Ontology based UX Personalization for Gamified Education

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Abstract: Gamification techniques are increasingly used in education, both in private and public sectors. These game design elements need to be carefully tailored to the students, considering a variety of factors if we want positive results. The key hindrance is the lack of systematic basic research in mapping out the connections between the metrics of the student and the game mechanics used. In this paper we present a conceptual framework for gamification implementation improvement. We show how ontologies and ontology-based reasoning can improve the basic research and the application of gamification in education.

1 INTRODUCTION

In the last decade there has been increased research into the gamification of learning. It is an educational approach to motivate students to learn by using video game design and game elements in learning environments (Shatz, 2015). Some of these elements in their turn come from psychology, entertainment (Skinner, 1935). The goal is to maximize enjoyment and engagement through capturing the interest of learners and inspiring them to continue learning. It must be clarified that gamification is not "Edutainment" and maximizing enjoyment should be to the point where it still aids in learning.

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.

At the current technological state, certain fields lend themselves for automated checking and grading better than others. Automated grading in computer science is reasonably achievable, it would however be practically impossible for modern art. We chose computer science because of this technical reason. Checking and grading computer science assignments have several problems associated with it (Cheang et al., 2003). The institution needs experienced/trained personnel to do the job. It is highly labor intensive to check a classroom full of students' work, while also helping them with their individual problems.

The work entails:

- checking if the solution is working as specified
- checking whether study material specific technical details have been met
- checking coding style
- checking for plagiarism

These by themselves can be hard problems to solve. It is also a problem for educators to properly teach while accomplishing the above in the short time available. Automation is a great tool, but it can be used for more when combined with gamification techniques.

The aim is to create a solution that allows for the easy use of gamification, is the most applicable in education and facilitates basic research in the field. Personalizing and automating part of the learning experience using ontologies allows for both. While there are several good studies recently that use ontologies with gamification the aim tends to add gamification features to an existing environment instead of personalizing them (Garcia et al., 2017). Testing a new hypothesis requires only defining it and learners who met the criteria will experience the automatically ad-

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justed mechanics and user interface. After trial the data needs analysis. In the meantime, changing the ontology to reflect the best current research will yield the learning experience best supported by science.

When tailoring structural and semantic elements on the individual level we need to base these on the learner's measurements. We consider 3 types of data into our model, but the model can be expanded to use more or to ignore some. The 3 measurements considered are:

- Narrative preferences, see Section 3.1
- Personality traits (Big 5), see Section 3.3
- Player types (Bartle), see Section 3.4

This paper is organized as follows: Related work on gamification of education in Section 2, description of system and model components in Section 3, model and implementation details in Section 4, conclusion and further work in Section 5, and finally acknowledgements and references.

2 BACKGROUND

A literature review of empirical studies shows that gamification works (Hamari et al., 2014). It also shows that it is not a silver bullet, and it needs to be tailored. We can conclude that context is of high importance when applying these techniques. If the context is ignored, then gamification techniques do not always work. Adding achievements and social comparison to a purely utilitarian service had no effect on the great majority of users and small effect for the rest (Hamari, 2013). The authors point out that hedonistic or mixed context favor gamification.

Gamification elements in education have been around for a long time, but gamification as a concept and its systematic application have only been used for a decade or so. A systematic review of gamification in education has shown that there is an increasing trend to use these elements (Dicheva et al., 2015). Most applications, according to the study, focus on a small number of game mechanics. Context matters in the application, but it is not always considered.

Gamification in the industry has a wider scope (Raftopoulos et al., 2015). The primary purpose according to the study are: customer loyalty, marketing, education, recruitment, innovation, community development, and motivation. The target audience: internal staff, customers, suppliers, community. With the wider scope, compared to the education of students, one gets a greater variety in techniques.

The effect of extrinsic rewards on schoolchildren can have detrimental effects so care must be taken, less so on university students (Deci et al., 2001). If care is taken, extrinsic motivators can increase intrinsic motivators. The optimum approach, according to the meta-analysis, is to provide more interesting activities, more choice, and ensure tasks are optimally challenging. Reward types and contingencies should be informational rather than controlling.

In the case of JFDI Academy the authors used several predefined gamification elements applied at group level. They taught introductory programming as an online game (Leong et al., 2011). They used the narrative of a Sci-Fi world, had achievements, missions, a 24h grading feedback loop. The results were positive, with marginally larger grades for a similar quantity of work, compared to previous semesters.

