Motivating Learners by Dynamic Score and Personalized Activity Stream

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Abstract—**Motivation is very important in any kind of human activity. This is especially true in the context of learning. Various educational systems therefore try to incorporate elements, which has motivating effects on their users – learners (students). Increasingly popular in this domain is employing elements of gamification. In our work, we propose specific type of one of the gamification mechanics – score. Our method for score computation works through dynamic regulation of score for particular activities that is based on whole group of students' activity. For motivational purposes we accompany the dynamic score calculation by an activity stream, which visualizes changes in score for particular activities that affects overall score calculation for individual students. Our hypothesis is that this motivates the students to perform activities currently preferred by their teacher evenly. Activity stream is interconnected with several gamification elements – it is primarily the student score, but also other elements like a set of badges, where the activity stream displays information about badges obtained by peers. Proposed gamification elements were integrated into the existing environment of adaptive web-based educational system ALEF used at the Slovak University of Technology in Bratislava for several courses. We present an experiment on dynamic score, which confirms our hypothesis.**

Keywords-motivation; web-based educational system; activity stream; dynamic score; gamification; personalization; badges

I. INTRODUCTION

Motivation is one of the general questions of learning process as well as one of the general questions of human activity in general. Motivation was studied by experts of several branches, computer science experts included. Reason is rather clear. Thanks to motivation people can do their tasks faster and better [10]. This is applicable to learners, especially students in their regular study, as well. Motivation in educational systems has its specifics comparing with other activities. For example, young people do not appreciate well importance of learning and get bored rather quickly.

This domain is more and more important in the last years, mainly thanks to theory of gamification. Gamification, which main idea is about use of game elements and mechanics in non-game contexts, is getting more popular and is being implemented into various systems, web portals and services more and more frequently. The key aspect is using those elements and mechanics, which motivate players of games to get as good results as possible often based on a competition with other players [3, 5]. Same or similar practices can be applied for applications, where gaming is not main goal.

In our work we focus on specific aspects of gamification and their integration into fully-fledged web-based educational system. We have been working mainly on student score, which can dynamically regulate amount of points awarded based on activity of the entire group of students. Thanks to this feature students are motivated by possibility of getting points by performing activities provided by the educational system. Our motivation was to give a teacher an option to guide students by changing preferences of those particular activities as well. At the same time our goal was to propose score computation method which can limit unnecessary and pointless activity of larger number of students only on very few types of activities (mainly because higher score), while other activities would remain ignored. In ideal word where we will be able to assign right score for every activity to be performed without much speculation on the effectivity, pure score calculation as it known from existing systems would suffice. But in general this is not possible. Even experienced teacher is not able to assess perfectly effort needed for accomplishing an activity, which is crucial for its scoring. Dynamic score can solve this problem. Moreover, it brings interesting aspect to the "educational game" with potential for further students' motivation. Very important for us was also question of visualization of changes in such dynamic score computation method for students using educational system.

In this paper, we propose a method of a dynamic score computation, which works as an extension to the basic (static) computation method, probably most widespread in the present. Part of our proposal is also visualization of this score computation by so-called activity stream. The activity stream visualizes changes in dynamic computation to the students thanks to short structured messages. It also provides useful interconnection with other gamification elements, e.g. badges.

Our proposal was partially guided also on a questionnaire which gave us a view on perceiving these aspects by our students, in particular the bachelor students in the course Principles of Software Engineering. The questionnaire included several questions about motivation and gamification itself. The purpose of questions was primarily our ambition to better understand thoughts and positions of an average student to the use of gamification elements in an educational system, their positives and negatives, benefits and potential risks. In overall 67 students participated in the questionnaire.

The structure of this paper is as follows. In section 2 we introduce existing practices in student motivation and general motivation as well. Section 3 presents our proposal of students' motivation through dynamic score calculation and activity stream. We describe the evaluation of our proposal in section 4. We conclude the paper by our conclusions and proposal for further work (section 5).

II. Related Work

Although gamification and its use in practice is relatively young, there are already a lot of websites, educational systems, gaming portals etc., which incorporate some of the gamification elements and mechanics. One of the most popular gamification elements are clearly score and badges and their variations, respectively. This was also showed by our questionnaire to students – 41% of students consider score as the most motivational gamification element, 33% of students pointed badges and achievements as the most motivational.

