Immersive user experience solutions in higher education

ZSIGMOND IMRE

Supervisor: Prof. Dr. PÂRV BASIL

Department of Mathematics and Computer Science
Babeș-Bolyai University

Summary

Table of contents

1 Research motivation **1**

1.1 Foreword and research goals . . . 1

1.2 Structure of thesis . . . 2

1.3 Original contributions . . . 2

2 Platform for gamification basic research **4**

2.1 Game mechanics used in education . . . 4

2.2 Gamification workbench . . . 4

2.2.1 Solution description . . . 4

2.2.2 Automated evaluation technical details . . . 5

2.2.3 Towards the first experiment . . . 6

2.3 GamifyCS: first case study . . . 6

2.3.1 Study description . . . 6

2.3.2 Data analysis . . . 7

2.4 GamifyCS: Second study . . . 8

2.4.1 Study description . . . 8

2.4.2 Data analysis for second case study . . . 9

3 Incentives for mastery **11**

3.1 Digital badges in education . . . 11

3.2 Findings on use of digital badges in education . . . 11

3.2.1 Review procedure . . . 11

3.2.2 Badge types . . . 11

3.2.3 Reported results . . . 12

3.2.4 Applications . . . 12

3.3 Awarding badges . . . 13

3.3.1 The need for badges . . . 13

3.3.2 Awarding algorithm . . . 14

3.3.3 Integration of digital badges and static code analysis in gamifyCS . . . 14

4 Advanced gamification techniques **16**
4.1 Introduction 16
4.1.1 Gamification personalization 16
4.2 Components 17
4.2.1 Gamification elements 17
4.2.2 Psychological Traits 18
4.2.3 Player types 18
4.3 Ontology to link gamification with traits 19
4.3.1 Metrics and formulae 19
4.3.2 Game rule formalization 21
4.4 Advanced UX: augmented reality use with gamification 22
4.4.1 Face detection 22
4.4.2 Skin conditions 22
4.4.3 Advanced UX: augmented reality solution and experiment 22

References **24**

Chapter 1

Research motivation

Keywords: Gamification, User experience, Automated evaluation, Experimental design, Data analysis, Static code analysis, Ontology, Augmented reality

1.1 Foreword and research goals

This Ph.D. thesis is the result of my original research, on the topics of immersive user experiences (UX) in the form of gamification, in computer science study. My work started in 2016 under the supervision of Prof. Dr. Bazil Pârv. The main objective of our research is the application of gamification techniques in higher education. To accomplish this goal we identified the following sub-goals:

1. Create and validate a gamification platform
2. Personalize the learning experience through dynamic gamification mechanics
3. Study the applied effects of gamification mechanics higher education

Our first sub-goal started by analyzing the literature, whereby the need for basic research was quickly identified. The gamification workbench platform was written, with successive experiments in mind. Created to be expandable, configurable, and metered. The main approach involved architecture and database design, web development, correctness check algorithms, and data analysis. For our research goals we were interested in studying instant feedback, and narrative gamification mechanics. Initially to compare them with the status quo. After that add well defined changes, design an experiment around it, analyze the data, then repeat for the best performing from the previous version and the new experiment.

Our second approach was concerned with exploring alternate directions for the use of gamification for improving UX. Our research goals involved exploration of the literature for future experiments on the main approach. As well as laying the foundations for a long term plan for the main approach to get to. Namely the personalization of education through dynamic gamification mechanics tied to the student's personality. Finally, as a third sub-goal we wanted to research the use of these techniques with other technologies, namely Augmented Reality. The second goal involved static code analysis, machine learning techniques, literature review, ontology creation, and augmented reality applications. Static code analysis integration was identified, and prototyped for use with the main approach. In parallel, an ontology was developed to link gamification to personality traits, and separately an AR solution was created to aid in disease study.

1.2 Structure of thesis

Chapter 2 contains a gamification workbench to conduct various experiments. The needs of the initial experiments was identified, and the initial correctness checker constructed, then the website was built with all the features required for the first experiment. Branching content of the OOP course material was created along with test scenarios. The first experiment pitted instant feedback and/or narratives against control, yielding conclusive support for our theory. The second experiment magnified the results of the first, all the while gathering data for our experiments and the ontology presented in Chapter 3.

Chapter 3 contains our literature review into the use of digital badges. 45 computer science papers reviewed, identifying types, results and applications. In continuation, investigation on how digital badges can be integrated to the system presented in the previous chapter was undertaken, concluding that static code analysis is required. Demonstration on how it can be integrated, along with machine learning techniques for badge generation, into the main application.

Chapter 4 contains the ontology created for linking gamification mechanics to two kinds of personality trait types. The goal of the ontology was to personalise the UX to user personality, and the mechanism for that is demonstrated. Further investigation on how it can be integrated in to the main application was concluded. The chapter continues describing an augmented reality application and study created to simulate pathologies on passers by to train medicine students in diagnosis by encouraging competition through the use of game mechanics.

1.3 Original contributions

The original contributions introduced in this thesis are contained in Chapters 2, 3 and 4 and they are as follows:

Theoretical contributions:

- Software architecture design for implementing gamification techniques, for computer science students [Section 2.2.1]
- Algorithm for evaluating software correctness through I/O manipulation [Section 2.2.2]
- Experimental design, and running first experiment on entire year of computer science students (200+) [Section 2.3.1]
- Data analysis of first experiment [Section 2.3.2]
- Experimental design, and running second experiment on entire year of computer science students (200+) [Section 2.4.1]
- Data analysis of second experiment [Section 2.4.2]
- Literature review of digital badge use [Section 3.2]

- Experimental design, for badge implementation and awarding [Section 3.3]
- Ontology for linking game mechanics to personality traits [Section 4.3]
- Experimental design, and running small scale experiment on use of AR application on medical students [Section 4.4.3]
- Game rule formalization example for use in ontology reasoning [Section 4.3.2]

Practical contributions:

- Implementation of proposed architecture [Section 2.2.2]
- Testing scripts for assignment verification [Section 2.2.2]
- Personalized graph based technical content creation for 5 narrative choices [Section 2.3.1]
- Plagiarism check POC for main application integration [Section 2.2.3]
- Static code analysis POC for main application integration [Section 3.3.3]
- Decision tree classifier for generating digital badges [Section 3.3.2]
- Functions for distributing students to UX based on student metrics [Section 4.3.1]
- Ontology POC for main application integration [Section 4.3.1]
- AR application for projecting pathology representations on faces [Section 4.4.1]
- Game mechanics for making the AR application more competitive [Section 4.4.3]

Chapter 2

Platform for gamification basic research

2.1 Game mechanics used in education

This chapter is dedicated to our work on the first and third research sub-goals. It details the development of the main gamification platform, and the implementation of the instant feedback and narrative gamification mechanics. It details the design of two mid scale empirical studies, the execution of the methodology, and the analysis of the data gathered.

Game mechanics in general are discussed in greater detail in Sections 3.1 and Section 4.2.1. The two used are instant feedback, implemented as automated grading, and narratives, as seen in the literature.

With the proliferation of gamification techniques used in the literature, a lack of basic research was noticed. A sentiment shared by [Dicheva et al. (2015)]. A systematic exploration of the paradigm was undertaken, by starting from the current best practices, and gradually adding new gamification elements, and comparing them to previous ones, validating at each step. This approach is in contrast to merely improving evaluation techniques [Chrysafiadi et al. (2018)]. The end goal is to explore the personalization of gamification mechanics to the student's personality traits. Our approach to this challenge was to make an gamification workbench, an online platform with configurability and expandability in mind.

