this is an exhaustive list of all used learning theories, which are important in a game development related manner.

2.1.1 Pedagogic Theories

Learning theories covered in D1.1 were *Behaviourist Theory, Instructional Theory* and *Constructivist Theory.* Models like the Flipped Classroom Model and PBL are usually based on Constructivist theory, but often include the administration of multiple theories that in themselves are heavily coinciding

(Xu & Shi, 2018). Other theories applied in the analysed games are usually also based on Constructivist learning. Early theories of behaviourist learning theories often focused on what students are learning, especially by observing how students react to a specific stimulus, and approaching learning as a series of reaction to selected stimuli. Constructivist theories on the other hand were formed in the first half of the 20th century and focus on why students learn and what students are thinking while learning (Piaget, 1971), and posit that learning occurs in the interaction of the students with their whole environment, and establish motivation as a core factor in learning.

Instructional theory does not move the student into focus at all, but only concentrates on the passive intake of education and an instructor who does not cater to his students' strengths nor weaknesses (Song, 2018). It is only minor relevant in modern education and irreconcilable with PBL and Flipped Classroom. The absence of any interactivity also makes it unsuited for gamified solutions.

2.1.1.1 Anchored Instruction and Elaboration Theory

Two major paradigms in digital learning are Anchored Instruction (Bransford, 1990) and the Elaboration Theory (Reigeluth, 1979). Both models introduce content in a simple, straightforward manner and then become increasingly complex as the student progresses.

Anchored Instruction is a pedagogy model used in middle and high schools. It makes use of "anchors" to create a macro-context for students. For raised engagement, anchors are taken from the real world and thus provide a comprehensive background and a realistic frame of reference for learning. Anchors usually introduce stories out of which learners need to construct their knowledge. Case Studies in tertiary and business education follow the same principle.

Elaboration Theory models work similar. Before each learning session, the learner is reminded of all content taught so far through a summary or a synthesis, to be prepared to create his own syntactical content.

In games, this can be applied in various ways.

Fold.it, Sharkworld, Cell Lab and a few of the coding games are good examples for this: Throughout the whole game, new mechanics get introduced while the game explains both the mechanics and the scientific or managerial principles used. Players must make use of tools introduced in the

beginning of those games in the latter parts of the game, but constantly have to adapt their strategies.

Anchors can be used in games to give students a restricted frame on possible options. In that case, anchors are not provided in a real-life context, but emerge from the game narrative. Sharkworld features a shark tank that needs to be built, and Cell Lab uses a digital doctor that leads you through the tutorials and acts as your supervisor. Advantage of fictional anchors over real life anchors like case studies is the relative simplicity and the elimination of unforeseen variables.

2.1.1.2 Andragogy

Andragogy refers to methods used in adult education, it explores the differences between adult and adolescent learning (Knowles, 1968).

As opposed to children, adults are more self-directed and able to take responsibility for their decisions, two behaviour patterns that need to be considered when creating a game-based learning experience for adults.

Adult learning programs often have different goals and focus more on specialization (Knowles, 1968), which can be translated into game development through careful selection of topics and a limitation of conveyed background or trivia information.

Adults need to know *why* they learn something, they need to have a topic of immediate value and approach learning in an experimental, problem-solving manner. Teaching strategies based on Andragogy are case studies, role-playing and simulations.

Some of the analysed games were clearly aimed at adults, for example Sharkworld, X-Plane 10 or Screeps, all of which are hard to complete for children or adolescents. They also feature a lesser amount of positive feedback than games aimed at younger target groups and have a clearer link of theme and education. Furthermore, they introduce many tools and mechanics very early in the game, require higher attention of the player and give clearer negative feedback when needed.

It should, however, be noted that games which do not feature Andragogy teaching principles, like Kahoot! or Fold.it, can still be very popular in different age groups.

2.1.1.3 Experimental Learning and Situated Learning

Hands-on learning and learning by doing, both mentioned as possible solutions on the position paper, can be applied, simple forms of Experimental Learning, but they often miss one of the key components: Self-reflection of the student and subsequent change of habits (Kolb, 1984).

Both the Experimental Learning model and the Situated Learning model (Lave & Wenger, 1991) attempt to combine hands-on learning and academic improvement and are therefore heavily based on other Constructivist models.

In flipped classroom models, particularly the application of learnt content is often both experimental and situational, as the student learns while solving tasks. Especially experiments can be very streamlined under instruction of the teacher.

Those models were used in most of the analysed games, as digital gaming is predestined for this type of learning. In Code Combat for example, the narrative of the game is completely detached from the content (medieval/fantasy narrative vs. programming as a mechanic) and therefore creates a situation where the player learns coding while playing. Proceeding in the game through trial and error is possible, as failing does not have any long-lasting impact.

However, to reach true experimental learning, self-reflection needs to occur. Especially in younger students, a teacher who requires the student to reflect on what he did and why he failed might be a necessary addition for a learning effect.

2.1.1.4 Functional Context

Functional Context is in some ways the opposite of lateral thinking as shown in section 2.1.2.4 of this deliverable. This approach values the importance of students learning in a relevant context, comparable to the elaboration theory (Sticht, 1975). New knowledge needs to be contextualized into former learnings and the real world, and used materials and data need to resemble their real-world counterparts to provide this context.

Examples for this are some of the analysed games focusing on teaching programming like CodinGame or Screeps. Instead of teaching in a made-up, simplified coding language, or via drag and drop, they use coding languages that exist, and the created code works outside of the game as well.

For Hotzone:Hazmat, a physical model was constructed to apply knowledge previously learnt in the computer game, and in Sharkworld real project management techniques and interfaces are used, both tied to the narrative and the game mechanics.

Through this context, games working in a functional context are impossible to play for users who do not have at least minor knowledge in the covered topics. However, this saves those games from a prevalent recurring issue in E-Learning: A lot of digital education apps only provide the very basics of a certain topic and have the player focus too much on gameplay (Toda et al., 2018).

2.1.1.5 Public Sphere Pedagogy

Public Sphere Pedagogy is a part of *Critical Pedagogy* and connects classroom activities with civic engagement (Swiencicki et al., 2011). While initially imagined as a real-life discourse, due to the progression of internet use the application of this model can also take place online. One example for this theory is the analysed game *World without Oil*.

The goal of this model is to engage students in civic discourse and provide value while teaching. It is especially useful in the context of political, philosophical, environmental and social teachings, as well as any content that requires discourse and profits from the voicing of different opinions.