3 SYSTEM COMPONENTS

3.1 Gamification Elements

The most accepted definition of Gamification is: *"The use of design elements characteristic for games in non-game contexts"* (Deterding et al., 2011). This definition leaves us with a wide array of tools, game mechanics, and design choices of how and what to implement for our learners. In the industry and private sector many game mechanics have been tried in various contexts (Raftopoulos et al., 2015). And it should be mentioned that only a subset of all mechanics should be used in a system. To reduce the scope of the model, only the most common elements have been integrated into our ontology.

Instant feedback is one of the basic gamification tools. It shortens the work-reward cycle and it is doable on computers. In the case of computationally intensive checks, small artificial delays can be added in the animation to give the impression of instant feedback. The classical example is a loading screen, which is displayed while the application starts up, giving the impression of something happening in the mean-time.

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. Certain systems apply multiple point types to balance objectives. Most often they are called points. In education, these usually take the form of grades, in a role-playing game(RPG) setting they are usually called experience.

Achievements or badges are specific rewards for a prespecified behavior separate from points and usually unique. Real world examples are medals in the military or merit badges in the scouts. The obtainment of badges represents extra goals, and some player types go out of their way to obtain them, mainly the achiever. By tailoring achievements to player types (Bartle, 1996) on a structural or semantic level greater interest can be achieved.

Missions and quests represent objectives to strive for. They may be required or optional. In this context they must be clear and verifiable.

Status, success, recognition is usually implemented in the form of leaderboards. These are lists of some or all participants, ordered usually by the number of points gathered. The primary role of leaderboards is to show status and skill, it can be a great motivator or demotivator depending on the context.

The concept of *leveling* is a progression mechanic, it originates from tabletop RPGs (Gygax and Arneson, 1974). After acquiring several points (usually referred to as experience) a milestone is reached. By tying bonuses to a level, it becomes a good motivational tool and a measure of progress. Leveling is different from levels in games, the former is essentially a set of milestones optionally accompanied by rewards, the latter is the stage where the game is played.

Narrative is one of the strong suits of games. A story aids in immersion and gives a sense of purpose to solving exercises. The two pitfalls of a narrative in a gamification setting are quality and specificity. A poorly written narrative can detract from the experience more than it can add to it, in these situations no narrative is the better option. On the aspect of specificity, if all other elements of the experience being the same, people react differently to different types of stories. Personalized story genre delivery is possible using software, even if it's labor intensive to prepare.

3.2 Automated Grading

This paper is a continuation of our work on (Zsigmond, 2019). To achieve instant feedback, it is necessary to automatically check the learner's solution to a task. The problem of automatic analysis and grading ranges from the complicated to the impossible. For the study of computer science, it usually boils down to: correctness check, coding style check, plagiarism check and various specific technical details check. Correctness check means to verify that the program runs according to specification. Specification in this context means that the program having received certain input under certain preconditions produces an expected output that meets the postconditions. The most widely used method to check this is to run the program with a set of provided inputs and expect a set of outputs. This can be automated if the program that is tested is monitored by another program written for this purpose.

Code style check is a subset of static code analysis, that verifies that the code is in accordance with readability, structure and documentation guidelines. In academia and business this is usually done by an experienced programmer aided by static code analysis. Many tools have been created to automate as much of this process as possible (Emanuelsson and Nilsson, 2008). These tools can be used to automate sufficient amount of the process to aid gamification efforts.

Plagiarism check is verifying if the students try to cheat by copying their peer's work. Plagiarism check is one of the necessary functionalities that cannot be completely automated. (Hage et al., 2010) Even though it cannot be fully automated this functionality needs not be fast. Main issues are project files that are generated by various integrated development environments that should not be checked and that sometimes it leads to false positives which would be detrimental to learning. There are many special cases and situations in practice that would lead to false positives. Our solution was to take the reports generated by Stanford's Measure Of Software Similarity tool (MOSS) (Schleimer et al., 2003) and check the ones with high similarity manually.

By various specific technical details check we mean tests that are specific to any given course. These need to be customized to the course and can be anything from object inheritance to SQL queries. The main issue here is that these custom checks need to be integrated in the system in a dynamic way.

Solutions that aim to do this can be found that are smaller in scale (Cheang et al., 2003), and as such the field to cover is vast. With that in mind this section will only focus on gamification of learning.