2.2 Gamification workbench

2.2.1 Solution description

The proposed tool requirements to be both an assignment validator and a gamification workbench. The process in general starts with an upload on the student's part, the archive is saved locally on the server, extracted, cleaned, and prepared for anti-plagiarism checks.

The proposed requirements dictated most of our architectural decisions. A web site was chosen for easier accessibility, a website developed using ASP.NET MVC in C#. The site has a large number of pages dedicated to data management for teachers, mostly CRUDs, and a small number of student accessible pages.

2.2.2 Automated evaluation technical details

Instant feedback is one of the simplest ideas in gamification, it is also one of the hardest to do. Near instant feedback aids greatly in the learning process by mirroring the real world.

To achieve a fast feedback cycle, an automated evaluation platform had to be designed. Fully automating correctness checks, and exercise assignment was decided, and semi-automating anti-plagiarism checks. Having near instant feedback might not be technically achievable in the future, especially with certain gamification mechanics requiring static code analysis.

Correctness check for general problem solving could be its very own PhD thesis, and entirely out of scope for this one. To reduce the scope each assignment a student received, has well-defined input and output sequences.

For this tool to be useful it had to support multiple programming languages, so it can be applied for many courses and requirements. The solution was to be language agnostic from the code's point of view and just swap in different functions that had the job of dealing with specific programming language features.

Execution of the uploaded project was one of the central issues of automation on the project, while supporting several potential languages. During the experiments only the C++ instance was used, although it also was working for Python and C#.

From this point, on the correctness verification thread, source code is compiled and linked in the case of programming languages needing compilation, or supplied to the interpreter otherwise. Separate instances of the resulting executable are run for each test to ensure clean runs, while redirecting the standard input, output (`stdio`). Then test scenarios are evaluated, the instances closed, and results are saved to be displayed later.

For student exercises to be testable, requirements had to be clearly specified. In turn the tests are a set of provided input and expected output sequences. The expected output is usually a regular expression. Let us illustrate with an example before continuing to discuss the internals: one requirement of one of the assignment needed to catalogue old maps, the `add` and `display` console commands were specified to take the form:

- `add mapCatalogueNumber, stateOfDeterioration, type, yearsOfStorage`
- `list`

One test aiming to check the `add` command with a valid input, started with sending the application: `add 1234, used, geographic, 20`, then sent: `list`, finally the regular expression checking the output was: `.*(1234)*.*used.*geographic.*20`. Note, that the regular expression ignores any formatting the student might have added. After the first study, the student would have the possibility to expand the test result to see the full I/O log.

Support was added for longer scenarios with multiple expected outputs in sequence. A example would be for testing `delete`, in which an entry must be `add`ed first, then `delete` is called, and the output should check for the lack of the previously added entry. The tester needs to make sure that `add` is working first, or it would yield a false positive. The tester only signals success if all expected output regexes matched.

2.2.3 Towards the first experiment

Narrative is one of the strong suits of R.P.G.s [G Gygax (1974)], which is where some of the gamification mechanics in popular usage originate from. It aids in immersion, and gives a sense of purpose to solving exercises. If a group was selected for narrative, then they saw an alternate text for their assignments that took part of an overarching story.

The concrete implementation of narratives mainly took the form of displaying different texts, based on choices the student made, and displaying information at specific times.

Plagiarism check is one of the basic functionalities for teaching, that cannot be completely automated [Hage et al. (2010)]. A POC automatic uploader for the site was built, but due to teacher preference for an existing uploader it was never used.

User interface was specifically designed to be minimalist and responsive. The goal was to remove distractions and appeal to current generation's standards. Regarding the security precautions for the site: for login and authorization by role, standard ASP.NET MVC controls were used, which are deemed safe enough.

2.3 GamifyCS: first case study

2.3.1 Study description

Applied gamification entails a vast spectrum of options and strategies. The research question, on which our first study was based, is how does instant feedback and/or narrative compare to traditional methods. The experiment ran an entire semester of 14 weeks, with all 210 students being divided into 14 subgroups. 4 experimental settings were devised, with all combinations of elements, 3 subgroups for each experimental setting and 5 for the control group.

Students in subgroups with instant feedback could upload solutions, any time of the day from anywhere with internet access. Students in subgroups without instant feedback had to come to the faculty during scheduled laboratory hours, and upload solutions only in that 2 hour interval, otherwise upload was disabled.

Students in subgroups with narrative chose one of 4 narrative genres at the first laboratory they came to. The four were chosen by reading habits after some market research: Fantasy, Sci-Fi, Horror, and Mystery. After that, all assignment texts, including laboratory exams, formed a narrative of that genre. Students in subgroups without narrative received a random exercise to do, without much text besides technical details.

In the case of the current study, the more specialized approach of narrative writing that has been opted for was of a mainly diegetic nature. The infrastructure of our gamified course most closely resembled interactive literary fiction.

The students provided with gamification narratives were immersed in one of four diegetic cycles, in which progression would occur and results would steadily accrue according to their own progress during the semester.

In order to facilitate the assigning of these branching sub-paths to different groups of students, all cycles and their structure were modelled to resemble directed graphs. A representation of the directed graph can be seen in Figure 2.1.

The multiple "endings" which the students received at the end would offer closure, for both the narrative cycle and the respective course.

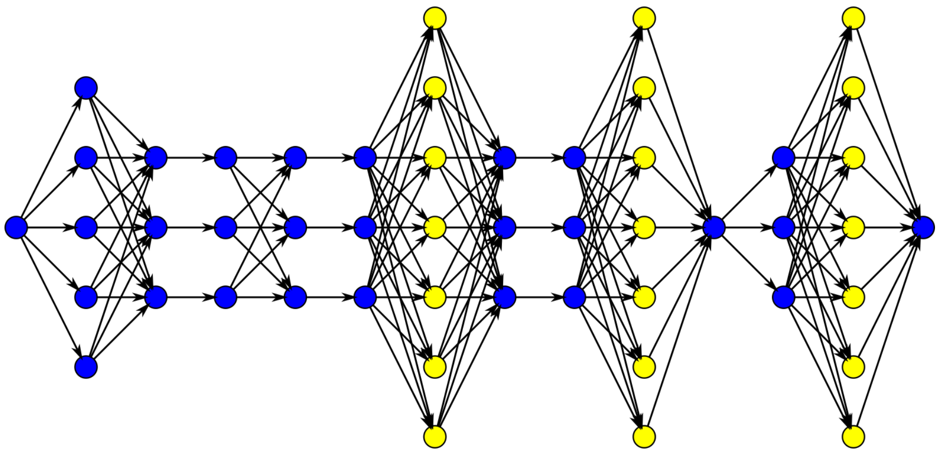

Fig. 2.1 Structure of the narrative progression.

Experimental group	Text Interesting	Text Clarity	A.T. for creation	A.T. for presentation	A.T. preferred
No Story, Instant Feedback	3.14	2.60	3.28	3.53	3.52
Story, Instant Feedback	3.63	2.26	4.10	4.32	3.90
Story, Late Feedback	3.58	2.48	3.19	3.39	3.55

Table 2.1 Centroids for survey data

To ensure comparability of assignments between narratives and to decrease workload, any particular assignment had a version without narrative and one for each of the 4 narrative types. Technically all versions were equivalent, and thus no groups had a harder or easier experience.

For each student, various data was gathered and anonymized before analysis. All uploaded solutions were stored, together with their time and test results. This allowed to check for engagement levels. A mainly Likert scale survey was conducted at weeks 4 and 12, with the same questions to gauge change over time. A couple of free form questions, in the second set of surveys to get more detailed data, were added.