Both of these elements are effectively implemented by Stack Overflow[1], popular question and answer site for programmers. Here, badges are awarded for a range of activities and are divided into categories of gold, silver and bronze badges by expected effort needed for performing activities they are awarded for. Interesting is also option to gain same badges repeatedly, which has according to [1] positive impact on users' activity. Score in Stack Overflow is implemented in the form of reputation and is tied primarily to asking and answering the questions. Another interesting fact is that users with higher reputation have also greater competences. However, reputation in Stack Overflow is computed only by simple points accumulation. It can work for large number of participants to some extent, but still poses several problems, which follow the very principle of motivational aspect of scoring – a wish to enrich portfolio or simply collect points, i.e. extrinsic motivation instead of intrinsic motivational factors that include in the Stack Overflow case a desire to help the community and learn [4].

An example of a more advanced method on how to calculate a score is an exercise sharing tool SOCIALX [7, 8], where we can speak about use of gamification elements in the context of education. In SOCIALX a reputation earned by students has impact on the weights of their further actions in the system. Reputation calculation thus have a dynamic character here, and is also influenced by several facets, like usefulness and competency.

Somewhat unconventional view of motivation was shown by another experiment, which followed an impact of a negative motivation [6]. When rating several types of badges on a multi-level scale according to their motivation level users have indicated that the risk of obtaining negative badge (e.g. badge for posting no comments) has a greater impact on them than possibility of gaining a positive one. However, this way of motivation is not common probably mainly because the threat of obtaining negative badges (especially if they are public) could lead to loss of motivation to use the system.

It is also common to combine several gamification elements. E.g., Stack Overflow has several types of activities which affect both increasing reputation and gaining badges when performing by users. It is also possible to combine those elements so badges will be awarded by achieving score/reputation milestones, what is the part of our proposal.

Most current score implementations as a gamification element use only simple static method to compute a score. It is easier to design and to implement, however it does not provide any advanced ways on how to motivate their users, for example to perform only some specific activities. This could be especially useful in an educational system. Our motivation was therefore to propose such a dynamic way of score computation and to evaluate its motivational impact on students in an educational system.

III. Elements of Motivation in an Educational System

For students' motivation in an educational web-based system, we propose an approach, which is composed of several interconnected motivational elements. Its primary goal is to motivate students to perform activities their teacher is willing and reward those students for this activity by additional points to their score. The part of our approach is also a visualization of preference changes, and application of game mechanics which are well-known from the theory of gamification to educational system as well.

A. Motivation by dynamic score

Our proposal of motivation by dynamic score assumes set of activities the students can perform while using an educational web-based system. There are no strict rules what can or cannot be counted as an activity, however the activity should be related to learning goal. For instance, as the activity we consider doing exercises, asking and answering questions, reading texts and highlighting important parts.

Score computation pursues two main goals. First, it is a regulation of points rewarded by current teacher's goals and requirements. The teacher can choose some of the activities present in the educational system and set them as preferred. By performing preferred activities the students can receive more points to their score as usual. This assumes

[1] http://www.stackoverflow.com/

increase of students' motivation because they earn for such activity more points as a reward for their effort.

The second goal of score computation is to balance amount of points received by students within preferred activities. This means, if some of the activities are performed more by the students than others, amount of points received for performing these activities will decrease in time. On the other hand, activities preferred by the teacher and being "ignored" by the students will record an increasing score as their *balancing factor*, so students will receive from this point of time more score points by performing such activities.

Score computation works incrementally as a sum of the score value in time *t* – 1 and a sum of each partial score for particular activities performed at given time *t* (Equation 1).

$$score(s,t) = score(s,t-1) + \sum_{i} partial\_score(C_i, s, t)$$

where $score(s,t)$ represents the score value of student *s* at time *t*. The score increment is computed as a sum of all partial scores represented by $partial\_score(C_{i,}, s, y)$, where C_i is particular activity.

Partial score computation is affected by three main factors:

- activity weight,
- activity preference and
- students' actions in the educational system.

