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GAMIFICATION OF BLENDED LEARNING WITH CHALLENGE UNICORDER^{TM*}

Trayan Iliev

The paper explores "knowledge fragmentation" and "context ex-aggregation" problems, and proposes a solution to them – the Unicorder^{TM} Integral Game-Based Learning Method. The method employs the Mechanics-Dynamics-Aesthetics game design framework, and combines elements of eXtreme Programming, flipped classroom, and stations rotation models. This problem is solved in the context of holistic, active, situated, and gamified group blended learning setup. In order to implement and evaluate the effectiveness of the proposed method, a client-server application called Challenge Unicorder^{TM} was developed. Unicorder allows the students and teams to log their progress along the learning path of challenges, provided in adaptive way at each station. The logging is done using multimodal (text, audio, video, gesture) mobile user interface. It allows for real-time tracking of learners' progress across all (online and offline) activities in order to enable dynamic adaptation and gamification of these activities, as well as informed support actions by the instructor.

1. Introduction. A fundamental problem of traditional lecture-based education is that the learning process is ex-aggregated from its natural "life" context, and is artificially implanted into classroom/lecture hall settings. Often there is a mismatch between the skills needed in real-life and the knowledge taught. This is especially important for the area of ICT where the rate of technology changes constantly increases. Therefore, the education should be teaching students how to learn, think and collaborate effectively, instead of just transferring knowledge.

As discussed in a previous author's publication [12], *active learning (AL)* has been recognized as an effective pedagogical approach in the field of *STEM* education. It includes different methods like *problem-based learning (PBL), inquiry learning, collaborative learning, situated learning,* and *learning by discovery.* Among the advantages of this approach are positive motivation; stimulation of deep learning, knowledge construction, comprehension and understanding; long term knowledge retention; promotion of lifelong learning by taking responsibility for own development [19].

According to the Chickering and Gamson [5], the good practice of teaching and learning: "*1) encourages contact between students and faculty, 2) develops reciprocity and cooperation among students, 3) encourages active learning, 4) gives prompt feedback, 5) emphasizes time on task, 6) communicates high expectations, and 7) respects diverse talents and ways of learning*". These practices can be employed individually, but their

[*] **Key words:** active learning, situated learning, blended learning, IoT, instructional method, learning analytics, adaptive learning, mobile learning, gamification.

effects multiply when combined, because "*they employ six powerful forces in education: Activity, Expectations, Cooperation, Interaction, Diversity, and Responsibility*". To tame the power of these forces we need to "*blend*" diverse active learning methods and perspectives in a coherent whole. We need *"blended learning"* to employ the advantages offered by *information and communication technologies (ICT)*, in the same time minimizing the drawbacks of pure eLearning approach like isolation and lack of emotional support offered by live community.

Coonradt who in 1984 wrote the book "*The Game of Work: How to Enjoy Work as Much as Play*" [6] defined the five rules of gamification as follows: 1) clearly defined goals, 2) better scorekeeping and scorecards, 3) more frequent feedback, 4) a higher degree of personal choice of methods, 5) consistent coaching. The resemblance of these gamification principles with good educational practices, proposed in [5] seems quite high. This leads us to the hypothesis that the *education can actually be modeled as a role-playing game (RPG)*, and that *gamification principles* and *game design frameworks* can successfully be applied to design a *high-quality educational-learning-gaming experience*.

This paper explores the above hypothesis and proposes a solution for the fundamental "context ex-aggeration" and "knowledge fragmentation" problems by employing the *Unicorder^{TM} Integral Game-Based Learning Method* developed by *IPT – Intellectual Products and Technologies Ltd*. It combines elements of active PBL, inquiry learning and exploration, dynamic assessment, situated learning, *flipped classroom* and *stations rotation* blended learning models, *gamification*, and *eXtreme Programming (XP)* practices. As described in a previous author's publication [12], the *IPT Challenge Unicorder^{TM}*[1] system operationalizes the proposed method and allows the teams of students to log their progress along the learning path of challenges, which are provided in adaptive way at each station.

