NEW MOBILE APPLICATION FOR EFFECTIVE PRACTICE OF BASIC NUMERICAL OPERATIONS AT PRIMARY SCHOOL WITH ELEMENTS OF GAMIFICATION AND HISTORY OF EXAMPLES

Petr Voborník

University of Hradec Králové, Department of Informatics (CZECH REPUBLIC)

Abstract

The Basic Numbers application for smart mobile, but also available on desktop devices, was developed to practice an elementary mathematical operation. Therefore, it is primarily intended for primary school pupils. The application combines the main advantages of competing applications, but it also brings some new innovative features to increase the efficiency of teaching. For example, not only the range (from-to) of values for individual numbers in examples and for the final result can be set, but also for the individual steps of partial calculations at gradual counting. This is very important for the first grade of primary school. Individual examples are generated randomly within given limits, but the algorithm based on backtracking constantly verifies that the criteria for partial calculations are met. The count of numbers in examples and decimal places can be increased for more advanced pupils. Gradual checking of the results brings gamification elements. The examples are marked with colour icons, each step of the evaluation is accompanied by sound effects and there is also a gradually increasing help, which, however, detracts from the star rating on each page with examples. Of course, there is also a final overall percentage result. The detailed analysis of each test is automatically stored in the application and can be retrieved at any time to check. It can be done by a teacher, parent or by pupil themselves. The application not only automatically evaluates the pupil, but also provides a feedback on the long-term development of his/her skills, specific mistakes in calculations, where revision is recommended, and, last but not least, the proof that the pupil has devoted themselves to this practice. The application can also be used for official testing. It is also possible to set the limitation of switching between applications on a mobile phone, so that the pupil cannot switch to a calculator app, for example. The entire access to the settings can be password protected, so that the pupil is not able to modify such test parameters in these cases. The development of the application continues, but already in pilot operation it has proven to be a good and useful tool for a modern way of effective teaching in the field of elementary mathematics.

Keywords: Application, Basic Numbers, smart phones, primary school, mathematics, gamification, testing.

1 INTRODUCTION

The Basic Numbers have been developed for the purpose of practicing basic mathematical operations. It is then intended for the first grade of primary school pupils. The application can be used by both pupils and teachers on smart mobiles containing operating system Android[1], it is however available for devices with Windows 10[2], i.e. on computers, notebooks and tablets.

2 METHODOLOGY

The development of the Basic Numbers application has been implemented by means of the multi-platform technology of Xamarin.Forms [1]. It allows a common code in language C#, respectively the XAML design definition, to compile into a native application for operating systems of Android, iOS and Windows 10 (UWP – Universal Windows Platform).

An algorithm on the backtracking base has been created (see [2]) intended for generating of examples entered in tests. This algorithm proceeds from left to right side, therefore by generating individual members and by selecting operators among them. All of that proceeds quite randomly between selected limits however these limitations are always monitored even for intermediate calculations and

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the total result. Therefore if e.g. a new added member overgrows the limitation intended for the intermediate calculation result, then it shall be replaced by another one. If it fails to find a suitable member during certain numbers of attempts, the generator shall go one step back and try to change the operator between members and everything will repeat. If even this change fails during certain numbers of attempts, these generating shall return one order back, i.e. to the foregoing member of the example's assignment. There had been used the same algorithm intended for the evaluation of mathematical expressions as in the Algorithms program (see [3]) described in [4].

3   RESULTS

The main result of this work is represented in particular the Basic Numbers application itself. Secondary results could be represented by assistance for chances of improving children's knowledges in the field of basic mathematics. Another positive contribution may be using the application at the education, which could be connected with its variation and e.g. even with facilitation of teacher's work in a case of an objective examination and the implementation of the Strategy of Digital education up to 2020 of the Ministry of Education, Youth and Sports of the Czech Republic [5].

3.1   Gamified Solution of Examples

There is the solution of mathematical examples enriched by elements of gamification. Particular examples in existing basic numbers are divided into pages, whereas the count of examples on the page and also the count of pages can be specified in setting. Each of the pages will be evaluated separately in three steps.

Firstly, it will be displayed one page for a pupil with individual examples (Fig. 1). His/her task consists in inserting a right result of each of the assigned examples into editing fields on the right side behind the equals sign. As soon as a pupil had finished the task, he/she can click the *Check* button in order to verify the rightness of his/her solution.

Figure 1. Introducing assignment of examples.