For the project, it might be interesting to give the possibility to integrate Public Sphere Pedagogy via e.g. surveys the students have to conduct. Due to the different infrastructure and locations of target institutions as well as the focus on STEM subjects, it should be integrated as optional, but can be a valuable extension if available.

2.1.1.6 Reflective Practice and Transformative Learning Theory

Reflective practice is a learning model where students reflect on their prior actions to improve (Schön, 1983), while Transformative Learning also takes the student's frame of reference into account (Mezirow, 1997).

By shifting their frame of reference and learning through their own actions, students continually improve. As they only compare their progress to their own former achievements and not to other students or benchmarks, this promotes a healthy, non-competitive learning atmosphere both for single students as well as for groups.

As might be expected, this type of teaching works better in adult learning due to a more comprehensive frame of experience by the student and is therefore closely tied to the concept of *Andragogy*.

Those models are particularly interesting as students especially in tertiary and business education often have a very diverse level of knowledge on the subject that is being taught. Therefore, the possibility of learning at one's own pace should be one of the objectives when developing an adult learning application.

Most of the analysed games applied those learning theories, as they are inherently interactive and require the user to learn from his former mistakes, as it is often not even reasonably possible to finish a level on the first try. Notable exceptions are Kahoot! And Gaming Through Government, those two games mainly feature multiple-choice questionnaires and require the student to react instead of being proactive.

2.1.1.7 Spaced Repetition

Spaced Repetition should be known to most people through flashcards used for vocabulary learning in high school. Difficult topics get reviewed more often, and the better a student knows them, the less frequently they are reviewed in order to stimulate long-term memory (Mace, 1932). This exploits the *Spacing Effect*, a psychological phenomenon where learning is more productive when studying the same content spread out over a longer time period (Smolen et al., 2016).

As opposed to e.g. Lateral Thinking as shown in section 2.1.2.4 of this deliverable. Spaced Repetition is especially useful in cases where students need to acquire a large mass of academic knowledge. When combined with more functional learning models like Experimental Learning, it is even more effective.

The analyzed game Cell Lab applies this very well. Simple content learnt in the beginning is still relevant towards the end of the game, but often additional factors force users to change their strategy and remember which scientific principles needed for a certain task they learnt beforehand.

2.1.2 Other Psychological Models

In addition to the learning theories introduced in the former section, there are a few cognitive models that are particularly suitable to coalesce a learning and gaming environment. While used in

some of the analysed games, they were not necessarily very prevalent and are not directly connected to pedagogy, but often other psychological fields.

2.1.2.1 Classical / Operant Conditioning

Classical conditioning is a process where stimuli that the tested subject is initially indifferent to are paired with other, positive or negative stimuli. The former neutral stimulus then will start to elicit an involuntary response (Pavlov, 1927), like drooling, movements, sweating or emotional responses. In operant conditioning, learnt behaviour is voluntary in a way that a conscious decision is made by the subject on whether to conduct their behaviour or not (Skinner, 1938).

Many games use those principles, especially operant conditioning, to foster engagement. When a game is fun and engaging, people make the conscious decision to come back and play it again, a process called *continuous reinforcement* (Skinner & Ferster, 1957).

This can also take a negative turn as it has happened with lootboxes in recent times. Lootboxes are gambling mechanisms where players pay and do not know whether they will get a reward or not, so-called *interval reinforcement* (Richardson, 2015). As players expect to get rewards from video games based on their former experiences, variable interval reinforcement schedules might condition them to buy until they get rewarded (Perez, 2018).

In educational games, those mechanisms can subtly be used to engage students more, especially in less interesting topics. One example of this would be Code Combat, where looting and collecting items are central part of the theme. However, as techniques like this can be unreliable and need to be executed precisely, they should be used as an additional mechanic and not as the main incentive of the game.

2.1.2.2 Connectivism

The internet has given rise to this pedagogic model which emphasizes on how internet technologies contribute to a new understanding of learning. One of the key premises of Connectivism is the ability to learn and share information across the World Wide Web instantly and without any errors (Siemens, 2005).
While Connectivism is derived from the Constructionist Theory, its' unique property is the view that

learning can take place outside the mind / outside an individual, for example within a database that is worked on and expanded by multiple people.

It is important that data is linked (therefore the name, “Connectivism”) and that the connections of those datasets are what students need to understand. Wikipedia is an excellent example for Connectivism as it provides millions of people with knowledge that they do not need to memorize.

Quite a few of the analysed games use Connectivism as an anchor and incentive to play them. Fold.it and CodinGame have challenges where the solution is made public and has a real-life impact. In the case of Fold.it, chemical solutions can be used in real chemistry and vice versa. There were instances of scientific breakthroughs reached through Fold.it community members working together and decoding a virus responsible for AIDS in monkeys (Boyle, 2011) or redesigned a protein used for computer catalysation (Eiben et al., 2012).

CodinGame uses a similar mechanic, where creative and exceptionally good solutions to community challenges are rewarded and made public.

2.1.2.3 Joyful Education

This learning model is often used among young children but can be expanded to other age groups as well. Joyful Education deals with the idea that pleasure and learning are not mutually exclusive, but, instead, that one can support the other. Scientific evidence seems to support the notion that information can be processed better in the brain while the learner is engaged, motivated and stress-less (Willis, 2007).
Key points of joyful education are the relevance of the provided information to the learner, positive associations, breaks and independent discovery learning. One of the main problems of this model is that its use for complex theoretical knowledge is very limited. At some point, information just gets too abstract and complex to convey it meaningfully via joyful education.

While it is inherently linked to game-based learning, most of the examples we analysed cannot be considered using joyful education as they usually feature the learning aspect more prominently without linking it to fun. The only analysed exception from this is Code Combat, a game that is rich in features, and ‘coding’ is just a small part of it.

2.1.2.4 Lateral Thinking

Lateral Thinking can mainly be described as a method to find creative solutions for problems which often cannot be solved via *Critical Thinking* (De Bono, 1967). Critical thinking requires the judgement of facts and statements to find errors (Glaser, 1942). In contrast, lateral thinking considers that problems have more than one way to be solved and more than one solution.

Lateral Thinking is not viable to use on any problems with predefined solutions, but it is a very useful tool for simulations and tasks that require students to think out of the box.

Especially in the analysed games Fold.it, CodinGame and Screeps, lateral thinking is strictly needed to progress: In the first two instances because there are simply no predefined solutions to the presented problems, and Screeps due to its MMO nature and the fact that other players will always try to find creative ways to infiltrate or attack the player.

It is, however, notable that this concept has been under criticism by psychologists as it clashes with other psychological models and does in many ways not meet scientific standards (Weisberg, 1993).