A common challenge when adopting the blended learning approach to active learning is to provide adequate tracking of learners' progress along the "offline" part of the learning path, and to identify the need for pedagogical intervention/help by the instructor. This is especially important when each team of students progresses with individual pace on nonlinear and personalized learning path. This article addresses the problem of collecting and processing real time data (learning analytics) about students' offline learning activities and progress, in order to enable dynamic adaptation and gamification of presented activities, as well as informed support actions by the instructor.

2. Active Learning: Blended, Situated, Project & Problem-Based Learning, Gamification.

2.1. Active Learning, ZPD, and Dynamic Assessment. The origins of term *Active Learning (AL)* can be traced back to the *"action learning"* method proposed by R. W. Revans [18], described as *"learning as reflection on experience, achieved through focusing on problems in a social context"*. The main ingredients in the above description are: 1) *practical experience* gained in some meaningful problem solving activity (preferably in real world context); 2) *student's personal reflection on that experience*; 3)

[1] All the experimental data, figures, tables, proposed new definitions, theoretical results, and original descriptions, Unicorder^{TM} learning method and its descriptions, Unicorder^{TM} software system and its descriptions, Unicorder^{TM}, Challenge Unicorder^{TM}, trademarks and other original names proposed by the author of this paper are exclusive intellectual property of IPT – Intellectual Products & Technologies Ltd. All rights are reserved. They are cited with permission from the IPT web site: `http://iproduct.org/`

"situated-ness" of that experience in concrete social context – interaction and collaboration with other team members, the mentor, and social environment.

Vygotsky [20] defines the *Zone of Proximal Development (ZPD)* as *"the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers"*. Scaffolding provides a structure of *"support points"* for performing an action [15]. Wass and Golding [21] suggest that giving students the hardest tasks they can do with scaffolding leads to the greatest learning gains. To accomplish this, we need to establish a system for dynamic sensing and adaptation of the learning tasks and the process of scaffolding. This is precisely the goal we try to achieve by developing the *IPT Challenge Unicorder*^{TM} mobile application for dynamic assessment, tracking, scaffolding and adaptation of different aspects of the learning process.

Dynamic assessment is an interactive approach to psychological or psychoeducational assessment where intervention is embedded within the assessment procedure. A number of dynamic assessment procedures [2, 3, 4] have been developed allowing for dynamic estimation of abilities and more accurate prediction of learners' difficulties [1].

The main purpose of the dynamic assessment is to determine the learners' potential to acquire new skills. When done continuously in real-time in accordance with Vygotsky's ZPD principle, it allows for dynamic adaptation of learning activities/resources/problems according to students' previous and current performance. Challenge Unicorder$^{\text{TM}}$ tries to accomplish this by implementing different kinds of learning analytics, statistically comparing the time necessary for a student or a group of students to accomplish finely-granular "learning by doing" actions.

2.2. Blended & Situated Learning. Pankin et al. at MIT define blended learning as "*structured opportunities to learn, which use more than one learning or training method, inside or outside the classroom. This definition includes different learning or instructional methods (lecture, discussion, guided practice, reading, games, case study, simulation), different delivery methods (live classroom or computer mediated), different scheduling (synchronous or asynchronous) and different levels of guidance (individual, instructor or expert led, or group/social learning)*" [16].

Situated learning is focused on *"cognition, social interaction, disciplinary practices, and culture"*. The learning is considered as social activity including participation in a *"communities of practice" (CoP)* [7].

We define *High Quality Blended Learning (HQBL)* in a sense that it blends not only traditional classroom didactic activities with computer-based and computer mediated ones, but that it should aim to achieve a *coherent high quality Learning Experience (LX),* promoting in full scale the potential advantages of active learning discussed above. So what should be blended is not only the learning technology itself, but different capabilities (affordances), aspects, perspectives, principles, and types of activities, in a way that they multiply each other's strengths, and cover existing weaknesses.