The questions inquired about were: how interesting the exercise texts were, how clear were the exercise texts, how helpful was the automated code testing for doing and presenting exercises, would they like automated code testing at other courses, code reviews usefulness, narrative to technical details ratio, and narrative choice happiness.

2.3.2 Data analysis

Various data analysis experiments have been performed to verify the relationships between evaluation results at lab works for students with different lab setups, and also, the relations between these lab results, and exam results at two pre-requisite examinations.

Evaluation grades were available for a number of 199 students and 3 disciplines, after all students with no grades at all were removed from the analysis. The disciplines at hand were the pre-requisite Fundamentals of Programming (FP) and Data Structures (DS), and the final lab grade for Object Oriented Programming (OOP). The 199 students were split along their lab work duties, in groups as follows: student items 1-63 (with traditional lab duties), items 64-113 (with No Story Instant Feedback), items 114-157 (with Story Instant Feedback), and items 158-199 (with Story Late Feedback).

Various traditional and fuzzy data analysis methods were used for this series of experiments. The fuzzy sets theory was created by Lotfi A. Zadeh in 1965 [Zadeh (1965)] as a way to deal with vagueness and uncertainty. A fuzzy set takes thus into account the variate degrees of membership each data item belongs to classes.

Fuzzy data analysis methods developed in Cluj were used. Very effective for our purpose are the various fuzzy clustering and fuzzy regression methods.

Linear regression testing

Efforts to determine the relationships between examination grades, at pre-requisite exams, and the final lab grade for all 199 students were made.

Cluster substructure testing

Next analysis entails determining whether a cluster analysis of the set of grades for the same 199 students with 3 disciplines is structured in any was around the four pre-labelled classes. At this point the FDHC algorithm has been used, with a fuzzy partition threshold of 0.4. This led to a fuzzy clustering hierarchy of four classes.

It is quite interesting to remark that the structure of the fuzzy prototypes (centroids) of the four final fuzzy classes, show a notable grade split-up, confirming that the identified four classes cluster substructure is indeed real. The fact that the students of the control group are mostly placed in the higher-grades classes may seem to indicate a different grading performed by another teacher.

Overall the trend is clear: text is more interesting with story elements and automated testing is preferred with instant feedback.

2.4 GamifyCS: Second study

2.4.1 Study description

Our first case study generated a lot of data and questions. We set out to answer them before adding more gamification elements. At the onset the following research questions were proposed:

- Changing Passed/Failed test results to I/O logs improve text clarity? Do they have an effect on any other metric?
- How does allowing to go without narrative affect narrative choice?
- Is there a statistically significant difference between the grades the student received, versus what we would expect based on FP and SDA grades or versus last year?

- Do students who perform best or worst have common psychological trait or narrative preference?
- Do certain psychological traits correlate to preference for implemented gamification mechanics, and if so what trait intervals to what mechanic?
- Do certain psychological traits correlate to preference for unimplemented gamification mechanics, and if so what trait intervals to what mechanic?
- * Do students prefer computer science study online or offline?

The "instant feedback and narrative elements" experimental setup generated the best results in the first case study, it was used as our new baseline. All students had access to narratives and instant feedback. Aside from fixing small bugs in code and text, the same setup was kept for comparability. The two main complaints last year in the free-form part of the surveys were: (a) test requirement fuzziness; and (b) either people in narrative groups wanting no narratives or the exact opposite. The two main changes were (a) adding a complete log of I/O operations to each test result, and (b) adding Default as a fifth option for narrative choice. Everything else was kept the same.

Various data had been gathered for each student, which has been anonymized before data analysis began. Each uploaded version of their solutions had been stored, together with timestamps and test results. A mostly Likert scale survey has been conducted in the middle of the semester. The survey had been completely optional, and asked for permission for data analysis.

The survey happened to be scheduled 2 weeks after the COVID-19 pandemic lockdown. Questions for student's preference for online vs offline study for course, seminar, and laboratory study were added on the Likert scale. The results of which can be seen in Table 2.2.

	1		2		3		4		5	
	Raw	%	Raw	%	Raw	%	Raw	%	Raw	%
Course	28	20.1%	19	13.7%	26	18.7%	23	16.5%	43	30.9%
Seminar	34	24.5%	21	15.1%	30	21.6%	30	21.6%	24	17.3%
Laboratory	29	20.9%	21	15.1%	40	28.8%	31	22.3%	18	12.9%

Table 2.2 Student preference for online vs offline study ranging from "Clearly in person" (score 1) to "Clearly in online" (score 5).

2.4.2 Data analysis for second case study

To satisfy research questions the relationship between this year's grades and last year's FP and SDA grades was analyzed.

One of the first areas looked into when the data was ready for analysis is the comparison of responses to the first case study. Much to our surprise, all metrics have significantly improved. The comparable results of the two experiments are summarized in Figure 2.2.

The responses based on narrative preference were grouped, as it was the only metric that could not be represented as a number for the correlation matrix. There are a good couple of questions where one group has a markedly different response than the others.

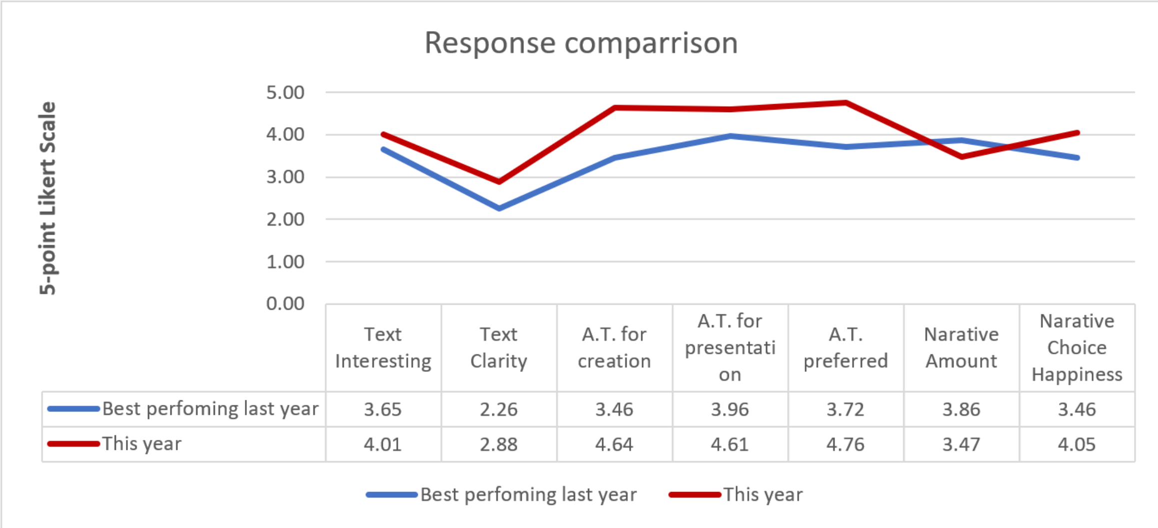

Fig. 2.2 Comparison of answers to the same questions between the two experiments on the Likert scale.

By looking at the big picture of the correlation matrix, several patterns emerge. The text related questions: perceived text clarity, how interesting it was, how pleased they were with their narrative choice, and their desire for technical details be hidden by narrative were highly, positively correlated together with agreeableness.

Another group of strongly correlated group of responses were related to the various automated testing preferences. They are also linked to code review preference and hence disliked by those with narrative preferences.

On the number of other student appearing on a leaderboard, "no leaderboard" is clearly preferred, with trait values spanning the whole spectrum for all traits.

On cooperative vs competitive tasks, more students lean toward cooperation.

On preference for many easy achievements vs fewer harder ones, the students lean toward many easy achievements.