2.1.2.5 Self-determination Theory & Intrinsically Motivating Instruction

A psychological theory of human motivation behind choices they make with or without external influence (Ryan & Deci, 2000). It differs between intrinsic and extrinsic motivations, whereas intrinsic motivation stands for the inherent drive of humans to engage in behavior which is naturally satisfying to them and extrinsic motivation stands for any externally regulated behavior.

External motivations can become internalized and turn into intrinsic motivation. One edge case is the so called ‘integrated regulation’, a type of extrinsic motivation that shares many qualities with intrinsic motivation and is very prone to abuse.

In 1981 an equivalent learning theory related to digital games emerged, the *Intrinsically Motivating Instruction* theory (Malone, 1981). While it is a very specific model, focusing on the abstract key categories challenge, fantasy and curiosity, it combines many of the elements of the self-determination theory.

Most of the analysed games feature extrinsic motivations like challenges or a score system.

One interesting exception is Fold.it, a game that only rewards players with public commendation and is frequently advertised as a game which enables players to make the world a better place through playing.

X-Plane 10 plays on a similar, more personal level and offers players an exceptionally big variety of customization and modding functionalities. It therefore enables players to reach self-actualization through this game.

Cell Lab uses a similar method. It does only feature minor rewards in the game like unlocking new functions, but one of the main reasons for players to play this game is the intrinsic motivation to educate themselves about evolution and microbiology.

2.1.3 Game-based Learning & Gamification

Game-based learning and gamification are two models introduced in recent years. While similar, there are some distinct differences which will be evaluated here. Since the term *game* has not been fully defined, those two theories are still being researched and iterated.

However, most scholars conclude that games for education need to be designed in a matter to include the subject but prioritize gameplay. This features a problem, as the design of an interesting game usually does not coincide with the requirements for effective learning (Kelle et al., 2011).

Gamification and game-based learning solve this problem in two different ways: While gamification usually *adds* gamified aspects to an existing task, game-based learning redesigns this task by using rules of play and artificial conflict to engage players (Plass et al., 2015).

This is very well displayed in the analysed games, where some of them fall more into the gamification area (X-Plane 10, World without Oil, MathiSiS, Hazmat: Hotzone, Gaming through Government, Kahoot!), others employ game-based learning and are therefore *serious* or *educational games* (Fold.it, Sharkworld, Simport, Cell Lab, Code Combat, Lightbot, Human Resource Machine, 7 Billion Humans, Screeps, CodinGame).

For a prototype, it needs to be decided whether to create a platform that supports gamification, game-based learning or both. Game-based learning has a significant impact on engagement and retention and is especially suited for teaching specific, complex topics (Findlay, 2016). Gamification, however, is often cheaper to implement, as no new content needs to be created. However, as it

provides less engagement, it is mainly suitable for simple topics and memorizations. Major behavioural changes as in the transformative learning theory are hard to implement via gamification (Findlay, 2016).

2.2 Gamification Methods and Game Mechanics

The analysed games used multiple gamification methods to combine learning and games. While some of those methods are also very prevalent in non-educational (digital) games, others are exclusive to serious games.

It will not be dissected which games feature which mechanics unless this is an important contextual information.

2.2.1 Rewards

Most of the analysed games except the simulations (X-Plane, World without Oil) have winning conditions and similar markers of success which the player can use to compare himself to other players or an abstract benchmark. Rewards are one way to implement positive reinforcement as described in *Schedules of Reinforcement* (Skinner & Ferster, 1957).

One of the easiest methods to produce this is a score system. When players perform actions which indicate that they are progressing and learning, they gain (experience) points. Those points can be used in high scores for the player to analyse his improvement or in leader boards to compare himself to other players.

The same mechanic can also be used for levelling up – After the player has gathered a certain predefined amount of points, he gets a reward. In case of educational games, this reward can be abstract (badges), digital (in-game items) or physical (e.g. reduction of homework).

Video games are the only medium that restrict players from accessing content if they fail to complete its challenges (Freyermuth, 2019), which means it can also be a reward for the player to unlock the next piece of content.

Many educational games make the mistake of having completely unlocked content in form of mini-games and hints, which leads to a much lower engagement rate, indifference and anxiety (Chanel et al., 2008).

This unlockable rewards / game content can also include customization and cosmetical items but should in any case have consequences on the gameplay.

Figure 11 - Screenshot from the Game Dungeon Boss (Boss Fight Entertainment, 2015)

2.2.2 Social Features

In non-educational gaming, social features are on the rise as they provide a low-cost method for marketing. However, they only work successful if the game itself is already engaging (Chartboost, n.d.).

Social features like co-op modes connect players and can be useful in environments where players have easy means of communicating, like a classroom.

Figure 12 - Puzzle & Dragons Friend list (GungHo Online Entertainment, 2012)

In their simplest iteration, social features just provide an in-game way for players to progress in the game with each other's help. This can be accomplished via dedicated groups, chats and a strong

community. Sharing of accomplishments as introduced in the former section can improve academic performance, raise engagement and increase a sense of teamwork (Shan et al., 2014), a soft skill that is necessary in most aspects of education and working today.

Students can also use social features to increase the learning effect by collaborating. This could lead to a network as imagined by Siemens (2005) in his model of Connectivism, where students gather knowledge together.

2.2.3 Player-Created Content

User-generated content is another way to increase engagement (Tint, 2016) which also has multiple applications in learning environments. Per definition, it is any content that is created and published by users outside of professional boundaries and practices (OECD, 2007). This includes mods, video clips, tutorials, streams and more. It usually requires the player to be self-initiative and create content outside of the intended interactive game space.

User-generated content often animates other players to interact with this content within the frame of the game, as a game modification. This raises possible engagement and playtime, as there is more content for players to explore. Additionally, players that create their own content often promote this content outside of the game community and might draw in more players (Tint, 2016).

In education, user-generated content needs to be implemented as teachers need to have the possibility to create their own courses and have a lot of freedom in doing so, as a developing team does not necessarily have the possibility to cater to niche subjects.

2.2.4 Objectives and Conflict

While section 2.2.1 deals with the feedback the game gives to the player, this section will introduce the thematic of challenges and conflict as obstacles to overcome if players want to earn rewards. Any game needs to provide artificial conflict. In digital games, those conflicts often come in the form of quests, levels, stages or challenges. In multiplayer games, competition alone provides a challenge, while in simulations players need to create their own objectives.

It is important to distinguish that not every challenge or even every game needs a rewarding system after reaching objectives. For example, especially in the beforehand mentioned simulations objectives are often created by the player himself and have no in-game counterpart. Reaching an

objective can be a reward in itself and therefore provides an ideal example for intrinsic motivation and self-actualization.