There are several well established models and practices for blended learning delivery such as "*flipped classroom"* [13, 14], *"stations/labs rotation model"* [8], etc. These models form the basis for the Unicorder$^{\text{TM}}$ focused learning method proposed in this paper, and were discussed in more details in [12]. Unicorder Method employs the mobile device assessment technology during the complete learning path, covering all the stations and

activities (both online and offline), and providing learning analytics updated in real-time by each learner – transparently and with minimum effort. In accordance with gamification principles, these detailed analytics can provide immediate feedback for the learner, allowing to compare achievements with others, and to receive support needed in case of problem blocking the learning path.

2.3. Gamification and Digital Game-Based Learning (DGBL). As discussed in previous author's publications [10, 11], *Digital Game-Based Learning (DGBL) and Gamification of Learning* can be considered representative example implementations of the above AL principles, by providing learners with [17, 10]:

- effective learning through intense involvement using gamification principles;
- higher interactivity and better emotional involvement and better motivation through enjoyment and immediate rewarding feedback;
- structuring learning experience through well-defined rules and goals;
- continuous challenges pushing the learners' abilities up to their limit and extending them, according to the zone of ZPD principle;
- multi-player game/collaborative learning environment fostering the interaction between learners and their soft skills;
- creativity and imagination development in the course of problem solving process;
- personalization and adaptation of learning process, encouraging learning from own mistakes.

*MDA (*Mechanics*, Dynamics, Aesthetics)* gamification framework was proposed by Hunicke et al. [9], including following main components:

- Mechanics – the structural elements and systems the user can interact with: story, challenges, levels, badges, points, leaderboards;
- Dynamics – dynamic aspects of user interaction with the system: onboarding, social engagement loops, feedback, customization, reinforcement;
- Aesthetics – the subjective experiences and emotions one experiences while playing, a composite outcome of the mechanics and dynamics interplay during the game.

There are different types of Aesthetics described in [9]: *Sensation* (Game as sense-pleasure), *Narrative* (Game as drama), *Fantasy* (Game as make-believe), *Challenge* (Game as obstacle course), *Fellowship* (Game as social framework), *Expression* (Game as self-discovery), *Submission* (Game as pastime), *Discovery* (Game as uncharted territory).

From learning perspective, we can map challenges to learning goals, feedback and points to positive reinforcement, levels to learning path, and leaderboards to learning analytics. Recognition and sense of accomplishment could be supported using badges. Both forces of collaboration (between the players in a team) and competition (comparing achievements with other teams) could be employed to design effective and engaging *learning experience (LX)*.

3. The Unicorder$^{\mathbf{TM}}$ Integral Game-Based Learning Method. The situated learning perspective and group learning by doing practice stay at heart of the *Unicorder^{TM} Integral Game-Based (Blended) Learning Method* proposed in this paper. The learners are usually divided in small groups (3–5 persons). Each group receives a particular task called *"challenge"*. The *challenges* include *missions* that require different skills and knowledge to be successfully accomplished. Each *mission* consists of concrete *actions*, which structure the learning process from one side, and from the other allow receiving

detailed real-time feedback about student/group progress, current status, and potential blocks and problems to be addressed by the instructor.