On the preferred narrative amount, the almost all responses fall in the neutral or slightly more technical categories. High agreeableness predisposes towards preferring more narrative.

On instant feedback through automated testing, all responses were at least neutral, with the wast majority strongly preferring it.

The results of this chapter have been published in the following articles: [Zsigmond (2019)] details our efforts on creating the gamification workbench described in Section 2.2. [Zsigmond et al. (2020c)] details our work on the first study with the platform, described in Section 2.3. [Zsigmond and Pop (2021)] details our work on the second study with the platform, described in Section 2.4.

Chapter 3

Incentives for mastery

3.1 Digital badges in education

This chapter is dedicated to our work on advancing the first and second research sub-goals. It covers our literature review of digital badge use in the public and private sectors. Building on the review, proof of concept solutions are presented for implementing digital badges in our main approach. The solutions include static code analysis, and machine learning, as well as an experimental design for testing the solutions.

3.2 Findings on use of digital badges in education

3.2.1 Review procedure

The search was conducted through Google Scholar, Scopus, IEEE and Web of Science databases, and selected literature review articles that summarize studies performed on the applications of badges, in educational and other learning environments.

While conducting the literature review, the following 3 aspects of badges were analyzed: What types of badges are used or defined? What were the results of implementing badges in various contexts? What applications used badges and how?

3.2.2 Badge types

Badges can be categorized based on different criteria such as function, structure, or design elements [Facey-Shaw et al. (2018b)]. Other criteria are the application area, or customized features that are unique to the conducted experiment.

The badge function that is emphasized the most is: motivation, the engagement of users in the activity that uses gamified elements [Facey-Shaw et al. (2018a); Hamari (2017); Majuri et al. (2018)]. Other functions mentioned by studies are behavioral changes, awareness, and the recognition of achievements [Facey-Shaw et al. (2018b)].

In our review we found the following badge types in the following number of papers Simple badges: 9, Progressive badges: 6, Hidden badges: 2, Locked badges: 2, Challenge badges: 3, Negative badges: 1, Not specified: 2. In addition to the previous, [Abramovich et al. (2013)] considered two distinct models for educational badges: merit badges and video game achievements. [Bista et al. (2012)] study presents permanent and temporary badges, temporary badges being refreshed fortnightly.

Badges are classified based on their design features.

Badges differ in terms of the fields of their applications. The majority of reviewed articles concentrate on badge usage in educational environments, that can be considered as part of the public sector.

3.2.3 Reported results

Before reporting the results, it must be stressed that experiments so far have been scattered across varying contexts, which yield somewhat inconclusive results. For the empirical case studies that were analyzed, 3 categories of success were chosen: Positive with 13 articles, Mixed or Inconclusive with 14 articles, and Negative with 4 articles. What follows are short summaries of the case studies.

The following studies reported **positive** results. In [Abrams and Walsh (2014)], high school students were the subjects of an online vocabulary study group. The authors report an increase of the study time, and number of memorized words, but we need to take into consideration the lack of control groups. In [Barata et al. (2013)] a computer engineering master's level college course was gamified. In comparison to the previous year, authors have reported 511% to 845% increase in forum engagement, while the increment in the case of faculty's forum activity was 373%. Grades did not increase compared to the previous year, only student engagement.

The following studies reported **mixed or inconclusive** results. In [Amriani et al. (2013)], the authors tried two tracks of the same course: one started with badges and gamification, while the other without. At the halfway point, they switched the settings for both groups. They reported a slight increase in activity for "no gamification to gamification" group, while in the case of the activity for the "gamification to no gamification" group a moderate decrease was observable. They had no control groups of either gamification or no gamification only, to compare against. Although, overall grades appeared to be similar for both groups. In [De-Marcos et al. (2014)], a competition focused gamification experiment was set against a cooperation based social network, and a control group in a basic computer knowledge course. While performance was similar for all 3 groups, in *Word* and *Excel* gamification trailed behind both other groups.

The following studies reported **no or negative** results. In [Hamari (2013)], the authors implemented a badge system on a purely utilitarian trading service, checking whether badge visibility affected the results. Their results showed that badges had no effect on how their application was used, concluding that likely more hedonistic contexts favor gamification. The study [Hakulinen et al. (2013)] on an online learning environment reported "no significant difference between the experimental and control groups", and mentioned that some of the badges encouraged unwanted behavior.

3.2.4 Applications

At present more and more companies incorporate the notion of gamification into their mobile apps and web pages. Several popular and interesting applications that use gamification techniques were reviewed, focusing

on the applications that award the users with badges. In what follows, the reviewed application and their badge use is presented.
Khan Academy is a learning website, which uses video lessons to teach different topics for users. Users receive rewards for watching instructional videos, answering questions and resolving quizzes in the form of badges.

Codeacademy is also a learning website that teaches computer science. Codeacademy uses badges in order to track the progress of learners, and to encourage perseverance.

Duolingo is one of the most popular educational gamified language-learning platforms, which uses several gamification elements in order to help users enhance their regular learning activity.

The number of applications and companies which try to draw attention to several important aspects of life, for example the importance of reading, environmental awareness or healthy lifestyle, has increased dramatically. Two fitness applications were analyzed, which use gamification elements. Fitocracy offers Streak badges (e.g. Get Low, Monster Squat) and Achievement badges. These badges are earned for various activities (e.g. "Let's get outta here" is given after 100km cycling). Samsung Health includes reward badges, which are earned if a user completes a goal or he/she breaks his/her own record in an activity (e.g. Best Pace - breaking our best pace in walking).

The number of websites and applications that incorporated badges in order to reflect the real skills of their users has increased in recent years.

3.3 Awarding badges

3.3.1 The need for badges

The popularity of digital badges can easily be linked with the ubiquity of video games [Hilliard (2013)]. In order to efficiently award digital badges to computer science students, we need an accurate measurement of their coding style/quality, and a generalized badge awarding system that can be used within University-level courses.

Static code analysis of programming assignments has been the focus of computer science research, all the while the specifics of code quality is a constantly debated subject [M. Striewe (2014)].

Source code is meant to be computer interpreted. Well understood best practices, and increased processing power lead to the development of software tools that enforce coding standards. Many of them also attempt to find bugs before, and during program execution.

Code quality analysis was prototyped with *StyleCop* for [Zsigmond (2019)]. *StyleCop* is an open source, static code analysis tool which has been used to success with .NET projects [Q. Zoubi (2012)]. The *StyleCop.Analyzers* project was used for the analysis.

One of the most widely used linter tools is the *SonarQube* platform. Freely available in the form of a Community Edition that supports 15 popular programming languages, *SonarQube* is available as a multi-platform server application, accessible through a web interface.

In addition to its open-source nature, there were two important reasons for selecting *SonarQube*, as our platform's next static analysis tool. First, source code analysis is implemented using a plugin system. Plugins can be created in order to cover new languages, or to improve the analysis of already supported languages, by implementing new rules and guidelines. Second, *SonarQube* includes the required tools to automate source code analysis and result extraction, which allows us to seamlessly integrate it within our platform.

A new proof of concept (POC) was made that integrates a *SonarQube Community Edition* server instance for static code analysis. The community version supports most popular programming languages, with the notable exception of C/C++, which is covered through a third party open-source plugin.

With regard to static analysis, an initial evaluation using the source code for several first year programming assignments has been carried out. *SonarQube*'s default rules for Python have been used.

3.3.2 Awarding algorithm

Defining an awarding system involves identifying and recording the achievements, as well as their trigger conditions. A good set of achievements is not straightforward to define, as it must take into account course objectives, the students' difficulties, challenges and ambitions.

Available achievements and their associated badges can be consulted by students at any time. Students can also consult already earned badges.