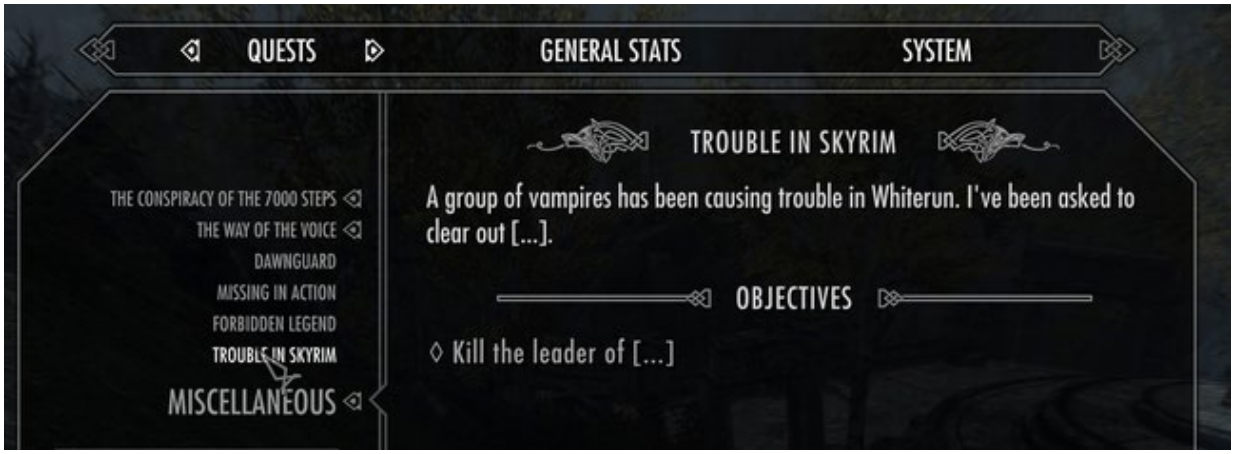

Figure 13 - Skyrim Quest Log (Bethesda Game Studios, 2011)

For artificial conflict to emerge, a game needs an objective, rules and a quantifiable outcome (Salen & Zimmerman, 2003). So, players need to know what goal to reach, they need to know how to reach it, what limitations the game world has and they need to know when they won or why they lost.

A simple example would be a game like Tic-Tac-Toe. Two competing players need to alternately draw their icons into empty cells of a 3 by 3 grid and the first one to connect a line of 3 own icons wins. The goal is simple ("Draw 3 icons next to each other"), the rules restrict players from winning easily ("Players have to draw alternately", and "Players can only draw one icon at once", "Players have to use empty cells") and provide the challenge, and only one player can win.

This provides the game with fun, but once players find a way to circumvent rules (drawing their icon in the middle cell to deter the other player to get a row), the game is not fun anymore, as the challenge is gone. Humans tend to optimize any problem solving, even if it makes the game less fun for them. In digital games, this can lead to grinding, griefing or cheating, and is undesired by the developer (Freyermuth, 2019).

A specific type of challenge is a *timer*. Timers restrict the player and make the game harder. They essentially add another constraint to the game. In an educational context, they also provide a different angle for evaluation, as all players start with the same conditions.

Other types of conflict found in the analysed games were daily challenges, which do not have a timer per se, but can only be attempted over the course of one day. They animate players to return daily

2.2.5 Customization

Comparable to user-generated content, customization is an approach for the player to create a permanent personal impression on their game. Opposed to user-generated content, customization is streamlined and intended by the developer (Bycer, 2018). Therefore, it does not exceed the game frame.

Figure 14 - Personalization options in Miitomo (Nintendo, 2016)

Customization has proven to increase player satisfaction, return rate and enjoyment rate (Turkay & Adinolf, 2015). It also allows the player to be more autonomous, which leads to positive associations with the game and a sense of competence. In this regard, it does not matter whether the customization aspect of the game has a direct impact on gameplay or not.

An important subcategory of customization is *Personalization*. Players that have access to personalization aspects in their game have a higher rate of identification and empathy. This can lead to a higher player engagement, motivation and enjoyment (Turkay & Kinzer, 2016). It is important to connect personalized aspects of the game with positive associations (Kao & Harrel, 2016), e.g. by not showing the personalized avatar on the game over screen, but to show it on winning screens.

2.2.6 In-Game Resources

In-game resources are primarily all the digital objects players need to collect in order to progress in the game. While it is an optional point in gamification, it can help the player define a goal and link in-game and other tasks. Carefully managed, items and resources can also be used to channel or streamline the gaming experience and alter the difficulty.

There are two types of in-game resources. The first one, items and resources, have a direct impact on the game and can be actively used by the player to progress. They directly unlock new functions - Examples for this could be a shovel that can dig, or a key which opens doors.

The second important resource is in-game currencies. Players can use them to unlock further content in the game, but they usually do not have any direct impact on the mechanic. The amount of a currency a player has does usually not affect his gameplay. Experience points are not a resource unless the player can, for example, actively decide between different skills by spending them.

Both types of resources can be used as rewards by the game to increase player engagement. In gamified applications without specified goals and simulations, players can also set their own goals, one of which might be to collect as much of the in-game currency as possible.

2.3 Learning Principles in gaming contexts

The next sections include a comparative analysis of gamification aspects and learning principles. The relationship between certain mechanics and the underlying didactic and pedagogic principles is explored and possible options for FLIP2G are derived.

2.3.1 Usage Models for Gamification

Different methods of gamification for digital learning experiences have been formulated by Sawyer & Smith (2008). Ten different ‘serious game pre-cursors’, different facets of applications which can benefit from gamification, were discussed by them, six of which are applicable in an E-Learning context.

The last two aspects are directly correlated to FLIP2G, as they deal with training, learning and education. The other aspects mainly deal with visual, audio and haptic feedback by the game and are viable for any serious game, not just in an E-Learning context. One of the main conclusions that

Sawyer & Smith come to is the fact that either of those aspects can be gamified with a purpose without having to gamify other aspects. This leads to an optimal exploitation of gamification without having to sacrifice any functionality of the application.

