BRNO UNIVERSITY OF TECHNOLOGY
VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF INFORMATION TECHNOLOGY
FAKULTA INFORMAČNÍCH TECHNOLOGIÍ

GAME ANALYTICS AND DATA VISUALIZATION IN GAMIFICATION

ESSAY

AUTHOR **Ing. OLENA PASTUSHENKO**
AUTOR PRÁCE

BRNO 2018

Contents

Chapter 1

Introduction

In every job that must be done, there is an element of fun.
You find the fun, and - SNAP - the job's a game!

Mary Poppins

Training and development has been approached in many ways to deal with specific learning objectives. From physical training manuals, to training videos and eLearning units, every medium has its strengths and weaknesses. The lynchpin that determines the success of any training effort is engagement. Increasing students' motivation is an essential task during the educational process. One of the possible ways how to achieve this is to use innovative educational mechanics, such as gamification or serious games. Gamification provides an opportunity to extend regular learning management systems and virtual learning environments with game-like elements, such as points, levels, and meaningful narrative. With a serious game initiative, the learning content is delivered in a game-based environment. These educational techniques are described in Chapter 2.

On the other hand, from an educational perspective, such focus on player performance is not necessarily beneficial for learning. Various authors explain the difference between a performance orientation and a learning orientation: while game play tends to focus on performance, which is linked with an attitude of achieving milestones and score (in many cases under time constraints), learning requires opportunities for reflection, repetition, self-evaluation, pauses, and even the preparedness to make mistakes. Hence, the process of gaming may readily counteract the process of learning. Having completed a serious game successfully with a high score doesn't necessarily imply successful learning. For preserving the efficiency of learning it is highly relevant to gain insights in the individual behaviours, activities and efforts that the players exhibit in order to reach the game's performance milestones: e.g. did a player achieve the milestones in an efficient and well-considered way, or was it a thoughtless trial and error style that took a lot of time without achieving any learning gains? That's why Chapter 3 describes the methods of data collection and analytics, data vizualization with the help of dashboards and possible future improvements.

Chapter 2

Innovative educational techniques

Quite often in higher education institutions teachers face the problem of low students' interest and engagement. That's why increasing students' motivation is an important task in the educational process [43]. Since higher education is an active and participatory activity, it requires motivation not only to begin, but also to keep up with the process. Researches show that when elements of self-direction and autonomy are required for the educational process, which is the case for university students, even higher level of motivation is required [18]. Therefore, students motivation plays a significant role in their successful higher education. Recently, in various areas where individuals' participation and motivation are engaged, gamification mechanics are considered. Furthermore, since nowadays almost every institution has an on-line learning management systems (LMS), and gamification originates from the digital media area - it is a perfect fit for extending the existing LMS.

All educational system might be considered already gamified: when viewing marks as achievement points, and grades - as levels. Students need to gain a certain amount of points to get to the next «level». Of course, studying at university is not a game, but that does not mean it is not possible to enhance studying efforts through game elements or with a game design within a common LMS [16]. A lot of researches suggest adding the more deeper level of gamification to the educational process, involving also separate courses or tasks. Some of them show that gamification helps to increase students motivation [43, 11, 19, 43]. It was firstly observed during studying the effects of the increase of the motivational and emotional insolvent during playing the video games [21]. The basic idea of gamification is to study, use and replicate the same motivation and flow of the users in other fields.

Currently, scientific discussion about gamification is mainly connected with game elements like points, badges or leader-boards [16]. This research studies the opportunities of integration of completely gamified framework into Informational Technology students' labs.

2.1 Gamification

Term «gamification» originates from a digital media industry, and mainly from a marketing area. There is a research [6], which studied 119 publications which had gamif* in their title and were published between 2000 and 2014 years. It was found out that biggest part of those papers define gamification as the application of gaming mechanics and elements in non-game environments. Also, there mainly is a clear difference between a game-based learning and a gamification. There exist several definitions of gamification. The most popular one comes from an article by Deterding et al [11]. According to Google Scholar

on 24.06.2018 it was already cited 3718 times (https://goo.gl/cwKrsA). Gamification is described there as the use of game elements characteristics in non-game contexts. Such elements might be: points, badges, progress bars, meaningful stories, profile development and etc (Table 2.1).

Table 2.1: Game elements and their functions in gamification practice.

Game element	**Functionality**
Levels	Show the participant's status, ranking and progression.
Challenges and Quests	Show the participant's status, ranking and progression.
Competition	Taking part in a contest. Motivates to finish the task quicker or better.
Cooperation	Motivates participants to work together and to collaborate in order to achieve better results.
Narrative	Consistent storyline, a background complex task which triggers fantasy as a motivational factor.

Taking a closer look at the definition of gamification, four components are of importance [37]:

1. The term *game* is usually understood to imply the following situational components: a goal, which has to be achieved; limiting rules which determine how to reach the goal; a feedback system which provides information about progress towards the goal; and the fact that participation is voluntary.

2. The term *element* helps to distinguish the concept of gamification from serious games, which describe full-fledged games for non-entertainment purposes (Section 2.2). Gamification on the other hand refers to the explicit use of particular elements of games in non-gaming contexts.

3. The term *design* refers to the use of game design instead of game-based technologies or practices of the wider game ecology.

4. As stated before, the area of application of gamification is very broad. To take account of that and to prevent limiting the definition to certain contexts, the area of application is just described by the term *non-game-contexts*.

This working definition with its related components is very broad. It helps to distinguish gamification from other concepts related to gaming and provides a basis for investigations without constricting the phenomenon. Though gamification is mostly associated with digital technology, gamification is not solely related to digital media. Non-digital realizations are possible as well.

Another research [17] adds the following constraints to describe how gamification is different from other terms, such as serious games or games:

1. More gameful, than playful;

2. not a complete game;

3. both a tool and game;

4. not primarily for entertainment;

5. not a pervasive game.

Virtual learning environments (VLE) allow university teachers to share different knowledge media with their students, iterate with students and monitor the statistics [28]. In VLEs known as Massive Open Online Course (MOOC), the majority of empirical studies have already proven the positive effect of implementation of the gamified elements [24]. We suggest that the same strongly positive effect would be achieved in the higher educational institutions VLEs too.

2.1.1 Successful gamification examples

There is a long list of successfula gamification examples, which made a social, educational, business or other positive impact. The next list gives a brief overview of some of them.

1. **Zamzee**[1] is a device that clips onto kids and tracks their activities when they run around - similar to the Nike+ FuelBand but cheaper for kids and has missions that are designed to get kids excited. Studies show that the activity rate for children between 9–15 have decreased by 60 percents, leading to obesity, diabetes or even worse diseases. With the help of Zamzee, Kids can upload their activity data onto a website and see how many points they received and whether they have accomplished interesting challenges as well as earned badges. Zamzee has concrete data to show that the activity rate of children increased by 59 percents, which is a very sizeable increase that will help encourage kids to go to the gym more when they grow up.

2. Energy is a serious issue in the world. It powers a nation's efficiency to produce and transport, but also leads to war in some cases. **OPower**[2] works to solve these problems by utilizing gamification to encourage people to use less energy. OPower works with utility companies to provide households with data on how much energy they are consuming, how they match up with neighbors, and if they are close to any new milestones. Compellingly, people are consuming on average 2 percents less energy, which in 2012 led to over 1 Terawatt of energy savings in the world. This equates to $120,000,000 in utility bill savings, and decreased pollutions equivalent of keeping 100,000 cars off the road.