3.3 Psychological Traits

In psychology, traits can be defined as relatively long-term patterns of behavior, thought, and emotion, which differ on an individual basis. We choose to use in our model the Big Five personality traits taxonomy, which is widely used in psychology (Goldberg, 1993). This theory uses descriptors of common language and association between words to categorize individuals and suggests five broad dimensions commonly used to describe the human personality. The five factors have been defined as openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism. The validity of these traits in education has been experimentally verified (Poropat, 2009). Each trait consists of facets, or dimensions which are used to measure it. In the following short descriptions of the different traits and their facets we list only those on the high end of the spectrum. If a person would score low on a spectrum they would be considered the opposite of the facet listed below. For example, high dutifulness would follow the rules, while low dutifulness would break the rules.

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.

3.4 Player Types

In Bartle taxonomy of player types, 4 player types are defined: Killers Achievers, Socializers, and Explorers (Bartle, 1996). 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. Each player falls on the spectrum of these scales.

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 for the social aspects 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 we need to ensure that in the context of education where learners join from the entire spectrum we do not ignore any player type. In the context of personalization this means that certain features need to be exaggerated or dropped completely based on player needs. Our taxonomies and decision making must take this aspect into account.

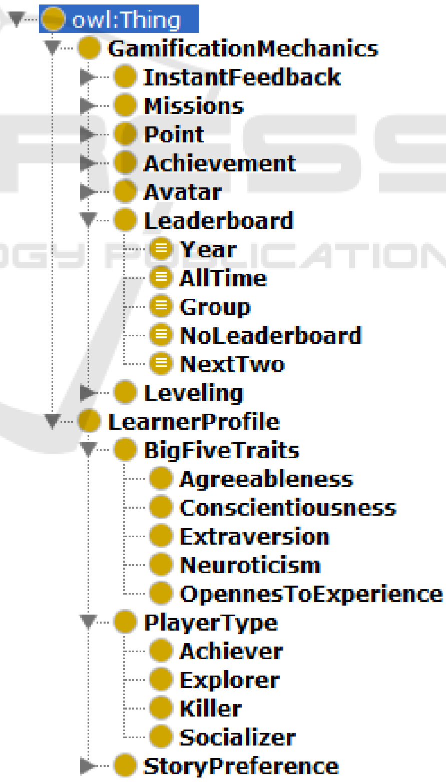

Figure 1: Ontology excerpt of Game Mechanics and Learner Profile.

3.5 Ontology and Ontology-based Reasoning

The classical definition of an ontology as often used is "explicit specification of a conceptualization" (Gruber, 1995). In a more practical, computer science perspective it boils down to modeling a domain of knowledge with the use of classes, attributes and relations between classes.

Ontologies are used in most fields to organize data into knowledge, usually in the form of taxonomies. The power of these formalisms is in being an adaptor between fields by experts agreeing on the relation between their terms.

In the field of education Ciuciu (Ciuciu and Tang, 2010) mentions DOGMA paradigm Developing Ontology Grounded Methodology and Applications. In the paper they use DOGMA to create personalized testing and suggestion for further study of medicine, here they use ODMF (Tang et al., 2010) for matching. Yu (Yu et al., 2008) recommends content provisioning for context-aware ubiquitous learning, Baloian's (Baloian et al., 2004) approach considers the learner's preferences and available resources to recommend learning material, while Schmidt (Schmidt and Winterhalter, 2004) tries modeling the learner's environment to capture the required context for e-Learning material delivery.

In our work we focused on mapping on the one hand psychological traits, player types, and narrative preferences measured for individuals to gamification elements. While presenting the ontology is not the focus of this paper, we included excerpts to illustrate the proposed solution, see Figure 1.

4 PROPOSED SYSTEM

4.1 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 show them and several experiences that they yield. Different metrics need to be associated to different types, within one game mechanic. In Figure 2 we illustrate the five different sub-types for the leaderboard mechanic and the metric influencers. The subtypes are: no leaderboard, showing only the next two students the rest being hidden, all students in the group/team, everybody in the year/currently in the company, and everybody since there are metrics. To this game mechanic, all player types contribute, but only Neuroticism, and Extraversion on the traits side.

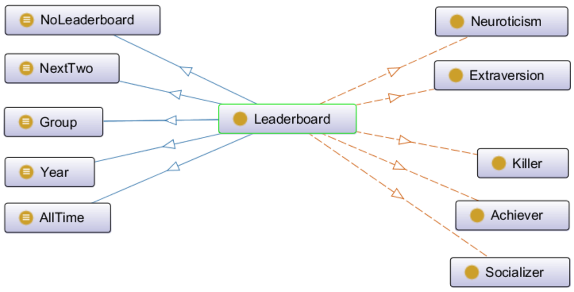

Figure 2: Leaderboard mechanic subtypes and metric influencers.