Activity weight is a static value representing an estimation of effort needed to perform particular activity. The exact values of weights were determined based on analyzing activities in ALEF and students' results in previous years as well as on an opinion given by teachers on how particular activities are difficult to perform. More demanding activities got higher weights.

Activity preference expresses current importance of the activity for the score computation. Activity preference can change in time. It is expressed by integer of range from 1 to 5, where 1 means that the activity is not preferred at the moment and 5 means that the activity is highly preferred.

Students' actions affect balancing factor already mentioned above. The balancing factor represents a ratio of

- *expected ratio* of score points received (by all students) for performing particular activity to all score points received and
- *current ratio* of score points received (by all students) for performing particular activity to all score points received up to the present time.

The expected ratio is calculated following activities weights – higher weight means higher expected ratio of this particular activity to all activities. However, unlike current ratio, expected ratio does not follow current system state and because based on static weights, it never changes as well. The value of balancing factor is cropped to interval <0.5;1.5>, so extreme high or low values are filtered out when computing score. The purpose of this operation is to avoid breaking of score computation by the extreme values. We have chosen the interval based on our observation on how to track important changes in balancing factor value whether it is above or below value of 1 and how not to break score computation by extreme values at the same time. We tested this empirically acquired interval on ALEF data.

The value of partial score is computed as a product of activity weight, activity preference, balancing factor and amount of points normally received for this activity:

$$partial\_score(c,s,t) = wg(c) * pref(c,t) * bal(c,t) * add(c,s,t) \quad (2)$$

where *c* is particular activity, *s* is student, *t* is time interval of computation, $wg(c)$ returns activity weight, $pref(c,t)$ returns activity preference, $bal(c,t)$ returns activity balance factor and $add(c,s,t)$ returns amount of points for performing activity.

We visualize score on right top corner of the screen, which is place of high visibility for users. Except of displaying the current value of score we present also ranging particular student in the class, i.e. the number of students that have higher score (see Fig. 1).

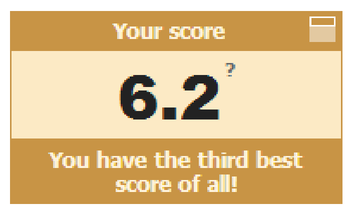

Fig. 1. Score widget in ALEF. It displays score value and the number of students who perform better.

B. *Motivation by activity stream*

Score computation highly depends on students actions. Therefore, it is important for high students' motivation to perform activities that the teacher prefers let the students know how and when or better how activity preference and balancing factors change. Monitoring pure score changes does not give the student particular information, so part of our proposal is an activity stream.

Activity stream is a graphical element, which is part of the educational system's user interface (student's profile). It shows short messages informing about important status changes such as changes associated with score computation (see Fig. 2). Left top part provides basic information about current score including a list of most and least performed activity. Right part visualizes the activity stream. Considering score part of the activity stream the most important is visualization of the change for particular activity performed by the student (decreasing either increasing).

Thanks to the activity stream, students have information which of activities is better to perform at the moment so