3. **RecycleBank**[3] saves the environment by rewarding points that can be redeemed for goods. There currently is a serious trash problem in the world. 195 Million Tons of Trash are tossed out by American's alone each year. The trash needs to go somewhere, and they generally go into landfills. The problem is, many products can take 100–400 years to decompose, and we are slowly running out of landfill space. RecycleBank was created to encourage people to recycle more and reduce landfill trash by awarding points for recycling, saving energy, and answering sustainability quizzes and pledges.

[1] https://www.zamzee.com
[2] https://ux.opower.com
[3] https://www.recyclebank.com

Points are redeemable for actual goods at WalMart, BestBuy and more places, as city government pays RecycleBank for reducing landfill waste. The project is backed by Al Gore and how won numerous awards in innovation, sustainability, and business. It now has 3 Million members and over 180 employees pushing the recycling envelope further.

4. **Khan Academy**[4] makes people more engaged with learning through Gamified Online Education. Khan Academy utilizes lots of game mechanics such as "skill-growth trees" to unlock new classes and learn new skills. First, subjects are all organized as a visual constellation on a Google map. The result looks like an RPG skill tree, and is organized so that lessons build off of one another. For example, Addition 1 branches off into Addition 2 and Subtraction 1. The motivational effect of visualizing knowledge as a map and a physical space to be navigated and progressed through is undeniable. 'Learning math' becomes a series of logical and satisfying steps within a network and is suddenly transformed from a dull classroom exercise into the exciting prospect of leveling and progressive knowledge building.

5. **DuoLingo**[5], the gamified language learning app (Fig. 2.1). When you reach your goal a few days in a row, you get a streak, which you have to work to maintain. For example, if you miss a couple of days' lessons, your streak goes down. Streak basically refers to your knowledge of words in that lesson, and if you don't keep up, it means you are forgetting those words, therefore your streak weakens to indicate that. Duolingo sends regular reminders to meet your daily goal, encouraging you to reach longer learning streaks. These reminders are fun and personalized, suggesting what you will be learning next, and motivating you to keep practicing. As you complete lessons and gain XP, you level up, earning lingots. Lingot is a virtual currency that allows you to buy various things from a store, right from dressing up your owl (the Duolingo mascot), to power ups and extra lessons.

2.2 Serious games

Serious Educational Game (SEG) refers to an alternative learning methodology that applies game technology to primarily promoting players' learning along with gaining positive cognitive and affective experience during such a learning process [30]. In other words, serious game is *a game designed for a primary purpose other then pure entertainment.* Its use has grown, particularly in such sectors as education, defense, aeronautics, science or health. Its purpose can be one of many: from training firefighter crews in emergency situations to training a sales team, teaching mathematics or practicing a language.

Serious games are multimedia tools by nature. As a subfamily of videogames, they combine different types of media (animations, music, text...) to create immersive experiences for the players.

Serious games are among the most challenging, most dynamic and most interactive learning environments. They commonly offer learners rich and interactive content, large degrees of control, freedom of movement and responsibility for the actions undertaken. Serious games are outstanding examples of adaptive systems, as they continuously adjust

[4] https://www.khanacademy.org
[5] https://www.duolingo.com

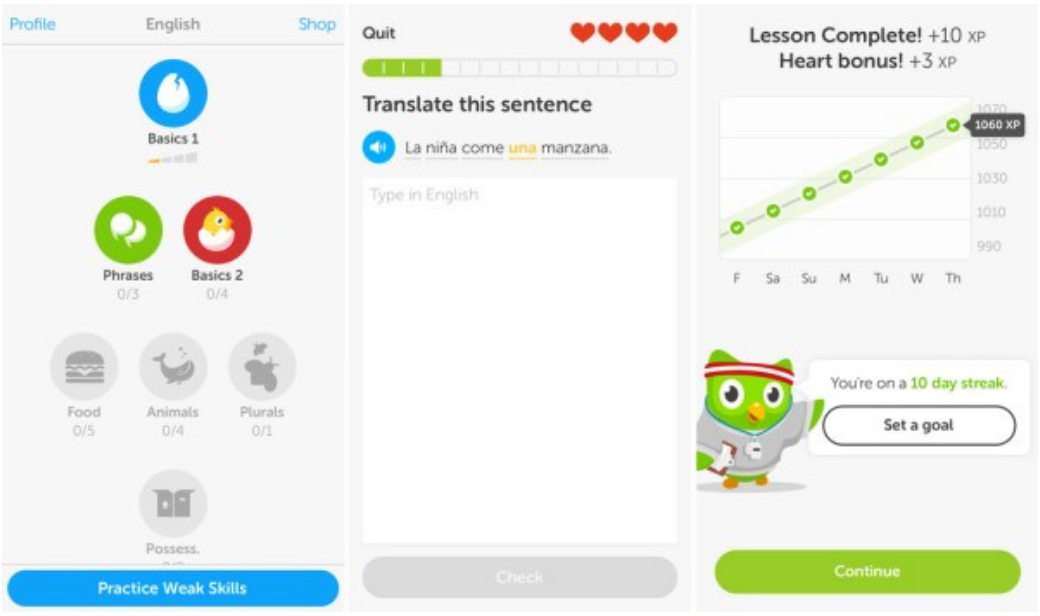

Figure 2.1: Duolingo extensive usage of gamification elements (badges, progress bars, achievements and etc) example.

their responses to the learners' actions for preserving favourable conditions for playing and learning.

2.2.1 Examples of influential serious games

There is a long list of successful implementations of serious games. Some them had purely scientific influence, some were educational, and others - influenced such areas as social life or politics.

The following list gives on overview of such games in the hronological order:

1. **Microsoft flight simulator** (1982). Flight Simulators are the grandfathers of serious games in general. But this one is considered to be the most famous one. Going since 1982 Microsoft Flight Simulator was designed to be a comprehensive simulation of civil aviation and it's one of the few non-combat flight simulators in existence. It is still maintained and updated. Last version release happened in 2014.

2. **Tiltfactor laboratory**[6] (2003). Established in 2003, serious game research centre, Tiltfactor Laboratory, saw success in the last few years with their innovative card games. The company's motto is "Game Design for Social Change" and with learning games like Pox and Awkward Moment, they teach players about serious topics like the impact of the anti-vaccination movements and avoiding social stereotypes.

3. **A force more powerful** (2006). In 1999, PBS released A Force More Powerful, a documentary about non-violent resistance. Breakaway Games developed a video game based on the series in collaboration with one of the leaders of Serbia's Otpor! Movement. The game was designed to teach nonviolent methods for waging conflict using player-built scenarios

[6] http://www.tiltfactor.org/games/

4. **Darfur is dying**[7] (2006). Between its launch in April 2006 and the following September, Darfur is Dying attracted 800,000 players. Under the umbrella of 'serious games', it is classified as a newsgame. In the journalistic spirit of exposing the truth, Darfur is Dying helped to shed a light on the war in Darfur and the consequent humanitarian disaster.

5. **Peacemaker**[8] (2007). Originally a university project, PeaceMaker became 'a video game to promote peace', focused on the Israeli-Palestine conflict. In this government simulator, players need represent one of the sides and make social, political and military decisions. The positive and negative consequences of these decisions teach the players about a vastly complex situation.

6. **World without oil**[9] (2007). "Play it – before you live it." So reads the tagline for World Without Oil, an alternate reality game (ARG) that lasted for 32 days in April-June, 2007. The game sought to make players understand how an oil crisis might affect their lives by getting them to describe how the crisis is affecting their area. After the 32 days were up, the game produced a valuable record to help anticipate problems and avoid a worst-case-scenario.