Table 1 - Serious Game models, adapted from Sawyer & Smith (2008)

Aspect	Purpose of Gamification	Advantage of Gamification
Simulation	Merge in-game approaches to visuals, interface, rules of play, and fidelity of model	Increase of exposure impact and improvement of accessibility
Visualization	Use visual technologies and techniques from games to create new forms of visualization and more accessible versions of visualization	Improvement of accessibility, engagement and relatability of the player
	Allow for higher levels of interactive visualization where user actions might affect resulting visualization	Visualization as an ingrained part of the gamified experience
Interface	Non-standard but highly symbiotic interface design produced often for games applied to other applications	Recognition value for users, as well as an encouraging, non-intimidating atmosphere
	Approach of making interaction with application “fun”, using concepts from gaming often associated with games	Improvement of accessibility, engagement and relatability of the player
Authoring & Production	Use of game elements to output some other result additional to in-game achievements	Improvement of accessibility, engagement and relatability of the player, lower entry threshold
Training	Add gameplay to enhance motivation to train, or effectiveness of content transfer, behaviour change, or specific goal of training	Contextualisation, additional goals, higher engagement and improved learning outcomes
Education & Learning	Using gameplay to enhance motivation to learn, engage education, or other specific learning outcome	Enhanced effectiveness of content transfer or other specific learning outcomes

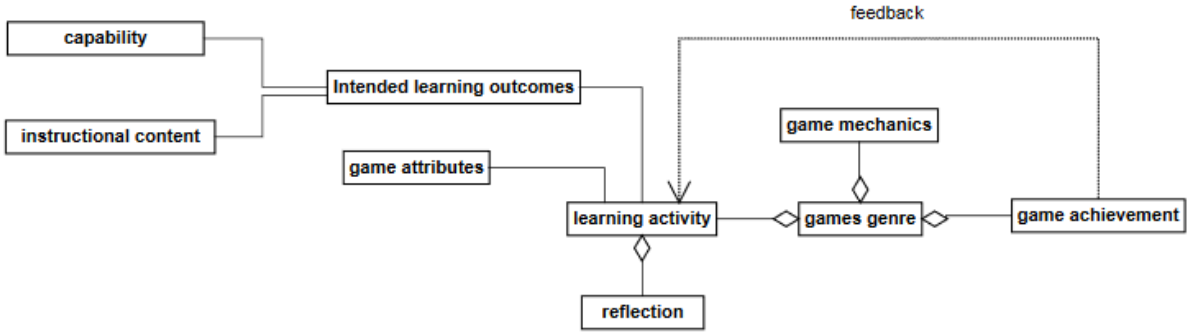

Figure 15 Conceptual Framework for Serious Games shown as a Structural Class Diagram (Yusoff et al., 2009)

2.3.2 Game Genres & Learning Principles

Figure 15 shows the relationship between different facets both from a learning and from a game perspective. One notable aspect is the fact that while genre and learning activities are directly linked, the cognitive processes behind learning can only indirectly be influenced by the game experience itself.

One important measure for this are achievements, i.e. means of the game to give feedback to the player. Students will quickly associate positive and negative feedback on the game progression with learning outcomes, if feedback and progression are linked meaningfully.

Following this framework, it is evident that the instructional content needs to be relatable to the genre, mechanics and achievements of the game, while the narrative is playing a minor role and will briefly be discussed in the next section.

As can be deduced from Table 2, most of the evaluated games are either puzzle or simulation games. Especially simulations are a viable approach for students to practice lateral thinking, as they do not provide a predetermined winning condition, but instead a realistic framework that aims to emulate the real world in a model over long-time operation (Oxford English Dicitionary, n.d.). Puzzles can serve a similar purpose if they are designed appropriately and compel the player to be creative.

Both puzzle and simulation games are useful to learn and improve problem solving skills (Wilson et al., 1990). “Trial and Error” practices, which lead to a reduced learning rate, are usually not viable for players due to the amount of interactive options those types of games provide.

Table 2 - The examined games and genres

Game Title	Genre
Screeps	MMO RTS
Foldit	Puzzle
MathiSiS Project	Puzzle
Cell Lab: Evolution Sandbox	Puzzle
Lightbot	Puzzle
Human Resource Machine	Puzzle
7 Billion Humans	Puzzle
Kahoot!	Quiz (Platform)
Gaming Through Government	Quiz , Puzzle, AR
Code Combat	RPG
CodinGame	Shooter
World without Oil	Simulation (ARG)
Simport	Simulation (Construction)
Hazmat: Hotzone	Simulation (Emergency)
X-Plane 10	Simulation (Flight)
Sharkworld	Simulation (Management)

Therefore students are forced to reflect upon their actions and develop a strategy while playing. Other methods to counter this type of practice can be found in the *Reflective Practice* model that gives students the time to reflect upon their own progression and to adapt their strategies under supervision.

Puzzles also often repeat similar problems in an increasingly difficult manner, and are therefore excellent in elaboration theory scenarios and spaced repetition under guidance.

The analysed quiz games focused around multiple-choice questions that players need to answer playfully. It is useful for recalling learnt information and testing students, and analytics can be combined very well with quiz games as they provide a strict, clear data set. However, quizzes lack in practical application of theoretical content. Especially in a flipped classroom, this can lead to complete absence of practicing. It is therefore advisable to add quizzes for enhanced analytics, but only as a method to assess students, and not to teach new content.

The other analysed games are an MMO RTS (Screeps), an RPG (Code Combat), and a shooter (CodinGame) - all three games teach coding. They require strategy and careful planning, and since

the player can code anything he wants, have no fixed solution. In that regard, they also promote lateral thinking.

2.3.3 Narrative, Storytelling & Learning Principles

As already mentioned, the narrative of a serious game is not necessarily a defining factor for its use (Yusoff et al., 2009). The analysed single-player games like Human Resource Machine focus more on narrative, and multiplayer games and simulations have a weaker narrative and a stronger ludic component.

A strong narrative and good storytelling can be more engaging, especially to players that are not intrinsically interested in the taught subject, as they can focus on aspects of the story that is interesting for them. Ryan (2004) thus underlined that many educational games focused too much on the mechanics to the detriment of storytelling, essential for the engagement of the player.

Humans also have an easier time learning if they have an applied context for the content they are learning (Yam, n.d.). Especially in topics that have an application in real life this could prove as a big factor. However, a real-life application can also take place on a smaller and more abstract level, as the game Sharkworld proves. Project managers from all areas and industries are expected to play as an aquarium architect.

Disadvantages of putting the narrative in the foreground are the possible distraction of the student from the learnt subject as well as a discouragement for players not interested in the chosen narrative – Someone scared of sharks might not want to play Sharkworld or learn efficiently from it. This is solved by improving the storytelling and, for example, giving optional narrative context for the player. One example of this would be the game *Bioshock* (Levine & Hellquist, 2007), where players can find radio snippets in the game world and choose to listen to them to get a narrative context.