If all the assigned examples for the pupil on Page have right solutions, there will be an icon displayed at all these examples which means the right solution and an information panel at the top signalizes the 100% success for this page (Fig. 2). Asterisks displaying the success rate of the page's solutions in form of a default play marking stay coloured all of three ones. However, if the solution contains a mistake, either one or all of the results are wrong, there won't be showed any icon confirming the correctness, the information panel at the top will inform that the solution contains mistakes and the last asterisk turns gray, because the pupil/user/player just has lost it (Fig. 3). In both of cases, a sound effect will be played, namely randomly selected from the particular sounds set (success or failure).
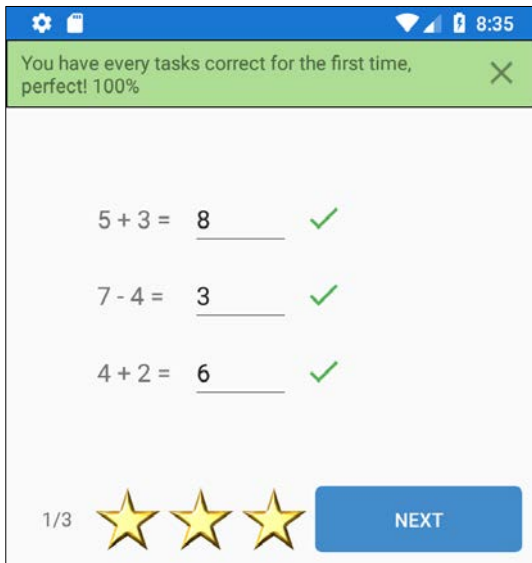
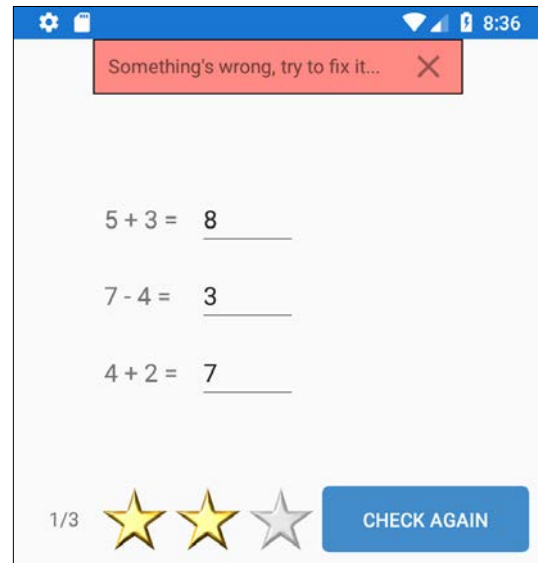*Figure 2. The page of examples solved at the first attempt.*

Figure 3. The page of examples containing a mistake at the first attempt.

If the first check of the solutions fails, the pupil will have possibility to correct the mistake. Since there has not been marked what example is correct and what is not, so when the pupil does not want to lose another asterisks, then he/she is forced to check all the examples in the page again, in order not to damage even a proper solution of another example due an inconsiderate correction. Just in that step the pupil usually learn and remember the most [6]. As soon as he/she has finished corrections, it can be used the *Check again* button.

The application will check all of the results again and there are always two possibilities – everything is correct or the solution contains some mistake/mistakes again. The success will be noticed at the same way as in the foregoing case however the pupil will obtain only two asterisks from three ones for that page (Fig. 4). The failure is then connected with loss of the second asterisks from three ones, with another notice that the solution still contains mistakes and indicating the failure by a sound effect. However in this case there will be displayed icons at the particular examples indicating the correctness of their solutions (Fig. 5).
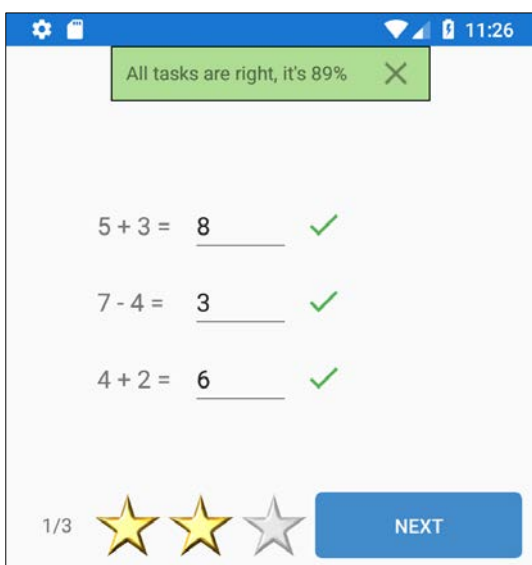