The solution we propose is 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 Extraversion 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 disjunct. The mathematical formula is:

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

For an example of values used for the Leaderboard mechanic see Table. 1. To see an implementation of the formula for NextTwo variant of the Leaderboard mechanic in protégé see Fig. 3. For consistency the values for neuroticism values are inverted using the 100-NeuroticismValue formula.

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 ontology can be queried using SPARQL to get the structural and semantic gamification elements for a

Table 1: Proposed values for Leaderboard mechanic.

		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

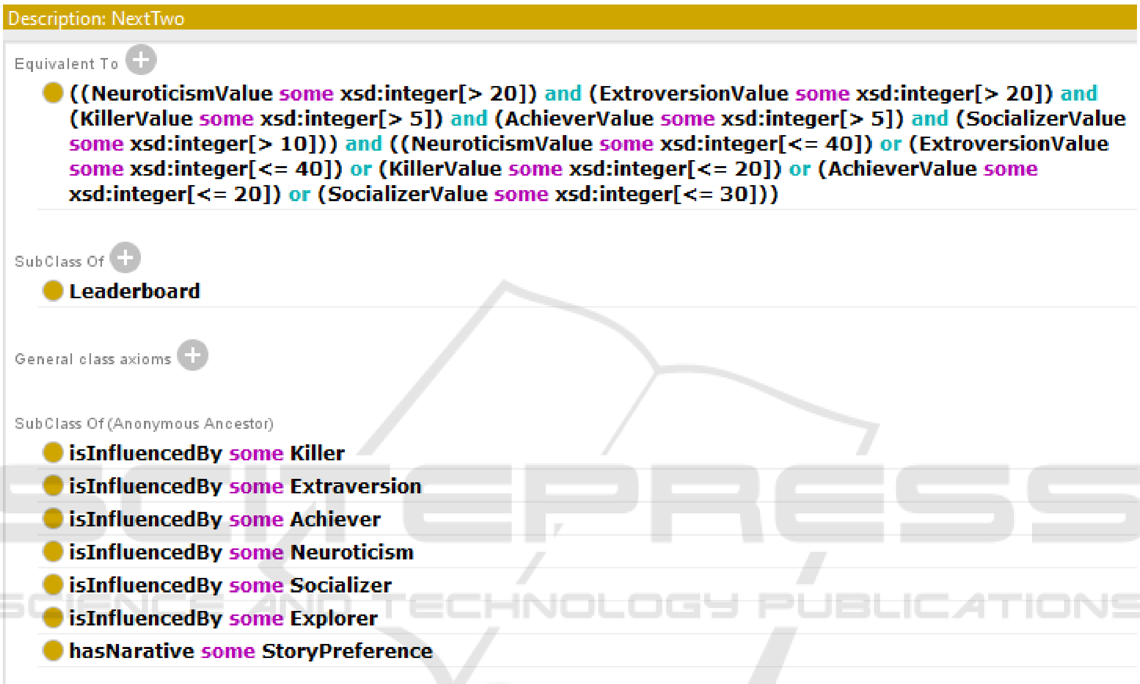

Figure 3: NextTwo variant of the Leaderboard mechanic implementation in protégé.

given learner. Example of a structural element would be a Leaderboard sub-type, while semantic would be Story Preference sub-type.

4.2 GamifyCS Project

The proposed system (Zsigmond, 2019) is partially implemented as a functional website written in ASP.NET MVC. The system is being used for academic research and evaluation purposes. It is being further developed to serve as a gamification test-bench and scientific tool. The user interface was designed to be minimalist and responsive. The goal was to remove distractions and appeal to the current generation's standards.

For successful usage of the ontology based UX tailoring, as well as data gathering for the psychological thresholds, we needed a platform to support the various gamification mechanics mentioned. Each mechanic on it's own requires certain technical solutions. These are the mechanics, and the way they were either implemented or prototyped in our system. An architectural view of the project with currently used and prototyped subsystems can be found in Figure 4.

The described ontology was created and tested in protégé. Integration with the GamifyCS project was prototyped and full integration awaits further gamification mechanic implementations and a validating experiment. The measurement of Big 5 personality traits and determination of Player types is beyond the scope of this project and should be measured by standardized tools. Once they are made and imported, the values must be converted to the 0-100 scale which the ontology uses.