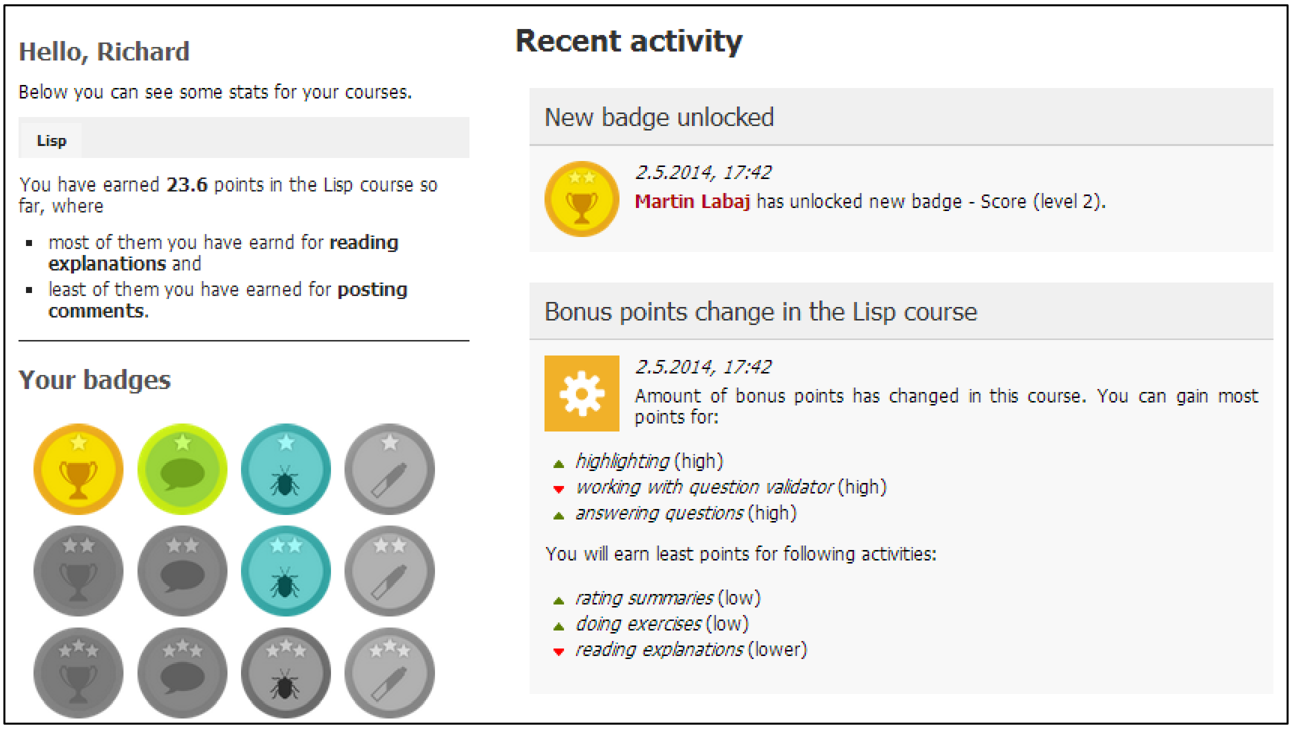

Fig. 2. Part of student's profile showing activity stream and badges.

they can receive more points when learning while using system. In other words, we motivate students by the activity stream to perform currently preferred activities.

C. *Motivation by badges*

Score is only one of the elements described by the theory of gamification. We proposed and realized also another gamification element linked with score and activity stream (based also on students' response in our questionnaire). It is set of badges students can receive by performing various activities, such as adding comments or reaching new milestones in their score value.

Each of the badges consists of three badge levels. Student can receive a badge of higher level only if he has already received all of the lower levels badges. When a student receives new badge, the new message is generated into activity stream, so all other students know about it.

The badges are visualized in student's profile along with the activity stream (see Fig. 2). It is located below basic information on student's activities. The student can see badges already achieved (in color) and prospective (grey).

IV. Evaluation

We realized our method for dynamic score calculation including its visualization by the activity stream in an environment of adaptive web-based educational system ALEF [9]. ALEF (Adaptive LEarning Framework) is a framework designed for creating adaptive and interactive educational environments. ALEF has been used for 5 years in four courses and has served more than 1 200 students.

ALEF's main strength is in collaboration and active learning support. Its core components covering enhanced learning support are [2]:

- *adaptation engine*, delivering tailored (in most cases personalized) learning experience,
- *annotation framework*, allowing various forms of collaboration and students' active participation in metadata and content creation, e.g. text highlights, collaborative creation of definitions, tagging,
- *extensible architecture*, enabling ALEF to interconnect with various services, e.g. automatic program/code evaluation and program interpreter feedback,
- *motivational components*, tracking activity of students and computing user ratings.

The ALEF content is presented to students in three basic types of learning objects: (i) explanations (explaining topics, similarly to a book section), (ii) questions (ranging from single-choice to plaintext input), and (iii) interactive exercises (ranging from simple tasks to complex exercises supported by external evaluation services).

For the purposes of implementation of our proposed dynamic score mechanism, we employed existing students' activity tracking mechanism in ALEF. Domain model of ALEF consists of metadata (tags, comments etc.) and educational content (learning objects), which creates appropriate setting for implementation of our gamification elements. Our dynamic score extends already existing infrastructure of static student score calculation based on several raters for particular activities and summed up together.