The awarding scheme described represents the first phase in the implementation of our long-term plans. The next phase is to define and employ more complex, progressive meta achievements, which recognise student achievements in a certain sub-field such as testing, documentation, or coding style. This will also be linked with other accomplishments of the student that did not merit issuing a standalone badge. This second, more complex achievement type employs more elaborate rules, for which a more complex server-side implementation is expected. For this reason, instead of directly defining a set of intricate conditionals, a more generalised approach is proposed.

3.3.3 Integration of digital badges and static code analysis in gamifyCS

The system described in Section 2.2, enriched with the badge awarding and static code analysis components is set up to be the next experiment.

2 groups of badges are aimed for: *Achievement* and *Style*. Badges in the *Achievement* group target performance and mastery. Badges in the *Style* group target minor achievements, or desired behavior. Their aim is for students to try small deviations from the optimal study plan, as well as to reinforce desired behaviors.

To mirror the first experiment, detailed in Section 2.3, the aim is to carry out an experimental evaluation of our approach, by enrolling all 14 student formations who take programming courses. The experimental question is how does student behavior change in relation to being exposed to either, both, or none of the aforementioned badge groups.

For a typical use case in the next experiment, students access the site, where they see their list of assignments and pick one they want to attempt. The site displays personalized versions of the text for each assignment, based on what narrative choice they made at the beginning of the semester. After coding a solution, they upload it. On the server side, the code is verified and pre-processed, followed by compilation and execution, since the course is using C++. Three tests are run in parallel: correctness, coding style and plagiarism. Results are saved to the database, and displayed to the student together with any badges they earned throughout the process. The student may try again if he/she wishes, by re-uploading a modified solution.

The results of this chapter have been published in the following articles: [Zsigmond et al. (2020b)] details our literature review in digital badge use, described in Section 3.2. [Zsigmond et al. (2020a)] details our work on the use of digital badge awarding based on static code analysis, described in Section 3.3.

Chapter 4

Advanced gamification techniques

4.1 Introduction

This chapter is dedicated to our work on advancing the second and third research sub-goals. It covers gamification elements in greater detail. Then it moves on to our ontology linking personality type to gamification elements. Finally it covers our work on using Augmented Reality on gamifying medical education, and the empirical study for it.

When considering advanced gamification techniques two different roads have been explored. The first, namely the personalization of education through gamification elements mapped to personality traits, via the use of ontologies. The second was the exploration of Augmented Reality in combination with gamification, and medical education. Let us now continue to advanced gamification techniques.

4.1.1 Gamification personalization

While most gamification techniques focus on using a game mechanic, for example points, for everybody in the audience, few have tried tailoring the experience on the individual. The two main hindrances have been the implied necessary effort, and the lack of useful information on how to do it properly. There are mentions of tailoring content to the learner's skill level, but usually little details are shared, or it is a manual process [Kiesler et al. (2011)]. To get the same benefits as games the process of customizing gamification elements and study materials needs to be automated. For automation to work and to be adjustable based on new data gathered from the field, ontologies and ontologies-based reasoning is a natural choice.

When tailoring structural and semantic elements on the individual level we need to base these on the learner's measurements. 3 types of data has been incorporated into our model, although the model can be expanded to use more, or to ignore some. The 3 measurements considered are: **Narrative preferences**, see Section 4.2.1, **Personality traits** (Big 5), see Section 4.2.2, **Player types** (Bartle), see Section 4.2.3.

Since the price of most AR devices can be prohibitive for most medicine students, the scope of our investigation was to know whether their study can be enhanced with smartphones/laptops, which they are likely to posses. Our approach overlays the likeness of various pathologies on the face of anybody it is pointed towards. The student then has various choices to identify the condition. In turn, they get to gain points and compete for high scores with their peers. Not only do the students get more varied exposure to pathologies, but it also incentivizes repetition through game mechanics. A small scale study has been conducted with third-year medical students on a working prototype with positive results.

4.2 Components

4.2.1 Gamification elements

Gamification mechanics have already seeped into everyday life. Game mechanics should be looked at in context with dynamics and aesthetics. The original paper on the subject stems from game design, and has been referred to in gamification papers [Hunicke et al. (2004)]. Mechanics are functional components in gamification, they allow for interaction with the system. Mechanics are low level, tend to boil down to data representation and algorithms, or the specific rules. Dynamics represent the system the mechanics form as players interact with mechanics. Aesthetics represent the emotions the designers aim to achieve in the player, through the system.

In order to expand the system presented in Section 2.2.1, and the ontology in Section 4.3, various game mechanics from the literature should be considered, why and when are they useful and how they may be implemented. To reduce the scope of the model, only the most common elements have been integrated into our ontology when it was initially designed. The following have been included in our ontology:

Instant feedback Instant feedback is like regular feedback just much faster. It shortens the work-reward cycle to real world levels, and is considered by some the most important game mechanic [Zichermann and Cunningham (2011) Bullón et al. (2018)].

Narrative is one of the strong suits of games, and tends to be one of the most used gamification element [Dicheva et al. (2015)]. A story aids in immersion, and gives a sense of purpose to solving tasks. The two pitfalls of a narrative in a gamification setting are quality, and specificity.

Points of many shapes and forms represent a reward for desired behavior, a form of currency, it may be the primary measurement of progression, or status [Nah et al. (2014)]. They are usually implemented by adding a numeric value to a total [Hiltbrand and Burke (2011)]. They can be a form or immediate feedback, as an external motivator [Sailer et al. (2017)]. *Achievements or Badges*: consider Section 3.2.

Missions and quests: Missions, or quests represent objectives to strive for in the world in question. Usually there is a narrative context for the required actions.

Leaderboards: Leaderboards are a publicly available UI element, usually in the form of a table, that display the order of players by a predetermined metric [Aldemir et al. (2018) Özhan and Kocadere (2020)]. Usually the metric is some type of points, it serves as a social comparison tool for the group, encouraging competition [Al-Towirgi et al. (2018)].

Levels: The concept of *leveling* is a progression mechanic, popularized by tabletop R.P.G.-s [Tibor and Dávid (2007)]. After acquiring several points (usually referred to as experience or Xp) a milestone is reached.

Avatars: Avatars represent a virtual persona of the player in question [Passos et al. (2011)]. Usually consisting of merely a name, sometimes associated by a picture. Avatars anonymize the player, freeing from social constraints.

4.2.2 Psychological Traits

In psychology, traits can be defined as "relatively long-term patterns of behavior, thought, and emotion, which differ on an individual basis". The Big Five personality traits taxonomy has been chosen for our model, which is widely used in psychology [Goldberg (1993)]. The Big Five Model uses every day language and word association to categorize people into 5 dimensions: openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism.

Openness to experience includes having active imagination, aesthetic sensitivity, wide interests, and being imaginative and insightful behavior. The associated facets are: Fantasy, Aesthetics, Feelings, Actions, Ideas, Values.

Conscientiousness includes having scrupulous, meticulous, principled behavior guided or conforming to one's own conscience. The associated facets are: Competence, Order, Dutifulness, Achievement-striving, Self-discipline, Deliberation.

Extroversion includes having outgoing, talkative, energetic behavior, projecting one's personality outward. The associated facets are: Warmth, Gregariousness, Assertiveness, Activity, Excitement-seeking, Positive Emotions.

Agreeableness includes having kind, sympathetic, cooperative, warm, and considerate behavior. The associated facets are: Trust, Compliance, Altruism, Straightforwardness, Modesty, Tender-mindedness.

Neuroticism includes having anxious, depressed, self-conscious, impulsive, vulnerable behavior and display angry hostility. The associated facets are: Anxiety, Hostility, Depression, Self-consciousness, Impulsiveness, Vulnerability.