7. **Foldit**[10] (2008). Three years after its release, players of the online puzzle game, FoldIt helped decipher the crystal structure of the Mason-Pfizer monkey virus, an AIDS-causing virus. Although the solution had troubled medical science for the preceding 15 years, the combined efforts of thousands of players produced an accurate model of the enzyme in only 10 days.

8. **IBM city one** (2010). With the world becoming more industrialised, IBM's City One provides a comprehensive educational resource. City One is designed to simulate the complexities of urban planning from water management to finance planning. Maxis' Sim City created a similar challenge over 20 years previously. The reason Sim City isn't in this list is that it was primarily designed for entertainment.

9. **Amnesty the game** (2011). In this game, players take the role of a Special Amnesty International Agent tasked with convincing populations and governments to abolish the death penalty. While the game does a lot to publicise the work of Amnesty International in general, it also encourages people to consider a politically volatile subject from new angles.

10. **Superbetter**[11] (2012). Finally, Superbetter is the brainchild of Jane McGonigal – world renowned gamification guru. After she suffered a concussion in 2009, the resulting symptoms left Jane feeling depressed and suicidal. While she recovered, she created Jane the Concussion-Slayer, a game designed to treat her condition (as well as keeping her occupied). Seeing the success of JtC-S, she renamed it 'Superbetter' and developed a gamified application to help people achieve goals and overcome obstacles.

11. **Saving lives!**[12] (2018) Award-winning game. Based on current American Heart Association Guidelines for chest compression and rhythm, Saving Lives! helps players

[7] http://www.darfurisdying.com
[8] http://www.peacemakergame.com
[9] http://writerguy.com/wwo/metahome.htm
[10] https://fold.it/portal/
[11] https://www.superbetter.com
[12] https://itunes.apple.com/us/app/appclinic-saving-lives/id1308644239?mt=8

practice their foundational CPR and basic life support skillsets by administering CPR to a patient in a simulated emergency scenario.

2.3 Students' motivation

Motivation refers to psychological processes that are responsible for initiating and continuing goal directed behaviors.

In regard to a motivation, the impact of a gamification on some specific motivational mechanisms was studied, described in [37] and [9]. One way to study different motivational factors is to use Octalysis Framework [9]. The framework includes the following core drives of gamification:

1. Epic Meaning & Calling – players are doing something greater than themselves or they feel like they were "chosen" to do something
2. Development & Accomplishment – making progress, developing skills, and eventually overcoming challenges
3. Empowerment of Creativity & Feedback – users are engaging in a creative process where they have to repeatedly figure things out and try different combinations
4. Social Influence & Relatedness – all the social elements that drive people, including: mentorship, acceptance, social responses, companionship, as well as competition and envy
5. Unpredictability & Curiosity – wanting to find out what will happen next
6. Loss & Avoidance – motivation to avoid something negative from happening

Games should be meaningful to users. And there are 3 main domains how this can be achieved: create believes, rules, challenges; setting up goals and providing feedback; creating a free, safe 'play space'.

For the purpose of this essay it was analyzed how to make the task meaningful in regards to several of the principal perspectives of motivation (in gamification domain) [37]:

- trait perspective: individual stable motives (achievement motive, need for power, need for affiliation) can evoke motivation.
- behaviorist learning perspective: results from past positive and negative reinforcements, which influence the probability of future behavior.
- perspective of self - determination: focuses on social - contextual conditions.
- perspective of interest: individual preferences and content aspects.

What can we actually learn from these perspectives on motivation? Each perspective provides implications for practice. As we are interested in how different game elements could motivate students in given situations, these perspectives have to be analyzed precisely in a process-oriented way. Therefore motivational perspectives were examined for motivational mechanisms, which potentially could be addressed by certain game elements. These motivational mechanisms are described as basic effect hypotheses.

2.4 Matching Motivational Mechanisms and Game Elements[37]

After game elements and motivational mechanisms have been introduced, the question arises, which motivational mechanisms can be addressed by certain game elements. The answer to this question could be given by providing a sophisticated matrix with game elements listed in the rows and motivational mechanisms listed in the columns. Thereby the different motivational functions of game elements would become visible.

1. *Points* are very basic game elements. Although they seem to be very simple at a first glance, they can address motivational mechanisms mostly referring to a behaviourist learning perspective. The primary mechanisms are the following:

    - Points function as immediate positive reinforcements
    - Points can be seen as mostly virtual rewards, provided for executed actions

2. *Badges* are visual representations of achievements. Such badges systems can take different levels of complexity. Main motivational mechanisms addressed by badges are the following:

    - Badges fulfill the players' need for success and thereby address people with a strong power motive.
    - Badges work as virtual status symbols and thereby address people with a strong power motive.
    - Badges function as a form of group identification by communicating shared experiences and activities and thereby address people with a strong affiliation motive.
    - Badges also have a goal setting function.
    - Badges can foster the players' feeling of competence.

3. *Leaderboards* provide information about a players' success. Regarding motivation, this element can be seen critical, as only some people will stand on top of such leaderboards, while most of the other players will end up – presumably demotivated – at the bottom. Nevertheless leaderboards can also address certain mechanisms and if designed as team-score displays, they could show some additional motivational effects.

    - Individual leaderboards foster competition and address achievement and power motives.
    - For players at the top of leaderboards, feelings of competence can arise.
    - leaderboards, which provide a team-score, can foster the team members feelings of social relatedness, as they emphasise collaboration and community activities provided by shared goals and opportunities for shared experiences.

4. *Progress bars* and performance graphs each focus on individual players and their progress. While progress bars symbolize progression towards a goal, performance graphs furthermore compare the individual scores to previously achieved scores. The following mechanisms are activated:

- Both progress bars and performance graphs provide feedback.
- Progress bars provide clear goals.
- Performance graphs compare players' performance to previous performances and thereby focus on improvement and foster a mastery orientation regarding goals.

5. *Quests* are little tasks, which usually show a person the directly linked rewards. This fosters the transparency of a possible success of action. Thus following motivational mechanisms are primarily addressed:

   - Quests provide clear goals.
   - Quests highlight resulting consequences of a goal.
   - Quests emphasize importance of a players' action within a giver situation.

6. Meaningful stories are often wrapped around certain activities. This stories primary activate the following mechanisms:

   - Stories can meet the players' interest and spark interest for the situational context.
   - By offering a variety of stories and meaningful choices within the stories, feelings of autonomy can arise.
   - Inspiring stories can also foster and increase positive feelings.

7. *Avatars* and *profile development* relate to a player's visual representation in form of a chosen character, which can take different developmental stages. Primary motivational mechanisms are the following:

   - Choices regarding the offered avatars, which are leading to different forms of gameplay, can foster feelings of autonomy.
   - Positive feelings and emotional bonds can arise by providing avatars and by taking a developmental progress with the avatar.

Single elements can help to enhance certain feelings, like feelings of competence, autonomy and social relatedness, but these feelings tend to refer to an overall experience within the gamification environment. Also emotions rather refer to an experience, the player undergoes within gamification, then to single elements. Thus it is important to be aware of the relationship of different elements. Single elements fulfill different functions, but in interaction with each other they can have varying and complex motivational effects.

Chapter 3

Game analytics and data visualization

Inherently, playing a serious game produces highly individualised data trails that reflect the player's personal choices, behaviours and performances. Now that data mining and data analytics are gaining attention among educational researchers and practitioners, serious games would be an excellent target.