Activity stream played a key role in the evaluation. By posting short messages it notified students about preferences and balancing factors changes so they knew by performing which activity they can receive more points to their score.

We designed an experiment to evaluate the effects of dynamic score calculation combined with the activity stream on the students and their decisions on what activity to perform next. Based on the dynamic score calculation (Eq. 2) we monitored changes in the balancing factor of several preferred activities in the experiment. Because the value of the balancing factor for a particular activity is increased when this activity is not performed at all, and is decreased when it is performed often, our aim was to determine whether the value of this factor converges to the value of 1 for preferred activities. The value of 1 for all preferred activities is the ideal state where ratios of points awarded for each activity by students are equal with the expected ones.

The experiment lasted two weeks in an uncontrolled form and was attended by the students attending course Principles of Software Engineering. During this period 223 students performed some activity in ALEF. Start of the experiment was preceded by setting preference values of particular activities as they were set by the teacher (Tab. 1), where sign of a dash (-) means activity was not preferred and value of 5 means activity was preferred by the highly possible level. We list here all currently possible activities in ALEF. However, each course has associated different set of widgets that provide user interface for particular activity. Basic activity is reading educational materials – here called "Explanations". In our courses we do not set usually preference to this activity, so it is scored according its defined weight only without any preference. The reason is that there are other mechanisms for motivating students for this activity such as short tests on the beginning of labs.

TABLE I. VALUES OF PREFERENCES OF PARTICULAR ACTIVITIES SET BEFORE EXPERIMENT STARTED

Activity type	Preference value	Activity type	Preference value
Comments	-	Bug reports	-
Highlights	-	External sources	4
Questions	2	Exercises	2
Explanations	-	Tags	3
Summaries	-	Question validator	4
Definitions	5		

During the experiment, there was a total of 300 changes in the balancing factors of all activities. We explored changes in the balancing factors in time, namely dependence of time and the balancing factor for each activity (it is visualized by graphs where the x-axis represents the time, and the y-axis represents the value of the balancing factor, see Fig. 3, 4,5). We can see that while in computation are used cropped value of balancing factor, we store their actual values into the database. This is reason why we can see such big and low values on the graphs.

Based on the graphs we found that the values of the balancing factors of 4 out of 6 preferred activities were actually converging to the value of 1. For the instance, graph of changes of the balancing factor of definitions (Fig. 3) shows that the value of this factors was decreasing from the high levels to the value of 1, which means that students decreased this value by performing the activity.

Fig. 4 presents changes of the balancing factor of questions. This value is increasing to the value of 1 from the lower levels. This means that the students at first answered the questions rarely, the dynamic score contributed to the increase of this value.