Instant feedback: The most notorious from a technical point of view, we had to implement an automated correctness checking mechanism. Since the tool had to support a wide range of programming lan-

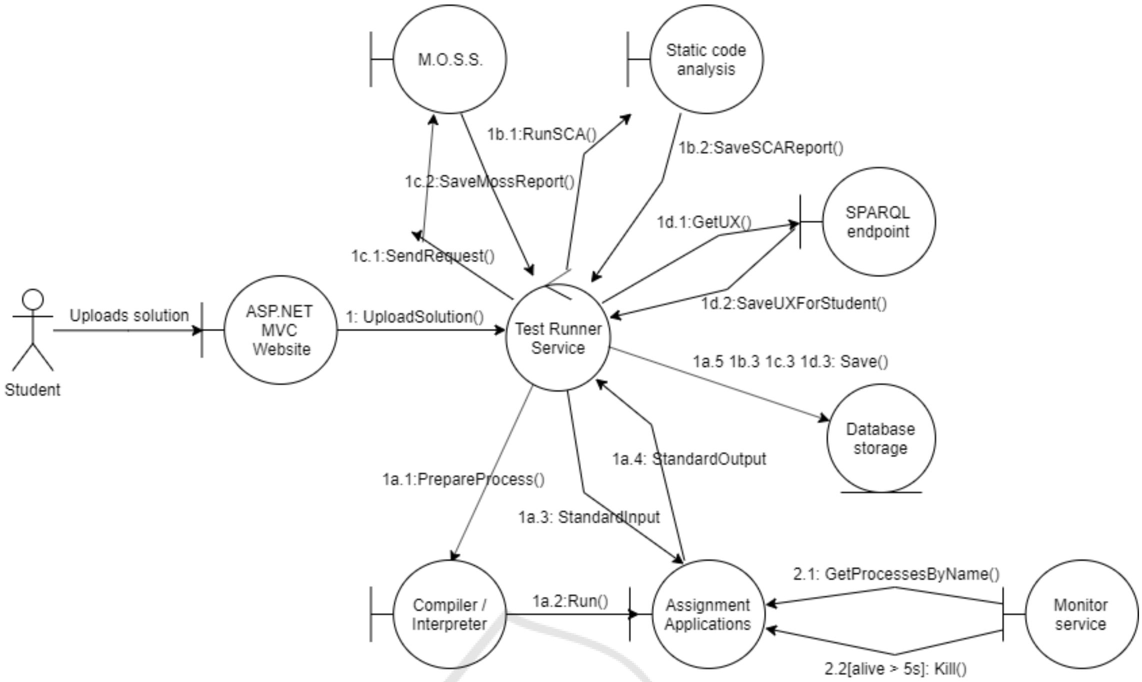

Figure 4: Architectecture of GamifyCS project.

guages we opted for an external compiler / interpreter. In our latest study the students uploaded their solutions, we compiled / interpreted their code, redirected the standard input/output then ran a predefined sequence of provided inputs and expected outputs. Then displayed the results in under a second.

Narrative and Missions: In our latest study students could choose among 4 different story styles. We created the website such that students could be assigned any number of exercises, which in turn had 4 different texts associated to them for each narrative style. While doing the same exercise different students would see read about their assignments as if part of that world.

Achievements: We prototyped awarding achievements based on static code analysis and completed assignments. A predefined logic together with a picture and description was created for each of the 5 prototyped achievements and the infrastructure to award them. This remains the subject of our next study.

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 tests for a given exercise or mission was created but proved to cumbersome to use in practice. A rewriting of the feature is future work. 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 fully integrated achievement system.

5 CONCLUDING REMARKS

The focus of the paper was to create a solution that allows for the easy use of gamification, is the most applicable in education and facilitates basic research in the field. We feel that personalizing the learning experience using ontologies achieves both. Testing a new hypothesis requires only defining it and learners who met the criteria will experience the automatically adjusted mechanics and user interface. In the meantime, changing the ontology to reflect the best current research will yield the learning experience best supported by science.

The system developed has great potential for experimentation. It is also an opportunity for education. Since it allows for features to be switched off via ontology and can be freely extended various experiments can designed around the tool. Since we store various code and usage data, data mining methods can be used to improve the tool and the experience in the future.

The further features that should be added to the system are: continually refine the ontology, use full blown sandboxes to run the executables in, the support for running queues to balance load and improve measurements, the support for more programming languages and UI languages.

Since the field of gamification is vast and so far under-researched, there are many techniques that should be added and tried, considerations for pacing might be added, for example, as well as for mastery to fuse in solutions that facilitate the study of fine grained computer knowledge.

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