It is also very important that not just the narrative, but also delivery and storytelling is well executed. This means that a game with a strong narrative element requires more developing resources, which should be weighted in case of an assessment.

2.4 Recommendations

2.4.1 Application of Gamification

First, it needs to be decided whether to develop a gamified app or a game-based learning app. *Gamification* refers to the creation of an app that is enhanced by game-like elements to a degree that it might even be recognizable as a game. *Game-based learning* refers to the development of a synergetic gaming and learning app. While it usually features better engagement and a better application of both game development and learning models, it also requires more resources and a more thorough cross-disciplinary development.

Additionally, the depth of narrative needs to be decided. As a general recommendation, narrative did not seem too decisive in the analysed games and should therefore be implemented it necessary, but not imposed.

A multiplayer is recommendable and should be implemented in the game. Finally, it should also be modular and feature different time restrains to enable teachers to organize and develop their own content.

2.4.2 Application of Learning Models

The most important inference taken from the analysis of pedagogic models is that especially other constructivist theories fit well with FLIP2G, PBL and flipped classroom models.

Extensive tutorials and introductions, the necessity of students to adapt their strategies while using the same tools, a healthy amount of abstraction and the constant reminder of previously learnt content (and integration of this into the newly learnt content) are the key pillars of developing a game-based learning app.

3 User Requirements

User requirements are defined as the essential conditions that users require to play a game. In case of FLIP2G, they need to be fulfilled in order to create an engaging game-based learning app. Technical requirements are based on user requirements and will follow in Chapter 4. Technical Requirements.

For the FLIP2G project, users will be divided into two groups with different requirements: teachers and students. Both groups have different interfaces and functions in the app and therefore require different functions.

A code will be assigned to each requirement and, consecutively numbered, displayed in brackets following this scheme: [XX01], [XX02]… . Optional functionalities will also be listed as following: [XX03o]. Those codes will be summarized in a table at the end of the chapter.

3.1 Status Quo

This section aims to recap the context in which FLIP2G is developed based on the project proposal and include the current status quo of development and research. Overall objective of the project is to jointly create a pedagogical model that combines flipped classroom, PBL, gamification and data analysis. This includes the development and design of a (simulation-based) serious gaming application in a 3D environment.

Messaging functionality, tips and hints, and collaborative tools need to be part of this application as the synergy between those functions and game-based learning is to be explored in FLIP2G. Additionally, a course structure is developed that is supported by this application. This model needs to be transferable into different disciplines, mainly in the STEM fields in secondary and tertiary education. All this needs to output enough data, that can be analysed by the analytical tool.

3.2 Teacher Requirements

Teachers are the instructors who conduct the course and introduce the game. They are usually tutors, instructors, professors, lecturers, supervisors, coaches, parents or trainers. Due to the diverse background of these groups, it cannot be anticipated whether a teacher has technological knowledge and to which degree.

Teachers can be of any age, gender or social and geographical background, but what connects them is the fact that they are knowledgeable in the topic they teach and that they need to understand and interact with the game to teach students their knowledge.

The objective of a teacher within the scope of a course is to teach students the contents of their course. Therefore, it is important to show teachers that FLIP2G is a more efficient, convenient method than traditional teaching.

3.2.1 Content Creation

Teachers need to be able to change the content of the game [TR01], based on the class they are teaching. Additionally, they need to adapt the difficulty for whole classes as well as for single students or groups of students [TR02].

Those actions need to be performable live [TR03], in case students are struggling or mistakes were done during preparation. Teachers need to be able to give hints [TR04] or enable and disable general help [TR05] for students. In that regard, they also need to write and receive messages [TR06] to single students in case they need help or have a remark.

Uploading media is an integral part of learning for the students to receive visual and auditory input. Videos, images and sounds should be uploadable [TR07] and integrated into the game. It could also be possible to create a functionality where teachers can upload datasheets for questionnaires [TR08o], depending on the context and timeframe.

To simplify and accommodate class preparation, the game should be modular with short tasks [TR09o]. Since FLIP2G adoptes the Flipped Classroom approach, the game needs to be ideally integrated into the course, and the length of each gaming session needs to be precisely determinable by the teacher. Therefore, an (optional) timer needs to be available [TR10].

3.2.2 Convenient User Experience

As already mentioned, teachers do not necessarily have a technological background. The user interface and the entire user experience needs to be usable out of the box [TR11] for teachers to adapt to this new teaching style. One way to reach this would be emulating known interfaces [TR12o] (e.g. from programs regularly used in education) to maximise convenience.

There should be an extensive tutorial covering the basic mechanics of the teacher interface and the game [TR13]. Every item on-screen needs to be explained, e.g. via a tooltip [TR14], and existing scenarios or a tutorial scenario show the teacher how to interact with the interface [TR15o]. Additionally, there should be a search function [TR16] as well as extensive documentation [TR17o] for teachers who need to look up specifics.

As teachers often hold their classes in lecture rooms with whiteboards, beamers or screens, those assets could be usable in some way, without requiring a long setup or additional hardware [TR18o].

3.2.3 Analytics & Student Evaluation

Teachers need to be able to check, track and observe a student's progression as well as his engagement [TR19]. This could be visually displayed in charts and diagrams [TR20o] as well as exportable tables [TR21o]. Whenever a student falls behind, a notification should warn the teacher [TR22].

Teachers need to compare different students, classes, and historical data with each other [TR23] to optimally supervise students. They also need to group students either under predefined groups [TR24] or be able to create new groups [TR25], for example for new courses or team work.

3.3 Student Requirements

Comparable to the teacher user group, students are a very broad, diverse target group. While they are usually younger than teachers, they can be of any age, gender or background. Especially high schoolers and university students are in general more tech-affine than their educators (Reaney, 2013) and it can be assumed that the majority of students has at least some gaming experience, with more than 60% of people aged 29 or younger playing video games (Duggan, 2015).

Students targeted by FLIP2G can broadly be divided into three subgroups:

- **University students**, who play education games as part of their courses. They are a very diverse group, consisting mainly of young adults that are generally proficient in technology usage and gaming. Courses can be any size and reach more than 1000 students.
- **Secondary education students**, i.e. middle and high school students. Their age ranges between 12 and 19 years, and they are highly proficient in smartphone use. Class sizes are

usually 20 – 30 students, and their societal background is usually relatively homogenous within a class.

- **Business trainees** are professionals from any industry and background who are highly specialized in their field and want to expand their knowledge through further education. They are usually highly motivated but may lack knowledge in further areas.

3.3.1 Engagement

A higher engagement rate from students is the main advantage of teaching through serious gaming. While that higher engagement rate stems from entertainment and pleasure, a perceived learning progress raises motivation of students (Amabile & Kramer, 2011).