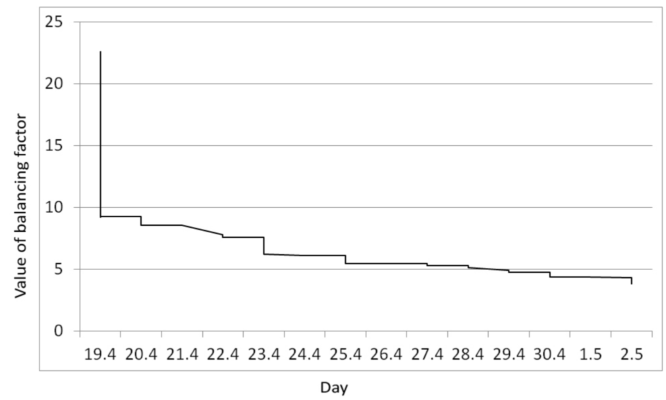

Fig. 3. Changes of the balancing factor of the definitions activity

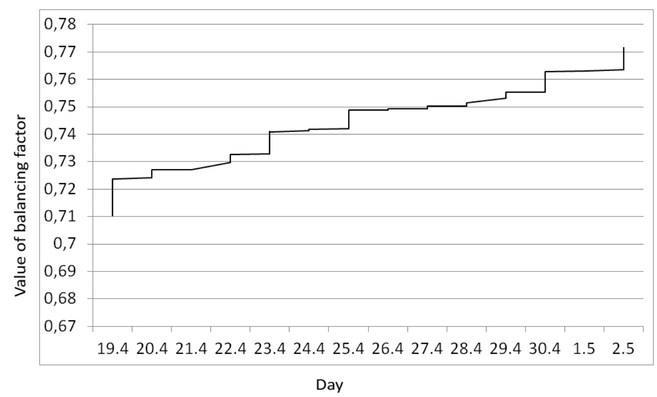

Fig. 4. Changes of the balancing factor of the questions activity

In the remaining two cases – tags and exercises, the trend of the changes was not clear as in previously mentioned cases. We can see this on the Fig. 5 changes of the balancing factor of tags. There may be several reasons for this as the experiment was realized in uncontrolled manner during semester and monitored period was rather short – two weeks mean that students prepared for their lectures and labs in most cases twice. Even though it is sufficient for showing basic trends it is not sufficient for detailed analysis. Important fact to be considered is also lower attractiveness of these activities for students as they were not explicitly promoted by the teacher and monitored period was rather short. Especially exercises require non trivial effort from students, so we suppose that for balancing this activity longer time is needed.

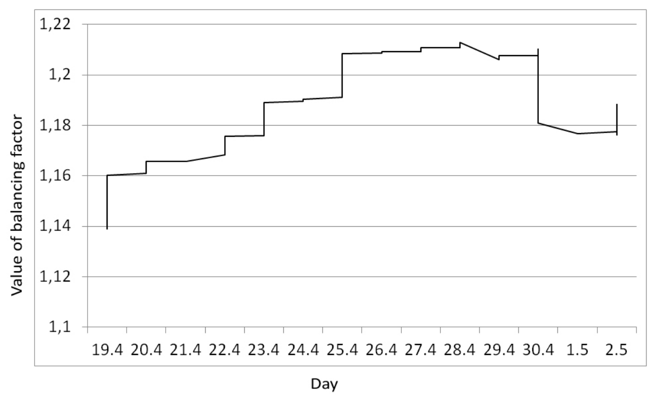

Fig. 5. Changes of the balancing factor of the tags activity

As in most cases balancing factor converged to the ideal value of 1, we can conclude that the dynamic score and the activity stream influenced the students' activity. We plan to monitor students' behavior for longer period including use of A/B testing to study students' behavior more deeply.

V. Conclusions

In this paper, we proposed an approach to student motivation using dynamic score computation in a web-based educational system. Our motivation for doing so was to allow a teacher to influence the number of points awarded for performing particular activities provided by system. Dynamic score provides an automatic balance of students actions based on activities preferred by the teacher, so students perform all preferred activities about equally.

Our proposal of dynamic score calculation count on three different factors – static activity weight, activity preference set by teacher and students actions in the system. It is students' actions what affects the changes in a balancing factor, which is key element of our proposal. Balancing factor decreases the number of points awarded by activity which is performed more than other activities, and vice versa. All of these changes are presented to students by an activity stream, which displays also messages on other gamification elements, such as receiving new badges by others.

We evaluate influence of changing score on student's activity by monitoring changes in the balancing factor of several preferred activities, which should converge to value of 1, which would mean, on the basis of its calculation that students perform activities of balancing factor greater than 1 and ignore activities of balancing factor is below the value of 1. Results show that in four out of six preferred activities there was a convergence of their balancing factor to the value of 1. Our dynamic score and activity stream have impact on students' decisions on what activity to perform.

There are several more possibilities for student motivation. Part of our questionnaire was a question about an integration of the activity stream messages into an environment of social network they use (e.g. Facebook). Students have not liked this idea, mainly because they consider their social network as a part of their private life and they would not like to mix it with their studies. However, some of the students would like to receive those messages in their school inbox.

There is a number of possibilities for further work. One is to provide smarter activity stream messages display, for example based on personalization. Even dynamic score can be adapted not only to the activity of students' class but also to particular student knowledge (activities on the content not mastered well are more valuable). Set of rules for specification of particular behavior of preference value can be used for this purpose. We plan also include some other gamification elements and connection them with the activity stream through new message types.

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