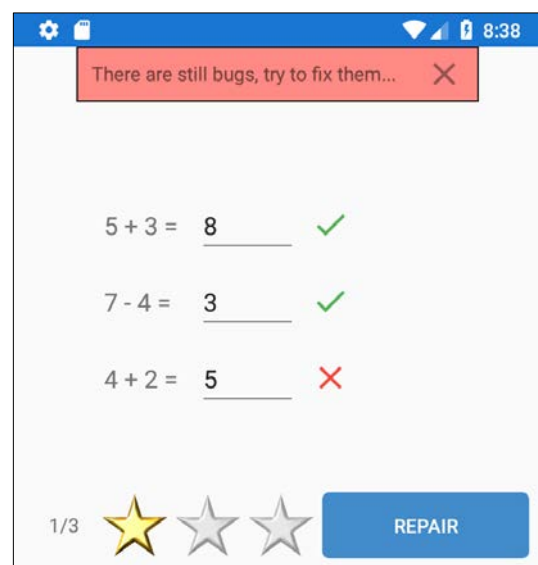*Figure 4. The page of examples solved at the second attempt.*

Figure 5. The page of examples containing a mistake even at the second attempt.

The pupil can see at last which of the examples are correct and which wrong. At the correct ones, there is in addition to set the read-only mode, in order the right values cannot be damaged by mistake. However, wrong results stay editable and the pupil still can correct the result, in order to obtain at least one asterisk from the given page. The next check is to be performed by the *Repair* button.

In the case of successful correcting, there will be added an icon of the correct solution behind the icon of the wrong solution (there are also both of them showed, i.e. foregoing marking the mistakes and current marking the correctness) and the page is fulfilled with a gain of one asterisk from three ones (Fig. 6). If the pupil failed even in this case, there shall be noticed the correct result of the example behind the failure icon. Herewith the last asterisk turns gray and there is a percentage evaluation of the given page in the information panel (Fig. 7).
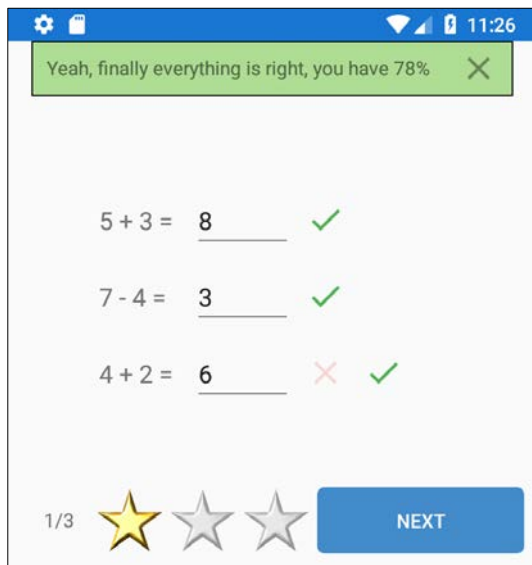

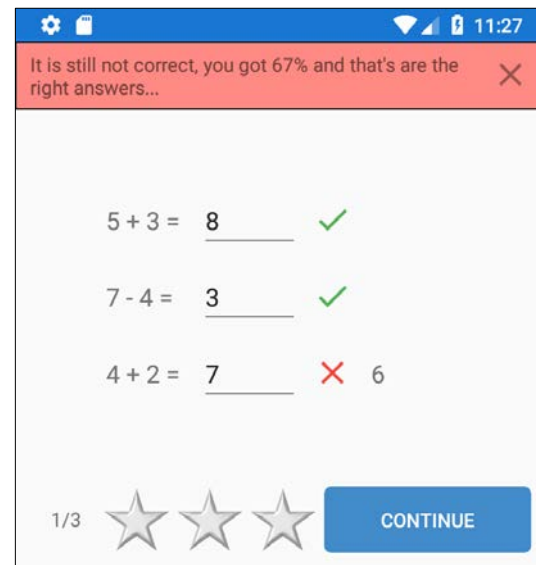Figure 6. The page of examples solved at the third attempt.

Figure 7. The page of examples containing a mistake even at the last third attempt.

Out of consideration for a success at any steps or quite without an asterisk, the pupil can go to the next page of examples by click to the *Continue* button. When the pupil is in the last page, then this button contains the *Complete* label.