The Society for Learning Analytics Research, (http://www.solaresearch.org/) uses the topical term "*learning analytics*" to indicate "*... the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs*". This emerging field arouses high hopes for gaining new insights into educational practices and devising new ways to improve teaching and learning. These expectations certainly apply to serious games. Indeed most serious games dynamically capture user data for evaluating appropriate system responses to the player's actions. In most cases, however, progression in a game is guided by simple performance criteria: the only relevant thing would then be to check whether the player achieves sufficient performance milestones within the constraints of the game rules. Both the lack of established methods and tools for linking logging data directly to game play and practical constraints such as restrictions to time and budget, may hinder game developers to exploit the player's full history for creating detailed user model [47].

Serious games (and video games in general) are particularly well suited for data analysis. Their highly interactive nature, based on a constant loop of user input followed by game feedback, pose them as rich sources of interaction data. These interactions can be later analyzed to explore how users play, and, in the case of serious games, understand how users learn. The video game industry has been performing these types of analysis in commercial games for years, via *Game Analytics* (GA). One of the main uses of GA is to measure balance in gameplay: a balanced video game is one that keeps its players in the flow zone, a state where the player feels challenged by the game, but neither bored nor frustrated [8]. GA helps to locate parts inside games where players get stuck or quit; and moments where a game's mechanics or internal rules fall short. GA also provides clues on how to fix these problems. Commercial video games usually collect data from their players in a non-disruptive way, with tracking systems that go unnoticed by the players.

3.1 Data collection

Analysing serious game log data clearly fits within the wider framework of learning analytics: using the ever-growing amounts of data about learners' activities and interests for improving learning outcomes [42]. A related term is *educational data mining* [4]. While the focus of educational data mining is on methods for extracting the data, *learning analytics* concerns the development and application of predictive models in instructional systems [34]. However, Zouaq, Jocsimovíc and Gasevíc [52] concluded after text mining of a large number of research papers, that educational data mining and learning analytics are very much used as synonyms.

Research on intelligent tutoring systems in the early nineties collected detailed user data and analysed these for making improvements. In recent years datasets have grown larger and have become more easily accessible. From Learning Management Systems such as Moodle and Blackboard student logging data are easily extracted and combined with user profile data, access statistics and test scores. An early example of successful educational data mining at an institutional level is provided by the Signals project at Purdue University [2], which showed how student data can be used in predictive m2odels and lead to higher grades and retention rates than were observed in control groups. Also, growing interest in open educational content, open standards and MOOCS produces big sets of learner data. Likewise, mobile learning adds significantly to the multitude of user trails.

Although the most common tool to assess serious games are questionnaires [5], several authors have addressed the implications of using non-disruptive tracking for this task.

Authors have proposed a set of minimum requirements to enable automatic assessment in serious games, and have addressed the game design implications of combining learning analytics and serious games [20]. The project ADAGE [32] is a framework that defines several "assessment mechanics" that capture basic gameplay progression and critical achievements.

Other authors have implemented their own ad-hoc analytics to, for instance, analyze players' steps in a math puzzle to predict their movements based on current game state [25], assess learning outcomes analyzing answers to quizzes integrated in the game [12], or analyze how players progress in learning-language courses to create rich visualizations for teachers [48]. It may be considered that serious game designers must take into account analytics and assessment constraints from the inception of the game and throughout the design phase. Existing works usually do not address key serious-game aspects, such as how to deliver knowledge and educational contents through gameplay or how to infer the corresponding learning outcomes. To summarize, there is a research that describes effective analytics-aware serious game design, but lacks concrete methodologies to infer learning outcomes. On the other hand, there is research that proposes ways to analyze serious game learning outcomes, either via general frameworks or ad-hoc analysis, but without addressing the implications of that assessment in the game design.

There also exists a research [41], that proposes to combine both approaches to define a methodology that tackles all the phases in the development of a serious game, from game design and implementation, to deployment and learning outcome analysis. Their methodology pursues two goals:

1. to ease the measurement of serious game learning outcomes and
2. to provide a systematic way to assess the effectiveness of serious games as a whole

To achieve these goals, their approach covers the complete lifecycle of the serious game (3.1).

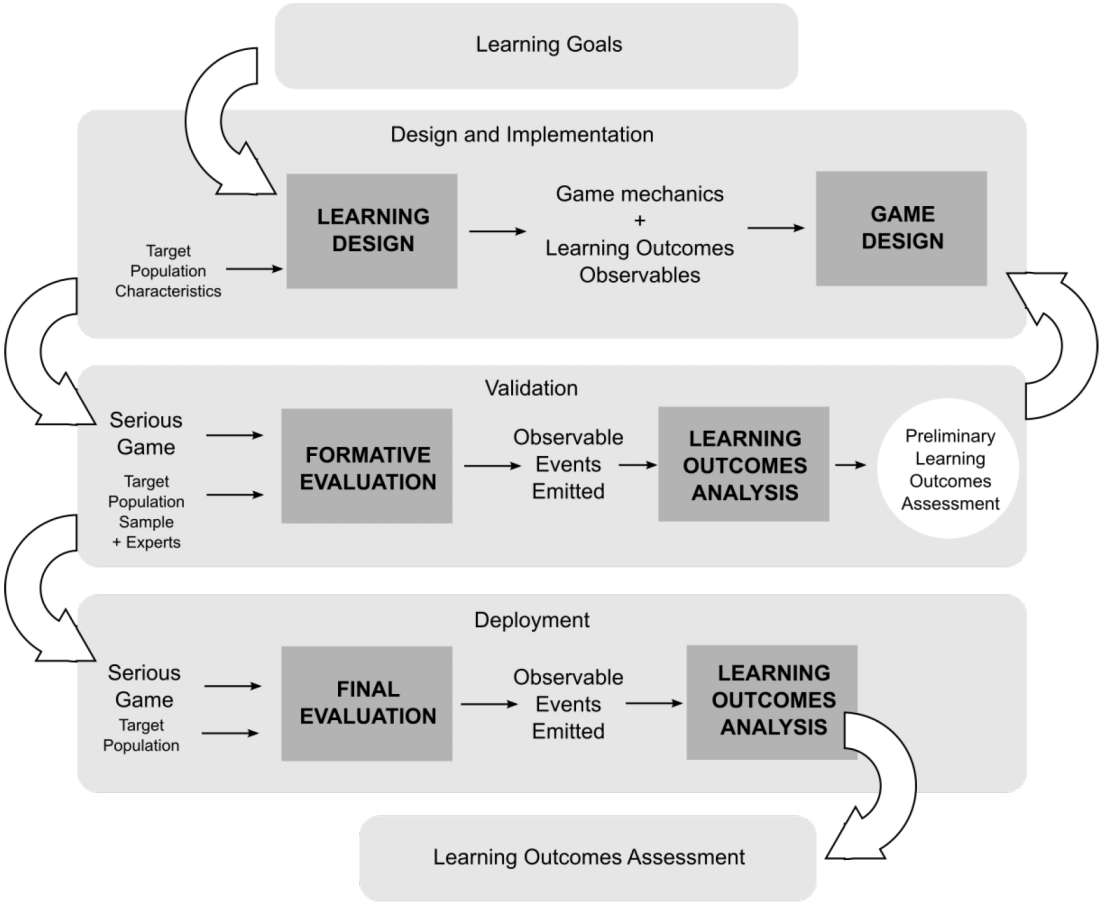

Figure 3.1: Serious game design and deployment process, with learning outcomes assessment[41]

The process starts in the design phase, where the learning goals and the target population are the basis to create a learning and game design. These designs combined are used to implement the game, which is then validated in a formative evaluation with a sample of the target population. This process is repeated until the game is fully validated. Then, the game is ready to be used by the target population (deployment).