While progressing in real life, this process needs to be reflected in game as well, for example via a mechanic where students can visually see their progress. In a gamified way this would be achieved through levels, achievements and scores [SR01], in a non-gamified way visualization would take place through charts, tables and diagrams [SR02o]. Ideally, both options are implemented.

3.3.2 Progression & Social Features

Unlockable content and progression are important factors in serious games. As discussed in section 2.2.1, social features enable students to interact with each other while learning from home, show their progress and raise the engagement rate.

Players need to be able to customize their experience [S03], for example through an avatar [S03o]. For this, user accounts and data saving are needed [S04]. They also need to be able to compare themselves with other students. However, due to data regulations and personal preferences this should be an optional functionality [S05]. A viable option might be to just show the class average or only a student's individual position in the class leader board [S06o].

The chat used for interaction with the teacher should also be usable for inter-student communication [S07]. A friends list [S08o] could make it easier to pair students as well as giving them the option to display their scores exclusively to their friends [S09o]. Especially in big, anonymous classes, this could prove to be feasible for creating a community and strengthening each student's own knowledge.

As an applied example of *Connectivism*, student-generated databases could be implemented [S10o]. Student groups can work on documents jointly, for example when taking notes during lectures [S11o] and presentation [S12o]. Searchable hashtags or links can be a suitable way to connect data points, essentially creating a wiki system [S13o].

3.3.3 Feedback Options

Feedback and evaluation are crucial tasks in this project. Therefore, any feedback infrastructure devised during the development of the application and used in quality assurance (e.g. in WP7) should be fleshed out enough to be usable in the final iteration of the application.

In traditional classes, students often feel like their feedback is not valued or they do not even have the technical functionality to give feedback. Changing this could be integral to the adaption rate among students. Students should be able to give feedback to teacher input [S14o] as well as to developers [S15o], to the latter especially in case of bugs.

In case of a digital implementation of feedback options, there should be different privacy options to guarantee anonymity if wished [S16o]. If a digital implementation is not wished, handouts or teacher instructions created by the consortium could be a viable alternative [S17o].

An immediate feedback option during playing could lead to more precise and sincere responses [S18o]. However, a possibility to return later and formulate feedback after class should be implemented if the schedule or course does not allow immediate feedback [S19o].

3.4 Game Modes

The following section will examine the used game modes in the analysed games from section 2.1, as well as other game modes applied in serious games that might be useful to evaluate in this project.

In the initial project outline, a simulation-based learning application was conceptualized. This, however, does not exclude cross-genre game modes. Sharkworld and Gaming through Government, for example, are simulations which also contain multiple choice quizzes, World without Oil is a simulation as well as an ARG and X-Plane 10 offers a lot of functionality outside of being just a flight simulation.

3.4.1 Text-based Game Modes

Non-text-based game modes and genres were analysed in section 2.3.2. However, while discussing possible adaptions for FLIP2G, text-based game modes were often mentioned by consortium members as they have multiple advantages against other genres due to their limited rules sets and clean data outputs.

Different game modes as proposed by members of the Consortium were:

- Quizzes & Multiple Choice / Multiple Response

  Quizzes were already evaluated in section 2.3.2 and suit well for recalling learnt information. Players get a question displayed and either need to answer it by typing in the right answer or by selecting the right answer from a multitude of answers (“Multiple-Choice-Quiz”).

  Another advantage of quizzes is the fact that they are easy to create, follow structures that could be implemented via data sets, and are easily gamified. However, if quizzes will be the sole mechanic in the game, it might not be appropriate for all educational content due to their limitations. Additionally, the market already stars a very big competitor with the gaming platform *Kahoot!*.

- Matching / Drag & Drop

  Matching data, as opposed to quizzes, does not require any text input and is therefore highly convenient for mobile players. Players see multiple statements and need to connect the ones which belong together.

  It is quick to play and could be used at the end of lessons to recall the content from the session. However, as it does not involve any creative input by the player, a game experience only with matching quizzes is not advisable.

- Filling in Blanks

  A sentence with one word missing is displayed to the player who needs to either type the answer in or select it from a list of possible options.

  This game mode is easy to adjust in difficulty and especially useful for younger students. However, on mobile it might be counterintuitive to write longer texts. Like quizzes, this

game mode only forces players to reproduce what they have learnt without requiring any reflection on the topic and is therefore unsuitable for creative tasks.

- True / False Statements

  Similar to the already discussed game modes, true and false statements feature an even stronger simplification of content as they only require students to input yes or no statements to a question.

  This oversimplification could lead to a lower quality of the collected analytical data as students could guess the answers without actually learning it. To see whether questionnaires with true / false statements are feasible, additional research will have to be conducted.

All those game modes share the fact that they can easily be tracked and compared. As there is only a predefined amount of right answers to each solution, a student that has learnt all the content from class will excel in those types of questionnaires. It is nonetheless important to clarify that any creative work, thinking outside of the box, soft skills, teamwork, and any type of applied, contextual and situational learning is not rewarded in those game modes. Therefore, if they are implemented in the game, complementary game mechanics for those activities should be developed as well.

3.4.2 Multi- & Single-Player

Based on the conducted research as well as the input of consortium members, it is evident that multiplayer options should be implemented in the game. Multiplayer tasks can be distributed via matchmaking, random algorithms or personal preference of the students, i.e. through their friend list.

A multiplayer game can be competitive, to incite students to compete, or co-operative. Especially on a co-operative level, it has been proven that mixing students of different skill levels and encouraging students to teach each other improves knowledge of both the mentor and mentee (Sawyer & Smith, 2008).

Due to teacher requirements as well as possible homework or courses with a small student count, single-player modes could be implemented as well. Both modes could be extended to have optional content for students who wish to study at home without pre-empting.

3.4.3 AR, ARG and VR

Augmented reality, alternative reality and virtual reality are three technologies to connect game content with the real world. For an educational game, they can be especially interesting as the learnt content already provides a textual link to the real world. Therefore, an educational game that aims to make use of AR, ARG or VR can use this content as a base and create a mechanic woven around it.

Of the analysed games, three had AR/ARG elements, namely *World without Oil*, *Gaming through Government* and *Hazmat: Hotzone*.

Hazmat: Hotzone utilizes AR elements in a practical approach to instruct emergency personnel on how to act in hazardous situations. The advantage of this method is that it gives realistic sensory input to trainees (fire, smoke, actors) while they practice countermeasures in a safe environment (Shell, 2002). Any theoretical or only digital method of teaching would not be sufficient, as it would provide trainees only with theoretical knowledge.