Our ontology uses the aforementioned taxonomy, it does not require it. With some adjustments our proposed system can be used to the same effect with an alternate theory if and only if it is a valid measurement of the learner.

4.2.3 Player types

[Bartle (1996)] defined in his taxonomy 4 player types: Killers Achievers, Socializers, and Explorers. These 4 characters represent quadrants along "the preference for interacting with other players vs. exploring the world axis and preference for interaction vs. unilateral action axis". The different types have different preferred actions during gameplay.

The taxonomy remains useful in classifying players and got included in our ontology. A short description of the player types follows:

Killers types thrive on competition with other players instead of competition with the world itself. In our hypothesis the mechanics that suit the killer profile are leader-boards to show status, battle to directly engage with other people, and displays of mastery.

Achievers prefer tangible rewards in the world, these may be points, badges, loot, prestige etc. They tend to strive to "beat" the game or having 100% completion. In our hypothesis the mechanics that suit the achiever are points, achievements, and progression.

Socializers play games because of the other players rather than the game itself. The game being no more than a tool to interact with people. In our hypothesis the mechanics that suit the socializers are group quests and missions.

Explorers prefer discovering details of the world, hidden features, puzzles, bugs, and "Easter eggs" (hidden references). In our hypothesis the mechanics that suit the explorer is narrative, optional missions, and achievements.

Since an engaging experience for each player type differs, it should be ensured that in the context of education where learners join from the entire spectrum, any particular player type is not ignored.

4.3 Ontology to link gamification with traits

4.3.1 Metrics and formulae

When constructing the ontology, the problem of deciding what game mechanic to use, based on the myriad of metrics collected on the learner arose. Care must be taken because, for a learner with high anxiety levels, it is detrimental to expose them to a highly competitive setting. The opposite is also true.

For each game mechanic there are several ways to display them, and several experiences that they yield. Different metrics need to be associated to different types, within one game mechanic.

The solution proposes to define ranges for the different metrics, and use Formula 1 and 2 to make decisions on it. Formula 1 guaranties that minimum values are respected across all learner metrics for a given mechanic sub-type, while at least one maximum value is also respected. In the formula M1 ... Mn refers to each relevant learner metric, for example Extroversion or Achiever. Formulas V(x) yields the measured value of a profile in a [0 100] interval, for example, Extroversion value of 35. Vmin(x) yields the minimum threshold of the learner metric for the current gamification mechanic, while Vmax(x) yields the maximum threshold. The formula assumes that the values used are increasing and disjoint. The mathematical formula is:

$$(\forall x \in \{M_1...M_n\}, V(x) > V_{min}(x)) \wedge$$
$$(\exists x \in \{M_1...M_n\}, V(x) < V_{max}(x))$$

		M1		M2		M3		M4		M5	
		Neuroticism		Extroversion		Killer		Achiever		Socializer	
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
G1	NoLeaderboard	0	20	0	20	0	5	0	5	0	10
G2	NextTwo	20	40	20	40	5	20	5	20	10	30
G3	Group	40	60	40	60	20	50	20	50	30	50
G4	Year	60	80	60	80	50	60	50	60	50	70
G5	AllTime	80	100	80	100	60	100	60	100	70	100

Table 4.1 Proposed values for Leaderboard mechanic

While Formula 1 gives the expected results for any single gamification mechanic, a general case should be presented for non-protégé implementation. Formula 2 extends Formula 1 by considering all gamification mechanics in the form of G1 ... Gm. Functions Vmin(x, y) yields the minimum threshold for the metric and mechanic, while Vmax(x, y) yields the maximum threshold.

$$\exists x \in \{G_1...G_m\}(\forall y \in \{M_1...M_n\}, V(y) > V_{min}(x,y)) \wedge$$
$$(\exists y \in \{M_1...M_n\}, V(y) < V_{max}(x,y))$$

The described ontology was created and tested in protégé. The ontology can be queried using SPARQL to get the structural and semantic gamification elements, for a given learner. Example of a structural element would be a Leaderboard sub-type, while semantic would be Story Preference sub-type. Integration with the GamifyCS project was prototyped, and full integration awaits further gamification mechanic implementations, and further validating experiments. An architectural view of the project with currently used, and prototyped subsystems can be found in Figure 4.1.

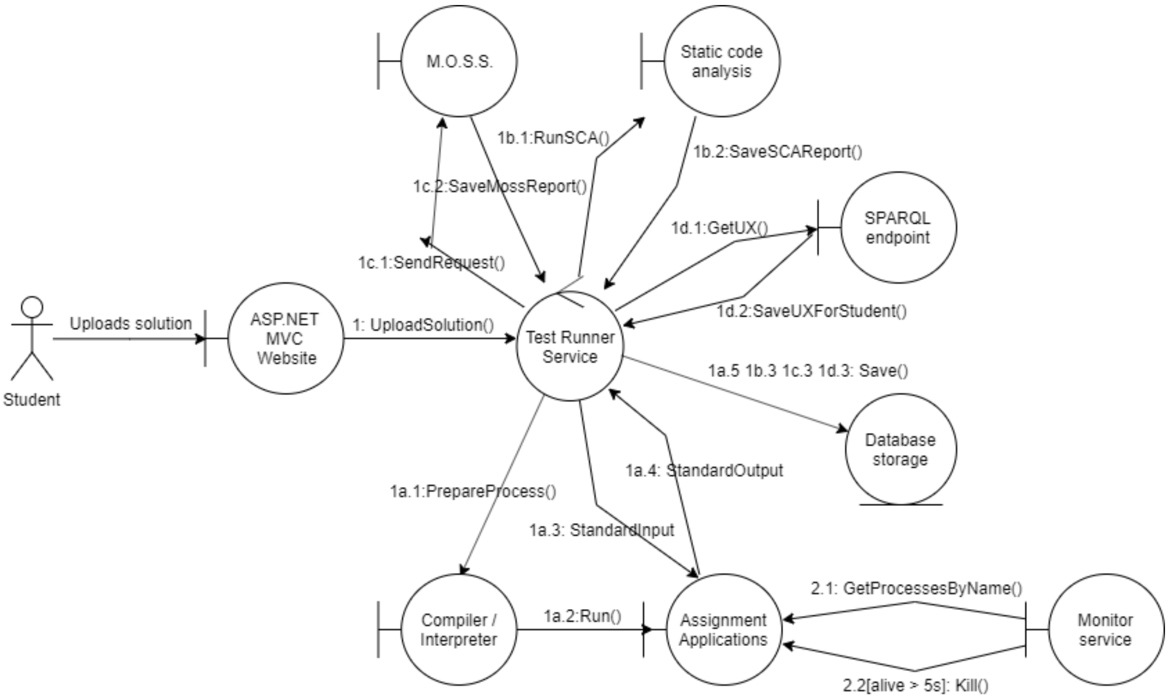

Fig. 4.1 Architecture of GamifyCS project

Instant feedback: The solution presented in Section 2.2.1.

Narrative and Missions: The solution presented in Section 2.2.3.

Achievements: The solution presented in Section 3.3.

Points and Leaderboards: At the moment points are used only in the form of grades. The awarding of grades at the successful completion of all requirements was integrated by experiment two, presented in Section 2.4. Leaderboards were not prototyped at all.

Avatars: Avatars would be represented by picture and name, provided by the students with text substitution in the narrative. Currently this is not supported or prototyped.

Status, Leveling and Mastery: Status related features would involve the possibility to view each other's avatars / profiles, to see points and achievements, or a leaderboard, which remain to be prototyped once those features are done. Leveling and Mastery will be prototyped together with the fully integrated achievement system.