3.2 Game analytics

To date a wide variety of methods and tools for the analysis of student data are available, including social network analysis, content analysis, discourse analysis, factor analysis, regression analysis, filtering and data visualisation. More specifically, the field of learning analytics focuses on tracking learning activities, and the context in which these activities occur, to promote awareness and reflection through algorithmic analysis or information visualization.

Recent studies in the UK notice considerable fragmentation of initiatives, though. Within higher and further education institutes different departments seem to work independently on their own solutions, for their own purposes, with their own tools (e.g. Excel, SPSS), while using their own datasets, e.g. library data, virtual learning environ-

ment, human resources, web statistics, student records, register of attendance, sensor data, curriculum data.

Research in the field mostly presents local cases and tailored solutions that aren't necessarily generalizable or transferable to other contexts. Gradually, however, harmonising efforts are made that propose generic frameworks or a shared set of approaches or technical standards.

Although learning analytics is generally qualified as an opportunity for improving the quality and effectiveness of learning, important concerns are raised because analytics could severely disempower and demotivate learners when they are provided with continuous feedback about their knowledge and performance gaps as compared with other students [10]. Also the capturing of unstructured personal traces across different platforms, social networks and contexts goes with some principle barriers linked with privacy protection and other legal issues [42]. These drawbacks also hold for serious gaming and should be taken into account.

3.3 Learning dashboards

Learning dashboards build on research in information visualization, learning analytics and educational data mining. It is a display which visualizes the results of educational data mining in a useful way.

Learning dashboards that have been deployed in recent years can be broadly categorized in three groups:

1. dashboards that support traditional face-to-face lectures;
2. dashboards that support face-to-face group work;
3. dashboards that support awareness, reflection, sensemaking, and behavior change in online or blended learning.

An educational dashboard holds various roles and values. First, it allows teachers to know students' learning status at real time and in a scalable way. In particular, in the online learning environment, where the teachers and learners are physically separated, students' learning activity pattern reported in the dashboard is useful. Second, it helps students themselves to improve self-knowledge by reviewing their learning status and history. Students can monitor their learning patterns through visualization of quantified information and refer to them as they modify their learning related plans and behaviors. Above all, as data mining technologies are advanced, the information displayed in the dashboard can lead to making more intelligent decisions. For example, a dashboard enables to identify at risk students or predict high performers as well as suggest proper feedbacks and guidelines to students. In a pedagogical approach, the dashboard may play a role to motivate students, improve their self-directed learning ability and help them achieve their learning goal effectively.

Research [50] provides a list of major educational dashboards that have been introduced through academic journals and international conferences:

1. Locoanalyst [1] - used to provide feedbacks on students' learning activities and performance

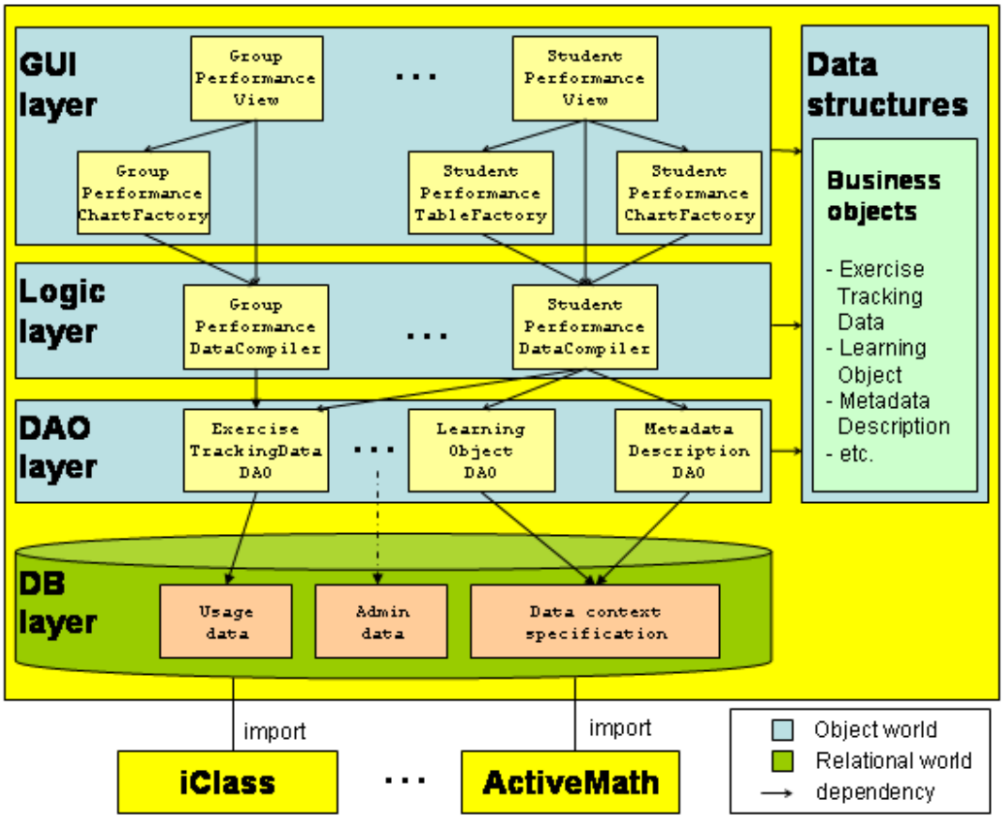

Figure 3.2: The STUDENT INSPECTOR's architecture [39]

2. Student Inspector [39] (Fig. 3.2) - to keep track of learners' interaction in e-learning systems
3. Students Success System [14] - to identify and treat at-risk students
4. Course Signal [2] - to improve retention and performance outcomes
5. GLASS [26] - to provide a visualization of learning performance with a comparison whole class group
6. Narcissus [45] (Fig. 3.3) - to help students see how well they are contributing to the group
7. Step-up [38] - to promote reflection and awareness of their activity

Good teachers know their students, and exploit this knowledge to adapt or optimize their instruction. Traditional teachers know their students because they interact with them face-to-face in classroom or one-to-one tutoring sessions. In these settings, they can build student models, i.e., by exploiting the multi-faceted nature of human-human communication. In distance-learning contexts, teacher and student have to cope with the lack of such direct interaction, and this must have detrimental effects for both teacher and student. In a past study we have analysed teacher requirements for tracking student actions in computer-mediated settings. Given the results of this study, we have devised and implemented a tool

Figure 3.3: The group view showing 20 days of activity of a group. Narcissus is structured with the visualisation on the left and an information panel on the right. Links for selecting one of three views are provided along the top. [45]

that allows teachers to keep track of their learners' interaction in e-learning systems. We present the tool's functionality and user interfaces, and an evaluation of its usability.

3.3.1 A dashboard

Because of the continuous progress in the areas of Information and Communication Technologies and fast-paced business environments, the amount of generated and consumed data increases significantly. This phenomenon is known as *information overload* [49]. It is the state, in which users are provided with too much information, which develops negative consequences. It may not influence only the task-related actions but also a health condition of the user. For example, a lower sense of task accomplishment might increase the stress level [27]. The problem evolves even more if we design the tools for using and representing the data poorly. This can lead to a situation when these tools distract users attention instead of helping them to make the decision. We can consider dashboards (Fig. 3.4) as one of the possible solutions to this problem. The well-designed dashboards should improve decision-making by supporting cognition and perception. Therefore, they should consist of appropriately chosen and arranged visual display media which can present a big amount of data in a meaningful way. It is crucial for the quick perception and processing of the data by the user [40].