The *Unicorder*^{TM} *method* is based on existing blended learning models such as "*flipped classroom*", and *"stations/labs rotation model"*. It combines practices from these models with existing best practice from agile software development methods such as *Extreme Programming (XP) – pair/group programming and building, small iterations, incremental design, retrospective meeting*, adapted to the learning domain. The key elements of *MDA* gamification mechanics are mixed in the blend too – engaging story /context, challenges, immediate feedback, points and levels, leaderboard, badges. The gamification dynamics and aesthetics are also addressed by including different types of challenges for each of the eight categories (*Sensation, Narrative, Fantasy, Challenge, Fellowship, Expression, Submission, Discovery,*) presented in section 2.3. The *challenges* difficulty is suitably and dynamically adapted according to the real-time performance metrics. Leaderboard and point system allows to compare own team performance with that of the other teams. *Fellowship* category is addressed by providing opportunities for group problem solving. *Fantasy* and *Discovery* are fostered by mixing open-ended activities (if performance level of participants is sufficiently high) in which participants should explore the problem domain and share their findings. *Sensation* and *Expression* are stimulated by including direct physical object manipulation tasks such as drawing pictures of things to be built, robot/ smart things construction, breadboard component wiring, active experimentation with the robot, etc. Results of each action are logged by the team in the form of short status messages, and usually are accompanied by *pictures*, short *podcasts (audio)*, and *video recordings* telling the story of achievements in a vivid and original way. The logging is accomplished using mobile devices of the participants – again by direct manipulation, engaging all senses of the learners.

The *missions* are *situated* in a *narrow problem solving contexts* that are possible to grasp in a short time – typically each mission should not be longer than half an hour. They are *closely focused* on solving particular problems – one at a time. It is possible to arrange different missions from simple to more complex, and the problems from structured to open-ended, in which case there should be predefined sequence in which all *learning stations* should be visited. In this case, it is possible to organize the teams in a pipeline (queue) – when one team moves to next station, the next team is welcome to take the mission. It is obvious that all the missions should have the same duration, and this duration should be minimal in order to minimize the upstart time for the teams. It is also possible to try to make different missions independent of each other in which case all the teams could start at the same time at different stations, without waiting. The duration of missions should allow participants to accomplish actions (and log the accomplishments) comfortably, without hurry. In this regard, the ability of *Challenge Unicorder* system to adapt the mission difficulty by revealing certain actions (Easter eggs) only to more accomplished teams is valuable, because it allows balancing the timing differences between teams.

About the gamification dynamics – it seems good idea to mark the end of each mission using visual/ audial cognitive signals – for example, playing energizing music and/or light effects. High achievements should be rewarded immediately. By providing immediate positive feedback, we reinforce the learners' motivation to develop further – e.g. using badges.

At the end of the challenge, in accordance with *Extreme Programming (XP)* best practices, we can organize a "*retrospective meeting*" during which every team could present its *story of individual experiences, difficulties and achievements* (already recorded using Unicorder), to reflect on what has been learned, and to formulate goals for further exploration. Valuable feature of the *Challenge Unicorder* system is to allow *automatic construction and multimedia presentation of storyline* for each team, including their achievements during the challenge.

The role of the instructor is to facilitate the personalized learning of each student and group, being more a *"block remover"* than a director. Students are encouraged to constantly log their progress, as well as blocking problems and questions, using Unicorder. The progress of each team/participant can be followed in real time by the participant itself, by others, and by the instructor. The instructor can react immediately, providing support, enabling hidden actions, and rewording achievements.

4. IPT Challenge Unicorder™ System. In order to implement and evaluate the effectiveness of the proposed *Unicorder™* method, a client-server application called *IPT Challenge Unicorder™* was developed. Unicorder allows the teams of students to log their progress along the learning path of challenges, which are provided in adaptive way at each learning station. This logging is done in multimodal (gesture, text, picture, audio, and video), easy to use graphical, and augmented reality mobile user interface. The collected data is used to gamify the learning process, to allow immediate feedback and achievement recognition of different student teams, as well as to present multimedia "stories" about the achievements at the end of the session.

The instructor role is also empowered by receiving real-time data analytics about the progress of individual teams. This allows the instructor to actively support the teams online (using Unicorder) or in face-to-face mode, when there is little progress reported. The instructor's effectiveness and efficiency are improved by interactive learning analytics dashboard presentation, allowing to track the learners' progress, and to identify the need for pedagogical intervention for multiple teams in parallel.