World without Oil is an ARG game with a holistic approach. It works in a way as if the world we live in is completely in the game world, i.e. in an alternative reality

This is an excellent utilization of its objective, to educate people on oil usage and pollution, by showing a simulation where those two factors escalate compared to our real world. While World without Oil might not serve as a direct inspiration for the upcoming game project, it should serve as a good reminder on what is possible if narrative, educational content and game mechanics are interconnected and dependent on one another.

One feature, which both games and many other AR/VR games share, is the fact that they need additional hardware and engagement to work. This might prove as a problem since additional setup time and more required tools could lead to a lower adaption rate by teachers.

Gaming through Government uses yet another method of AR. Students can access the website[1] and receive missions which compel them to find data on other websites, for example official American government websites. This innovative method of using AR does not require any additional hardware

[1] http://gamingthroughgovernment.weebly.com/

or installations. Students can access both the website and other required data sources through any device. The main disadvantage in this method lies in using resources.

When implementing those technologies, it should be ensured that they are convenient to use for teachers and students, that they do not need additional (expensive) hardware or additional engagement by users. In this case, useless complications of easy tasks constitute as “additional engagement”, e.g. in some cases drag and drop can be replaced by jus tapping the right answer.

4 Technical Requirements

For the requirements discussed in Chapter 3, a technical framework needs to be created. It should comprise the following items.

4.1 User Interface(s) / Frontend

The user interfaces need to be asymmetrical to provide the teacher with more information and options and the students with the game content. Three outputs (teacher, student and an optional displaying device in class) can be considered when developing the game.

The teacher interface needs to be usable via PC, and should optimally be web-based [TeR01] to enable an easy login from different computers. It should furthermore be convenient to use while displaying all the necessary analytical data, documentation and a search function. It should be usable out of the box without a long setup, registration process or log in.

The student interface needs to be supported by different devices and should be web-based as well [TeR02].

4.2 Social Requirements

Social functions are integral to the success of this project. Chat and group functionalities need to be implemented and adapted to the different needs, for example an asymmetrical chat for teachers and students or public chats for groups. In this context, a friends list is also required.

In case of a multiplayer, special measurements need to be taken to ensure the connection of the multiplayer and social features. Feedback options, leader boards [TeR03o] and high scores [TeR04o] need to be integrated as well.

4.3 Backend

Analytical data needs to be saved and analysed by an algorithm, which can display data, compare it [TeR05] and mark outliers [TeR06]. An SQL Server is necessary for that [TeR07].

Data uploaded by teachers as well as by students needs to be saved in a resource-efficient way. An automatic deleting function after some time or after the end of the course could be useful in this regard [TeR08o].

Additionally, a matchmaking algorithm for multiplayer should be developed [TeR09o].

5 Conclusion

This report documents the work done in regards of requirements and functionality for connecting gaming environments with pedagogic methodology. The identified requirements can be found in the following sections. Additionally, the findings from section 2.1 should be kept in mind when developing the application and the adjacent pedagogic methodology.

The focus of this project lies in constructivist theories, enabling students to learn in a creative, self-determined environment. The different target groups have surprisingly similar needs and developing a gamified app for all the targeted groups is a feasible, reachable goal. Inspiration for the content of the app can be drawn from the analysed games, which mostly feature puzzle, simulation and quiz games. The next step is creating a structural outline for the project – both in the classroom and in the digital parts - and expounding the connection between those two areas.

5.1 Teacher Requirements

Table 3 Teacher's Requirements table

No.	Requirement
TR01	**Change the content of the game**
TR02	**Adapt difficulty**
TR03	**Perform TR01 and TR02 live**
TR04	**Give hints to students**
TR05	**Enable and disable help for students**
TR06	**Write and receive messages to single students**
TR07	**Upload different types of data (videos, images, sounds)**
TR08o	Upload datasheets for questionnaires
TR09o	Assemble the game from predefined modules
TR10o	(De-)activate and adjust an optional timer
TR11	**Uncomplicated UI & UX**
TR12o	Emulate interfaces teachers are familiar with

	TR13	**Interface Tutorial**
	TR14	**Tooltips for on-screen items and buttons**
	TR15o	Pre-built game scenarios
	TR16	**Search function**
TR17o	Documentation	
TR18o	Utilization of additional hardware commonly found in class rooms	
TR19	**Track, check, observe student engagement and progression**	
	TR20o	Display in charts and diagrams
	TR21o	Export of data
	TR22	**Push up notifications**
	TR23	Comparison of data
TR24	**Group students**	
	TR25	**Create new groups**

5.2 Learner's Requirements

Table 4 Learner's Requirement table

No.	Requirement	
LR01	**Link their in-game process and learning progress**	
	LR02o	Visualize their learning progress
LR03	**Customization & Personalization options**	
LR04	**Save data**	
LR05	**Compare each other (e.g. through leaderboards) [optional]**	
	LR06o	See their position in course / overall average
LR07	**Chat between peers**	
	LR08o	Friends list
	LR09o	Display and share their scores with peers

LR10o	Student-generated databases	
	LR11o	Joint note sheets for lectures
	LR12o	Slideshows & Presentations
	LR13o	Tags & Links between documents
LR14o	Teacher feedback options	
	LR15o	Developer feedback options / Bug reporting
	LR16o	Privacy options for feedback
	LR17o	Handouts & instructions for teachers for analogue feedback
	LR18o	Immediate feedback
	LR19o	Delayed feedback

5.3 Technical Requirements

Table 5 Technical Requirements table

No.	Requirement	
TeR01	**Web-based solution for teachers**	
	TeR02	**Web-based solution for students**
TeR03o	Leader boards	
	TeR04o	High scores
TeR05	**Save & Compare data**	
	TeR06	**Find outliers**
	TeR07	**SQL server**
TeR08	Automatic delete function	
TeR09	Matchmaking algorithm	
TeR10	Learning Analytics Data Storage	
TeR11	Learning Analytics generation	
TeR12	Learning Analytics Visualization Methods	

5.4 Learning Analytics Requirements

Table 6 Learning Analytics Requirements

No.	Requirement
LAR01	**Machine Learning Algorithms for Predictions and Interventions**
LAR02	**Learner-Based Personalization and Recommendations**
LAR03o	Learner-Based Adaptation and Customizations of Study Material
LAR04o	Learning Output for Learner-Centric Mentoring
LAR05	**Continuous Formative and Self-Assessment Systems for Guidance**
LAR06	**Visualisation of the Ongoing Process, Achievements and Comparison**

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