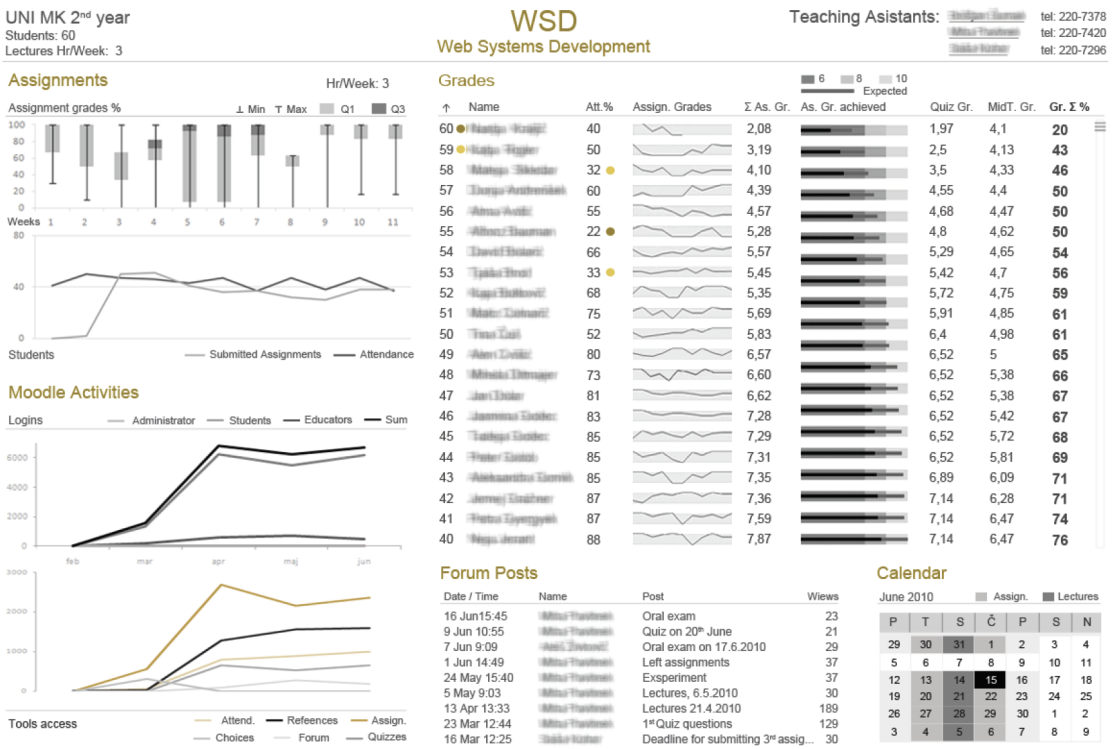

Figure 3.4: The example of the learning dashboard designed for lecturers. It contains the general data about the course, detailed overview of the grades, attendances, assignments and other information regarding education processes. Source of the dashboard: [35].

Few [15] stated that the well-designed dashboard is '*a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance.*' According to [29], the dashboard is '*a rich computer interface with charts, reports, visual indicators, and alert mechanisms that are consolidated into a dynamic and relevant information platform.*' The main idea of the dashboard is not only to display or visualize some specific data but also to be a useful tool in the decision-making process. It can help users monitor the status of key performance indicators or notify them when some measures are out of predefined bounds. A *performance dashboard* is 'a multi-layered application built on business intelligence and data integration infrastructure that enables organizations to measure, monitor, and manage business performance more effectively' [13]. The dashboard represents the presentation layer. It is a type of display and form of a presentation designed to communicate. Dashboards are composed of different data visualization tools, such as maps, charts, grids, and gauges. Each specific part of a dashboard, representing a specific type of information is called a *widget*.

Categorizing the dashboard plays an essential role in its development, as it may help to distinguish and select the main features and concepts of the design. According to [15], we can distinguish dashboards using several taxonomies, such as:

1. the role of the dashboard: analytical, operational, strategical
2. the data domain: executive, health-care, marketing, learning, performance

3. the type of data: quantitative, non-quantitative

4. interactivity: static display, interactive display

The prospective benefits and practical implications of data collected about users and processes are well-known and widely used in business intelligence [13]. However, the areas which could benefit from dashboards are not limited to the business environment only. Data analysis tools are widely used to predict customers' behavior and understand their motivation. Since students might be seen as customers within higher education institutions, the analysis and appropriate visualization of educational data can help to increase the efficiency of the studies and improve the learning process [35, 36]. In such case, we talk about the *learning dashboards*.

3.3.2 Using dashboards for educational data visualization and analysis

Education is a representative example of the area where rich datasets are involved. In the e-learning platforms, the information about the users might be gathered from various sources of context, such as forums and chats activity, assessments timings and results, comments with rating [38]. Combined with data analysis, the learning dashboards can lead teachers to discover students' performance patterns, predict problems and find motivational elements [35]. The information about the factors which affect learning is one of the most investigated questions in education [36]. The learning dashboard concept is based on such areas as the educational data mining, learning analytics, and information visualization. It is a single display that aggregates multiple visualizations of different indicators about learner(s), learning process(es) and learning context(s) [40]. An example of the learning dashboard is shown in Figure 3.4.

The introduction of advanced data visualization and reporting improves the understanding of current learning status of both the group and a specific student. When combined with some advanced data analysis, such as data mining, several implications are possible: to discover potential student groups with similar characteristics and reactions to a particular pedagogical strategy, to detect students' misuse or game-playing, to group students who are hint-driven or failure-driven and find common misconceptions that students possess, to identify learners with low motivation and find remedial actions to lower drop-out rates, to predict/classify students when using intelligent tutoring systems, etc.

Using the described information dashboards, some interesting patterns have been discovered in various researches. For example, [35], was trying to find out how to assess the motivation of students for a specific subject and to see how important the motivation is for students' success on exams. The potentially useful and also available data included: obligatory and optional assignments (number and time of views, submission time, mark), number and time of views of materials (lecture notes, additional sources, optional documents), etc. From this data the motivation level has been experimentally determined. Finally, this motivation level has been used together with other measurable attributes to predict the success of a student at the exams. Several models were built for this purpose and one such classification tree is presented on Fig. 3.5, with the error rate of 9.52 percents.

It can be interpreted in the following manner: if a student is highly motivated for a subject he/she will pass the exam; if a student is not highly motivated, the success will depend on the average grade (the lowest passing grade is 6 and the highest 10). The possible explanation is that students with higher average grade (either a conscientious student or a very bright one, or both) shall pass the exams even when they are not highly motivated.

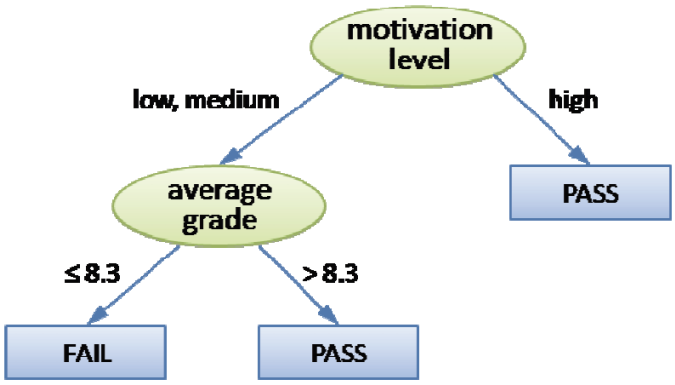

Figure 3.5: The obtained in [35] simple classification tree for predicting whether a student will pass or fail the exam.