Unicorder allows the instructor to adapt the sequence and difficulty of challenges according to the previous results of students. This allows to fit the problem to learning context requirements, as discussed in previous author's publications [10,11]. In the spirit of gamification, certain actions are dynamically "unlocked" only when previous challenge tasks were completed with sufficiently high performance.

The architecture of *IPT Challenge Unicorder* system and two example screens are depicted on Fig. 1.

IPT Challenge Unicorder is a client-server application, which is implemented using latest, mobile-first responsive web design technologies – Angular TypeScript library and Angular Material Design (MD) component library. Hybrid web/mobile client application uses HTML 5 device APIs to access camera, microphone and accelerometers data on the mobile device. The access to device camera is important because taking picture of the action result is the fastest and most convenient way to log the completion of each action during the mission. The status text (as shown in Fig. 1) is optional and allows to add more details about the completion status of an action.

The pictures/videos and status messages submitted to log each action completion become immediately available to the instructor's dashboard application, which tracks all active challenge sessions of different participants. It is possible for the instructor to

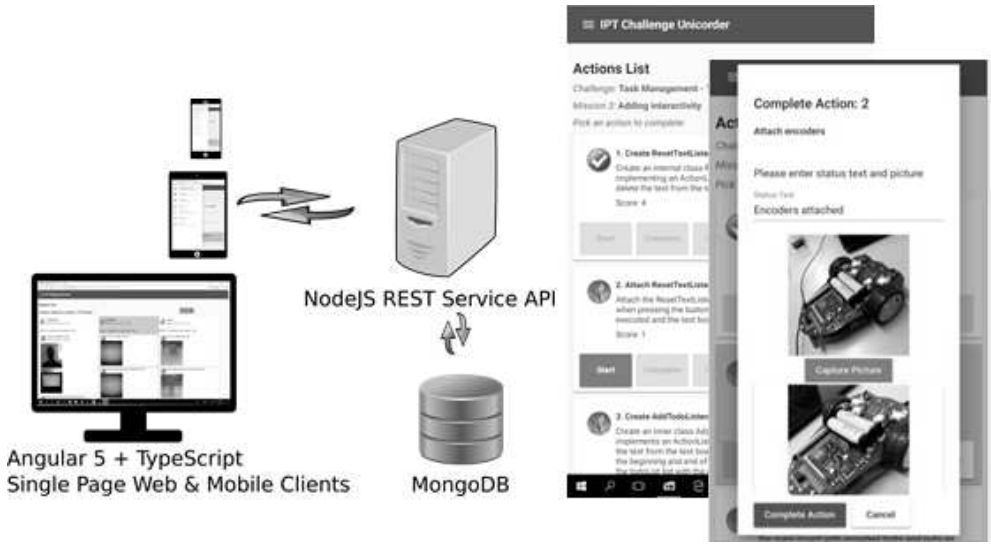

Fig. 1. IPT Challenge Unicorder^{TM} system architecture

choose specific completed action by particular student. Then an action details view is shown, which presents the pictures/videos in larger scale, together with some statistical data about the time needed to complete the action, compared to that of others. This allows the instructor to verify the quality of completed action results, and to provide immediate feedback in the form of *points* and sometimes *badges* earned. Using Unicorder, the instructor can sometimes also ask the students to revise the action results and resubmit them, if necessary. Short status message (qualitative feedback) can be provided to learners, in addition to score points (quantitative feedback).

The back-end system is implemented as a *Representational State Transfer (REST)* style web service using *NodeJS*, *ExpressJS*, and *MongoDB* technologies. Angular web clients running on mobile devices of the participants submit the data in real time using HTTP protocol. The server stores all the events received for further statistical processing in the database. The minimal configuration requirements for the server are: Windows 10/Ubuntu v16.04/ Red Hat Enterprise Linux v6.9/CentOS Linux v6.9 server with at least 4 Core 64-Bit CPU @1.4+GHz, 4 GB of RAM, and 100 GB disk space. The mobile clients currently require a mobile device running Android v4.4+ operating system with support for mobile Chrome v41+ web browser.