4.3.2 Game rule formalization

Ontologies with protege can be used to great effect as a reasoning engine. For this we need to formalize our rule-set. For a demonstration of how this can be done, the following is from our paper on generalizing chess moves to *n* dimensions [Cristea et al. (2019)]. The move formalization extends [Hurd (2005)]. Definitions other than the ones below remain as is in original article. For clarification: i, j refers to some dimension number < N and k refers to all dimension numbers < N that differ from i and j.

$$boardSize \equiv 8;$$

$$dim\ i(d_1,...,d_n) \equiv d_i;$$

$$board_n \equiv \{pos, i \mid dim\ i\ pos < boardSize\};$$

$$sameDim\ i\ pos_1\ pos_2 \equiv (dim\ i\ pos_1 = dim\ i\ pos_2);$$

$$\begin{aligned} sameDiag\ i\ j\ pos_1\ pos_2 \equiv\ & (dim\ i\ pos_1 + dim\ j\ pos_2 = dim\ i\ pos_2 + dim\ j\ pos_1) \vee \\ & (dim\ i\ pos_1 + dim\ j\ pos_2 = dim\ i\ pos_2 + dim\ j\ pos_1); \end{aligned}$$

$$\text{diff}\ m\ n \equiv \begin{cases} \text{n - m, if } m \leq n \\ \text{m - n, otherwise} \end{cases}$$

$$\text{diff}\ i\ pos_1\ pos_2 \equiv \text{diff}(dim\ i\ pos_1)(dim\ i\ pos_2);$$

The bishop may move to any square, along a diagonal on which it stands.

$$biAtt\ pos_1\ pos_2 \equiv sameDiag\ i\ j\ pos_1\ pos_2 \wedge pos_1\ \neq\ pos_2 \wedge \text{diff}\ k\ pos_1\ pos_2\ =\ 0;$$

The rook may move to any square, along the file or the rank on which it stands.

$$roAtt\ pos_1\ pos_2 \equiv sameDim\ i\ pos_1\ pos_2 \wedge pos_1\ \neq\ pos_2 \wedge \text{diff}\ k\ pos_1\ pos_2\ =\ 0;$$

The queen may move to any square, along the file, the rank, or a diagonal on which it stands.

$$quAtt\ pos_1\ pos_2 \equiv roAtt\ i\ j\ pos_1\ pos_2 \vee biAtt\ i\ j\ pos_1\ pos_2;$$

When making these moves the bishop, rook or queen may not move over any intervening pieces. The knight may move to one of the squares, nearest to that on which it stands but not on the same rank, file or diagonal.

$$\begin{aligned} knAtt\ pos_1\ pos_2 \equiv\ & (\text{diff}\ i\ pos_1\ pos_2\ =\ 1 \wedge \text{diff}\ j\ pos_1\ pos_2\ =\ 2) \vee \\ & (\text{diff}\ i\ pos_1\ pos_2\ =\ 2 \wedge \text{diff}\ j\ pos_1\ pos_2\ =\ 1); \end{aligned}$$

The king may move to any adjoining square, not attacked by one or more of the opponent's pieces. The opponent‘s pieces are considered to attack a square, even if such pieces cannot themselves move.

$$kiAtt\ pos_1\ pos_2 \equiv pos_1 \neq pos_2 \wedge ((\mathrm{diff}\ i\ pos_1\ pos_2 = 1) \vee$$
$$(sameDiag\ i\ j\ pos_1\ pos_2 \wedge \mathrm{diff}\ i\ pos_1\ pos_2 = 1))$$

4.4 Advanced UX: augmented reality use with gamification

4.4.1 Face detection

The Human face is a very difficult object to detect, since it comes in many forms and colors, is highly dynamic and a lot of times the features are not regular. For practicality a marker-less AR in the classical sense was chosen, and use the human face itself as a marker. The core of our application is the Open Computer Vision Library (OpenCV), together with the Unity3D cross-platform game engine [1]. The classification algorithm used in this project for object and face detection is AdaBoost, with a machine learning approach proposed by Paul Viola and Michael Jones, based on Haar Feature cascade classifiers [Viola et al. (2001)].

OpenCV is an open-source library computer vision, image processing, video processing, and object detection. In order to use it inside Unity3D, a third party plugin was needed, that lets you use OpenCV inside Unity3D by translating OpenCV into C# provided by Enox Software. The AdaBoost Classifier cascades, are based on Haar-like features weak classifiers [Delbiaggio (2017)].

4.4.2 Skin conditions

For the study, 3 types of diseases and skin conditions have been chosen, that have really specific characteristics: xanthelasma, herpes, malignant melanoma.

The xanthelasma appears most often around the eyelids. This condition was chosen because it is usually found around the eyes, and its yellowish color, which makes it instantly recognisable to medical students.

"Malignant melanoma is a malignant tumor of melanocytes. It mostly appears on the skin.

Herpes simplex virus 1 is a member of the Herpesviridae family.In depicting the disease oral herpes was chosen.

Photos of the mentioned maladies as they appear in the application can be seen in figure 4.2. The original background was set to transparent in order to eliminate the clutter of the picture, and to be accurate for any skin color of the subject. After every picture was cropped and adapted according to our needs, a normal map and a specular map of them was created, using ShaderMap4. The 3D models of the diseases were made using the Unity in-game editor.

4.4.3 Advanced UX: augmented reality solution and experiment

During design time an instant feedback approach, for a positive feedback loop, together with auditory feedback was chosen. Buttons were added to the bottom of the screen such that the player can choose what disease they believe is showing on the subject's face. If the player guesses correctly 10 points are added to his overall score. If he chose wrong 5 points will be subtracted from the final score.

[1] https://unity.com/

Fig. 4.2 Rendered Xanthelasma

As the primary gameplay loop, a disease is mapped on the subject once the algorithm detects a face in the live video stream. The first disease is chosen randomly and stays until the user makes its choice. For a stronger competition the leaderboard would need to be shared amongst the participants, together with a timer. As well as some kind of progression mechanic, possibly in the form of leveling.

A study was conducted on third-year Medical Students with ages between 21-23. The sample size is low, only 9 participants. The study consisted of explaining to the students the concept of the application, and letting them use it for 5-10 minutes. At the end of their trial usage, they were asked to complete a survey. All of them correctly recognised the diseases. Results of the study is summarized in Table 4.2.

Table 4.2 Likert scale survey results

Concept of interest	Very negative	Negative	Neutral	Positive	Very positive
Visual accuracy compared to medical textbook	0%	0%	0%	66.67%	33.33%
Visual accurate compared to real life	0%	0%	0%	0%	100%
Perceived usefulness	0%	0%	0%	33.33%	66.67%
Willingness to compete with peers?	0%	0%	0%	66.67%	33.33%
Likeliness to recommend	0%	0%	0%	0%	100%

Subsequently, some of them were interested if more gamified elements could be added to the application, for example the concept of "combo", winning streaks or timers.

Since all responses were purely positive, the demonstration of statistical significance is not warranted.

The results of this chapter have been published in the following articles: [Zsigmond (2020)] details our ontology, linking gamification mechanics to personality traits, described in Section 4.3. [Zsigmond and Buhai (2021)] details our work on the use of augmented reality use in medical education, described in Section 4.4.

References

Abramovich, S., Schunn, C., and Higashi, R. M. (2013). Are badges useful in education?: It depends upon the type of badge and expertise of learner. *Educational Technology Research and Development*, 61(2):217–232.

Abrams, S. S. and Walsh, S. (2014). Gamified vocabulary. *Journal of Adolescent & Adult Literacy*, 58(1):49–58.