3.3.3 Usability matters

The gathered information can be used to analyze students' behavior and the effectiveness of course design, to predict students' performance and their final mark, to group students according to their preferences, and to improve the educational process [51]. Many authors found that teachers rarely use this complex statistical data since it is predominantly numerical, and often incomprehensible, with a poor logical organization that is difficult to follow. Getting a clear vision of individual's or collaborate course progress is difficult and time consuming for instructors. And that's why presenting this data in a form of a well-structured dashboard is a promising solution.

We should design and develop dashboards appropriately to achieve their maximal usage and benefits. Researchers have shown that teachers hardly use raw statistical data of learning dashboards [51]. It is often more complicated to follow data presented textually than graphically. Thus, most of the researches regarding learning dashboards focus on identifying what data is meaningful to various stakeholders in the educational process, and how they should visualize these data [40]. Improving the data visualization quality and their logical organization is an important task not only for learning dashboards but all dashboards in general. [15] highlights that poorly designed dashboards would cause inefficient and ineffective communication. The science regarding the visual perception and sense-making is complicated, and those who develop dashboards do not always need to master it. Quantitative design guidelines should be developed to help the developers to design and implement appropriate dashboards without diving into this science.

3.3.4 Dashboards usability guidelines

Few's definition of dashboard establishes the design requirement: present the information consolidated and arranged on a single screen so the information can be monitored at a glance. A user should be able to get quickly familiarized with the content of the dashboard and find something that deserves attention. Few have provided a framework based on a knowledge of famous books regarding design and graphics e. g., [44, 46]. This framework contains guidelines for the dashboard design, including examples of well-designed dashboards. Examples of such guidelines are:

1. Eliminate the non-data pixels (decorations) to decrease the distraction of users (based on [44]).
2. Consider Gestalt principles to help a user recognize the logical groups better (based on [46]).
3. Select of appropriate charts and colors for emphasizing the relationship between data and highlighting of the critical information (Figure 3.6).

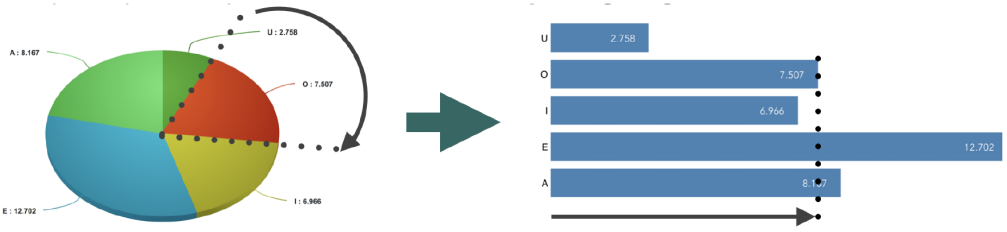

Figure 3.6: An example of the design guideline. It is easier to compare the values using the bar chart. It is also better to use one subtle color than several vivid colors which should be used to emphasize important information.

Even more than ten years after the release of Few's publication, we can still observe that the majority of dashboards ignore Few's design guidelines or express them in their own way. We assume that the reason might be the complexity and vague definition of the framework and the lack of other sources which would provide formal and quantitative knowledge in the area of dashboard design. Guidelines are usually described qualitatively, and it is difficult to convert them into a set of strict rules. For instance, the selection of appropriate charts and colors usually depends on an actual context, and it cannot be completely generalized. It is difficult to describe Gestalt principles formally as well as summarized by [23]. Hence, the guidelines are usually simplified into basic rules with limited usage. We described an example of simple quantitative dashboard design metrics and guidelines [22]. We have shown that we can distinguish the well-designed dashboards by the measuring of their overall colorfulness or analysis of their histograms. However, metrics consider UI screen as a matrix of pixels which does not correspond with user perception.

One possible step in improving the metric-based evaluation is to analyze the objects (*widgets*) in the screen and their properties (e.g., size or position) as described by [7]. The objects are usually represented by their boundaries. The analysis of objects in the screen is more similar to the real interpretation of the screen by a human than the analysis of particular pixels (objects within the scene as described by [3]). [31] have published an example of advanced object-based metrics. They provide 13 metrics measuring aesthetic aspects of the screen.

Possible solution to improving the dashboards usability is described in [33]. That research describes a framework for generating and gradually improving the quality of dashboard samples. Hence, the optimized design guidelines might be produced.

Chapter 4

Conclusion

This essay covers the broad area of such innovative educational methods, as gamification and serious games.

Since this is mainly just a theoretical state of the art, the future work lies in the practical are of the implementation of the gamified framework. Some part of it is already done, in a form of a single gamified exercise for learning jQuery in a Web Development course at VUT FIT. Next steps include more testing and evaluation, and also developing more tasks to cover other topics. After this, machine learning should be used to build an extensive learning dashboard in order to improve learning analytics.

Bibliography

[1] Ali, L.; Hatala, M.; Gašević, D.; et al.: A qualitative evaluation of evolution of a learning analytics tool. *Computers & Education*. vol. 58, no. 1. 2012: pp. 470–489.

[2] Arnold, K. E.; Pistilli, M. D.: Course signals at Purdue: Using learning analytics to increase student success. In *Proceedings of the 2nd international conference on learning analytics and knowledge*. ACM. 2012. pp. 267–270.

[3] Baker, J.; Jones, D.; Burkman, J.: Using visual representations of data to enhance sensemaking in data exploration tasks. *Journal of the Association for Information Systems*. vol. 10, no. 7. 2009: page 2.

[4] Bakhshinategh, B.; Zaiane, O. R.; ElAtia, S.; et al.: Educational data mining applications and tasks: A survey of the last 10 years. *Education and Information Technologies*. vol. 23, no. 1. 2018: pp. 537–553.

[5] Calderón, A.; Ruiz, M.: A systematic literature review on serious games evaluation: An application to software project management. *Computers & Education*. vol. 87. 2015: pp. 396–422.

[6] Caponetto, I.; Earp, J.; Ott, M.: Gamification and education: A literature review. In *European Conference on Games Based Learning*, vol. 1. Academic Conferences International Limited. 2014. page 50.

[7] Charfi, S.; Trabelsi, A.; Ezzedine, H.; et al.: Widgets dedicated to user interface evaluation. *International Journal of Human-Computer Interaction*. vol. 30, no. 5. 2014: pp. 408–421. doi:10.1080/10447318.2013.873280.

[8] Chen, J.: Flow in games (and everything else). *Communications of the ACM*. vol. 50, no. 4. 2007: pp. 31–34.

[9] Chou, Y.-k.: *Actionable gamification: Beyond points, badges, and leaderboards*. Octalysis Group. 2015.

[10] Crawford, K.; et al.: Six provocations for big data. 2011.

[11] Deterding, S.; Dixon, D.; Khaled, R.; et al.: From game design elements to gamefulness: defining gamification. In *Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments*. ACM. 2011. pp. 9–15.

[12] Dudzinski, M.; Greenhill, D.; Kayyali, R.; et al.: The design and evaluation of a multiplayer serious game for pharmacy students. In *European Conference on Games Based Learning*. Academic Conferences International Limited. 2013. page 140.

[13] Eckerson, W. W.: *Performance dashboards: measuring, monitoring, and managing your business*. John Wiley & Sons. 2010.

[14] Essa, A.; Ayad, H.: Student success system: risk analytics and data visualization using ensembles of predictive models. In *Proceedings of the 2nd international conference on learning analytics and knowledge*. ACM. 2012. pp. 158–161.

[15] Few, S.: *Information dashboard design*. O'Reilly Sebastopol, CA. 2006.