5. Preliminary Results. IPT Challenge Unicorder active learning method and software are works-in-progress, and there are no conclusive evaluation results available yet about their effectiveness in real classroom settings. We have done some preliminary alpha testing with 11th grade students from *National Mathematics High School "Prof. Lubomir Chakalov", Sofia*. The Challenge Unicorder software was tested with two groups of students – 9 students in total. The students were using the Unicorder software individually with a challenge (goal) to develop a desktop application using Java Swing technology, including 16 actions.

After completing, the challenge, the students were asked to share their impressions

by completing anonymous survey. The survey questionnaire had four sections. The first section asked the students to estimate the system quality. The second section asked them to compare learning with Unicorder to traditional one, in terms of interactivity, motivation, support from instructor, etc. The last two sections were formulated as open questions about difficulties using the system, and suggestions for improvement. The system estimation questions were scaled from 1 (poor) to 5 (excellent). The results are summarized in Table 1.

Table 1. Results from Challenge Unicorder alpha testing

	Minimal	Maximal	Average
1.1. System Interface	2	5	4
1.3. Content	3	5	4.44
1.4. User Experience (UX)	3	5	4.33
2.1. Interactivity	3	5	4.22
2.2. Motivation	2	5	3.55
2.3. Instructor support	3	5	4.44
2.5. Degree of learning	3	5	3.88
2.6. Immediate feedback	3	5	4.5
2.8. Results demonstration	3	5	4.33

As seen from the survey results, the overall feedback is positive – above the average for all questions. According to student responses, the most valuable feature of Unicorder system is the immediate feedback, followed by the instructor support and content. Ability to easily demonstrate results is also highly valued by students.

6. Conclusions. IPT Challenge Unicorder active learning method and software system are works in progress, and there are no conclusive evaluation results about their real world effectiveness yet. According to preliminary evaluation results, the system was well accepted by students. There were suggestions about the system interface and functionality we will try to implement in the next version of Unicorder. Despite the initial prototyping stage, the system was considered useful by students, providing immediate feedback and improved instructor support.

There are many directions for further improvement – such as implementing more advanced learning analytics, dashboards, and data visualizations. More extensive experimental data is needed to estimate the Unicorder effectiveness, usability, and to optimize the learning experience in production settings.

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Trayan Iliev
Faculty of Mathematics and Informatics "St. Kliment Ohridski"
University of Sofia
5, James Bourchier Blvd
1164 Sofia, Bulgaria
e-mail: t_iliev@fmi.uni-sofia.bg

ГЕЙМИФИКАЦИЯ НА СМЕСЕНО (BLENDED) ОБУЧЕНИЕ С CHALLENGE UNICORDER™

Траян Илиев

Статията изследва проблемите за „фрагментиране на знанията“ и „изваждането им от контекст“ и предлага решение за тях – Unicorder™ Integral Game-Based Learning метод. Методът използва Mechanics-Dynamics-Aesthetics рамка за игрово проектиране и комбинира елементи на eXtreme Programming, модел на „обърната“ класна стая и модел на ротиране на станции. За реализиране и оценка на ефективността на предложения метод е реализирано клиент-сървър приложение, наречено Challenge Unicorder™. Unicorder позволява на обучаваните да записват своя прогрес по пътя на обучение, включващ предизвикателства, осигурявани на всяка станция по адаптивен начин. Записването1 се извършва чрез мулти-модален (жестове, текст, аудио, видео) мобилен потребителски интерфейс. Той позволява следене в реално време на прогреса на обучаваните през всички (онлайн и офлайн) дейности. Това позволява реализиране на динамична адаптация и геймификация на тези дейности, а също иницииране на информирани подпомагащи действия от страна на инструктора.