Al-Towirgi, R. S., Daghestani, L. F., and Ibrahim, L. F. (2018). Increasing students engagement in data structure course using gamification. *International Journal of e-Education, e-Business, e-Management and e-Learning Increasing*, 8(4):193–211.

Aldemir, T., Celik, B., and Kaplan, G. (2018). A qualitative investigation of student perceptions of game elements in a gamified course. *Computers in Human Behavior*, 78:235–254.

Amriani, A., Aji, A. F., Utomo, A. Y., and Junus, K. M. (2013). An empirical study of gamification impact on e-learning environment. In *Proceedings of 2013 3rd International Conference on Computer Science and Network Technology*, pages 265 – 269. IEEE.

Barata, G., Gama, S., Jorge, J., and Gonçalves, D. (2013). Engaging engineering students with gamification. In *2013 5th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, pages 1–8. IEEE.

Bartle, R. (1996). Hearts, clubs, diamonds, spades: Players who suit muds. *Journal of MUD research*, 1(1):19.

Bista, S. K., Nepal, S., Colineau, N., and Paris, C. (2012). Using gamification in an online community. In *8th International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom)*, pages 611–618. IEEE.

Bullón, J. J., Encinas, A. H., Sánchez, M. J. S., and Martínez, V. G. (2018). Analysis of student feedback when using gamification tools in math subjects. In *2018 IEEE Global Engineering Education Conference (EDUCON)*, pages 1818–1823. IEEE.

Chrysafiadi, K., Troussas, C., and Virvou, M. (2018). A framework for creating automated online adaptive tests using multiple-criteria decision analysis. In *2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pages 226–231. IEEE.

Cristea, D.-M., Zsigmond, I., Sima, I., Trofin, B.-G., and Kovács, R. (2019). Neural network adaptability from 2d to 3d chess. In *2019 IEEE 13th International Symposium on Applied Computational Intelligence and Informatics (SACI)*, pages 201–204. IEEE.

De-Marcos, L., Domínguez, A., Saenz-de Navarrete, J., and Pagés, C. (2014). An empirical study comparing gamification and social networking on e-learning. *Computers & Education*, 75:82–91.

Delbiaggio, N. (2017). A comparison of facial recognition's algorithms. *Haaga-Helia ammattikorkeakoulu*.

Dicheva, D., Dichev, C., Agre, G., Angelova, G., et al. (2015). Gamification in education: A systematic mapping study. *Educational Technology & Society*, 18(3):75–88.

Facey-Shaw, L., Specht, M., and Bartley-Bryan, J. (2018a). Digital badges for motivating introductory programmers: Qualitative findings from focus groups. In *2018 IEEE Frontiers in Education Conference (FIE)*, pages 1–7.

Facey-Shaw, L., Specht, M., van Rosmalen, P., Brner, D., and Bartley-Bryan, J. (2018b). Educational functions and design of badge systems: A conceptual literature review. *IEEE Transactions on Learning Technologies*, 11(4):536 – 544.

G Gygax, D. A. (1974). *Dungeons and dragons*. TACTICAL STUDY RULES.

Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American psychologist*, 48(1):26.

Hage, J., Rademaker, P., and van Vugt, N. (2010). A comparison of plagiarism detection tools. *Utrecht University. Utrecht, The Netherlands*, 28:1.

Hakulinen, L., Auvinen, T., and Korhonen, A. (2013). Empirical study on the effect of achievement badges in trakla2 online learning environment. In *2013 Learning and teaching in computing and engineering*, pages 47–54. IEEE.

Hamari, J. (2013). Transforming homo economicus into homo ludens: A field experiment on gamification in a utilitarian peer-to-peer trading service. *Electronic Commerce Research and Applications*, 12(4):236 – 245. Social Commerce- Part 2.

Hamari, J. (2017). Do badges increase user activity? A field experiment on the effects of gamification. *Computers in human behavior*, 71:469 – 478.

Hilliard, K. (2013). Activision badges - the original gaming achievement (2013, october 23). Retrieved October, 2019, from Game Informer: https://www.gameinformer.com/b/features/archive /2013/10/26/activision-badges-the-original-gaming-achievement.aspx.

Hiltbrand, T. and Burke, M. (2011). How gamification will change business intelligence. *Business Intelligence Journal*, 6.

Hunicke, R., LeBlanc, M., and Zubek, R. (2004). Mda: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI*, volume 4, page 1722.

Hurd, J. (2005). Formal verification of chess endgame databases. In *Theorem Proving in Higher Order Logics: Emerging Trends Proceedings*, page 85.

Kiesler, S., Kraut, R. E., Koedinger, K. R., Aleven, V., and Mclaren, B. M. (2011). Gamification in education: What, how, why bother? *Academic exchange quarterly*, 15(2):1–5.

M. Striewe, M. (2014). A review of static analysis approaches for programming exercises. *Computer Assisted Assessment. Research into E-Assessment.*, pages 100–113.

Majuri, J., Koivisto, J., and Hamari, J. (2018). Gamification of education and learning: A review of empirical literature. In *Proceedings of the 2nd international GamiFIN conference, GamiFIN 2018*. CEUR-WS.

Nah, F. F.-H., Eschenbrenner, B., Zeng, Q., Telaprolu, V. R., and Sepehr, S. (2014). Flow in gaming: literature synthesis and framework development. *International Journal of Information Systems and Management*, 1(1-2):83–124.

Özhan, Ş. Ç. and Kocadere, S. A. (2020). The effects of flow, emotional engagement, and motivation on success in a gamified online learning environment. *Journal of Educational Computing Research*, 57(8):2006–2031.

Passos, E., Medeiros, D., Neto, P., and Clua, E. (2011). Turning real-world software development into a game. In *2011 Brazilian Symposium on Games and Digital Entertainment*, pages 260–269.

Q. Zoubi, I. Alsmadi, B. A.-H. (2012). Study the impact of improving source code on software metrics. *2012 International Conference on Computer, Information and Telecommunication Systems (CITS)*.

Sailer, M., Hense, J. U., Mayr, S. K., and Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69:371–380.

Tibor, B. and Dávid, K. (2007). *Új Törvénykönyv*. Tuan Kiadó.

Viola, P., Jones, M., et al. (2001). Rapid object detection using a boosted cascade of simple features. *CVPR (1)*, 1:511–518.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control*, 8:338–353.

Zichermann, G. and Cunningham, C. (2011). *Gamification by design: Implementing game mechanics in web and mobile apps*. " O'Reilly Media, Inc.".

Zsigmond, I. (2019). Automation and gamification of computer science study. *Studia Universitatis Babes-Bolyai, Informatica*, 64(2).

Zsigmond, I. (2020). Ontology based ux personalization for gamified education. In *ENASE*, pages 415–422.

Zsigmond, I., Bocicor, M.-I., and Molnar, A.-J. (2020a). Gamification based learning environment for computer science students. In *ENASE*, pages 556–563.

Zsigmond, I. and Buhai, A. (2021). Augmented reality in medical education, an empirical study. *Computational Science and Its Applications – ICCSA 2021*, 12958:631–640.

Zsigmond, I., Lorincz, B., and Molnar, A. (2020b). Review of digital badges in computer science literature and applications. *Studia Universitatis Babeș-Bolyai Informatica*, 65(1):17–32.

Zsigmond, I. and Pop, H. F. (2021). Linking gamification preferences to personality traits in computer science education. In *Accepted for ICCP 2021*, pages 000–000.

Zsigmond, I., Zamfirescu, A., and Pop, H. F. (2020c). Automated evaluation and narratives in computer science education. In *ENASE*, pages 430–437.