[16] Fischer, H.; Heinz, M.; Schlenker, L.; et al.: Gamifying higher education. Beyond badges, points and Leaderboards. In *Proceedings of the 11th International Forum on Knowledge Asset Dynamics. IFKAD*. 2016. pp. 15–17.

[17] Fitz-Walter, Z. J.: *Achievement unlocked: Investigating the design of effective gamification experiences for mobile applications and devices*. PhD. Thesis. Queensland University of Technology. 2015.

[18] Glover, I.: Play as you learn: gamification as a technique for motivating learners. In *EdMedia: World Conference on Educational Media and Technology*. Association for the Advancement of Computing in Education (AACE). 2013. pp. 1999–2008.

[19] Hamari, J.; Koivisto, J.: Social Motivations To Use Gamification: An Empirical Study Of Gamifying Exercise. In *ECIS*, vol. 105. 2013.

[20] Hauge, J. B.; Berta, R.; Fiucci, G.; et al.: Implications of learning analytics for serious game design. In *Advanced Learning Technologies (ICALT), 2014 IEEE 14th International Conference on*. IEEE. 2014. pp. 230–232.

[21] Hense, J.; Mandl, H.: Learning in or with Games? In *Digital systems for open access to formal and informal learning*. Springer. 2014. pp. 181–193.

[22] Hynek, J.; Hruška, T.: Pixel-based analysis of information dashboard attributes. In *East European Conference on Advances in Databases and Information Systems*. Springer. 2016. pp. 29–36. doi:10.1007/978-3-319-44066-8_3.

[23] Jäkel, F.; Singh, M.; Wichmann, F. A.; et al.: An overview of quantitative approaches in Gestalt perception. *Vision research*. vol. 126. 2016: pp. 3–8. doi:10.1016/j.visres.2016.06.004.

[24] Khalil, M.; Wong, J.; de Koning, B.; et al.: Gamification in MOOCs: A Review of the State of the Art. In *Global Engineering Education Conference (EDUCON), 2018 IEEE*. IEEE. 2018. pp. 1629–1638.

[25] Lee, S. J.; Liu, Y.-E.; Popovic, Z.: Learning individual behavior in an educational game: a data-driven approach. In *Educational Data Mining 2014*. 2014.

[26] Leony, D.; Pardo, A.; de la Fuente Valentín, L.; et al.: GLASS: a learning analytics visualization tool. In *Proceedings of the 2nd international conference on learning analytics and knowledge*. ACM. 2012. pp. 162–163.

[27] Levy, D. M.: Information overload. *The handbook of information and computer ethics*. 2008: page 497.

[28] Mahdizadeh, H.; Biemans, H.; Mulder, M.: Determining factors of the use of e-learning environments by university teachers. *Computers & Education*. vol. 51, no. 1. 2008: pp. 142–154.

[29] Malik, S.: *Enterprise dashboards: design and best practices for IT*. John Wiley & Sons. 2005.

[30] Michael, D. R.; Chen, S. L.: Serious games. games that educate, train, and inform (Lernmaterialien): Games that educate, train, and info. 2005.

[31] Ngo, D. C. L.; Teo, L. S.; Byrne, J. G.: Modelling interface aesthetics. *Information Sciences*. vol. 152. 2003: pp. 25–46. doi:\mbox{10.1016/S0020-0255(02)00404-8}.

[32] Owen, V. E.; Ramirez, D.; Salmon, A.; et al.: Capturing learner trajectories in educational games through ADAGE (Assessment Data Aggregator for Game Environments): a click-stream data framework for assessment of learning in play. In *American Educational Research Association Annual Meeting*. 2014. pp. 1–7.

[33] Pastushenko, O.; Hynek, J.; Hruška, T.: Generation of Test Samples for Construction of Dashboard Design Guidelines: Impact of Color on Layout Balance. In *World Conference on Information Systems and Technologies*. Springer. 2018. pp. 980–990. doi:10.1007/978-3-319-77712-2_93.

[34] Peters, M. A.; Araya, D.: Transforming american education: learning powered by technology. 2011.

[35] Podgorelec, V.; Kuhar, S.: Taking advantage of education data: Advanced data analysis and reporting in virtual learning environments. *Elektronika ir Elektrotechnika*. vol. 114, no. 8. 2011: pp. 111–116. doi:10.5755/j01.eee.114.8.708.

[36] Ruipérez-Valiente, J. A.; Muñoz-Merino, P. J.; Delgado Kloos, C.: Improving the prediction of learning outcomes in educational platforms including higher level interaction indicators. *Expert Systems*: page e12298. doi:10.1111/exsy.12298.

[37] Sailer, M.; Hense, J.; Mandl, H.; et al.: Psychological perspectives on motivation through gamification. *IxD&A*. vol. 19. 2013: pp. 28–37.

[38] Santos, O. C.; Boticario, J. G.: User-centred design and educational data mining support during the recommendations elicitation process in social online learning environments. *Expert Systems*. vol. 32, no. 2. 2015: pp. 293–311. doi:10.1111/exsy.12041.

[39] Scheu, O.; Zinn, C.: How did the e-learning session go? The Student Inspector. In *13th International Conference on Artificial Intelligence and Education (AIED 2007)*. IOS Press. 2007.

[40] Schwendimann, B. A.; Rodríguez-Triana, M. J.; Vozniuk, A.; et al.: Understanding learning at a glance: An overview of learning dashboard studies. In *Proceedings of the sixth international conference on learning analytics & knowledge*. 2016. pp. 532–533. doi:10.1111/exsy.12298.

[41] Serrano-Laguna, Á.; Manero, B.; Freire, M.; et al.: A methodology for assessing the effectiveness of serious games and for inferring player learning outcomes. *Multimedia Tools and Applications*. vol. 77, no. 2. 2018: pp. 2849–2871.

[42] Shum, S. B.; Ferguson, R.: Social learning analytics. *Journal of educational technology & society*. vol. 15, no. 3. 2012.

[43] Szabó, K.; Szemere, A.: Engaging students in higher education: some considerations on the relation between gamification, motivation, and flow. *RICERCAZIONE*. 2017: page 51.

[44] Tufte, E. R.: *The Visual Display of Quantitative Information*. Graphic Press. 1983.

[45] Upton, K.; Kay, J.: Narcissus: group and individual models to support small group work. In *International Conference on User Modeling, Adaptation, and Personalization*. Springer. 2009. pp. 54–65.

[46] Ware, C.: *Information visualization: perception for design*. Elsevier. 2012.

[47] Westera, W.; Nadolski, R.; Hummel, H.: Serious gaming analytics: What students log files tell us about gaming and learning. 2014.

[48] Ye, F.: Validity, reliability, and concordance of the Duolingo English Test. *Google Scholar*. 2014.

[49] Yigitbasioglu, O. M.; Velcu, O.: A review of dashboards in performance management: Implications for design and research. *International Journal of Accounting Information Systems*. vol. 13, no. 1. 2012: pp. 41–59. doi:10.1016/j.accinf.2011.08.002.

[50] Yoo, Y.; Lee, H.; Jo, I.-H.; et al.: Educational dashboards for smart learning: Review of case studies. In *Emerging issues in smart learning*. Springer. 2015. pp. 145–155.

[51] Zorrilla, M.; García, D.; Álvarez, E.: A decision support system to improve e-learning environments. In *Proceedings of the 2010 EDBT/ICDT Workshops*. ACM. 2010. page 11. doi:10.1145/1754239.1754252.

[52] Zouaq, A.; Joksimovic, S.; Gasevic, D.: Ontology Learning to Analyze Research Trends in Learning Analytics Publications. In *LAK (Data Challenge)*. 2013.