It is also clear from the play component principle for examinations that it is very important to suitable select the count of examples for the page and the count of pages in order the particular pupil can have a chance to calculate the page successfully even with the gain of three asterisks, but at the same time to obtain sometimes an opportunity to learn from his/her own mistakes while searching his/her own oversights.

A lot of different mobile games are recently provided with evaluations of particular levels by means of three asterisks and children are often accustomed to obtain all of the three ones on each level, even though is need to repeated it several times, because they will be rewarded for that success by some bonus elements, e.g. extra lives, magic objects for using in next levels, advances into a next sections of levels or placing in first positions of the score table. The Basic Numbers application does not provide these benefits at least also for the time being, nevertheless it could not be a problem in the real world for a teacher (e.g. in form of grade A or "a small insignificant plus" at the evaluation) or for parents (appreciations, sweets, rewards, option of using the mobile phone, etc.) to assure that.

The percentage evaluation comes from the evaluation of particular examples. For the correct solution of one example in the first round (at 3 asterisks) will be awarded by 1 point, for the second round is ⅔ point only, in the third one is ⅓ only and for an unsolved example is 0 point. The percentage evaluation of every page represents an average number of these points at the examples in the given page multiplied by 100%. A percentage result of the test shall be the average of all the examples of the whole test in all its pages.
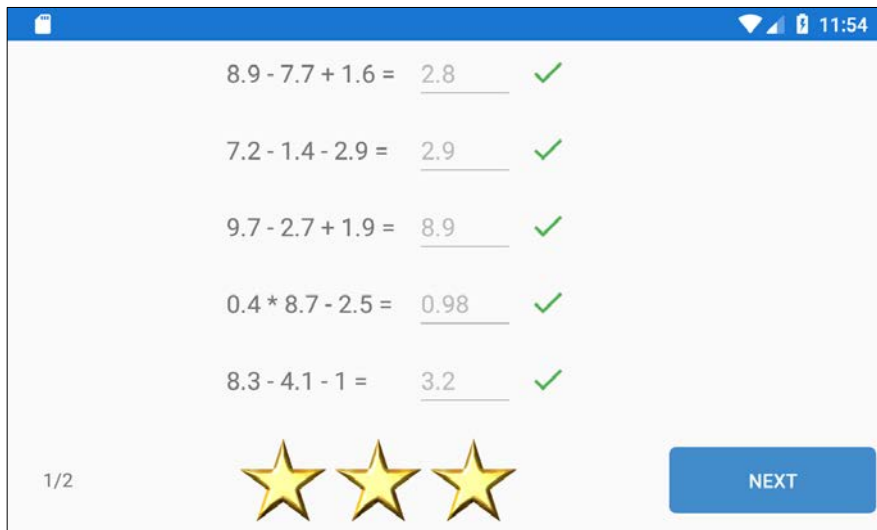
Figure 8. The page of examples with different setting in the landscape mode.

3.2 Application Settings Options

The Basic Numbers application contains a possibility for the examination setting (Fig. 10). The basic function is represented by a selection of arithmetic operations which could be contained in examples, i.e. addition, subtraction, multiplication and division. The other parameter is a range of values which could be used in examples. A range of members of examples can be defined separately including possible results, however it can be determined the range of intermediate calculations at progressive counting of examples with more members[3]. Thanks to it there can be set an assignment either for counting the addition and the subtraction up to ten or twenty (the first class of the elementary school), but also for practicing the small multiplication table (*, members of 1–10, results 1–100, respectively without limitation).

Furthermore it is possible to affect numbers of members for particular examples, numbers of decimal points of the example's members and results (they shall be rounded to this number of decimal points[4]), numbers of examples for one page and numbers of pages. No repetition of the same examples in the test it is monitored during the assignment generation. Thanks to all these setting possibilities it can be selected such a combination, which to prepare an assignment of test won't be possible for[5]. In such the case, this fact will be announced during trying start the examination (Fig. 9 – the *Start* button).

Of course, there can be activated and deactivated other functions as well. The first of them represents an option of storing results (detailed records) concerning every examination which was started and finished in some way. A content of these records will be described in detail in the following part.

There can be switched also sound effects on or off, which could be important for motivation of some children to use this application. However, when these sounds could disturb other pupils in the class during education, it is possible to switch them off here.

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[3] E.g. example „5 - 8 + 4" has every members and its result in range 0–10, however a pupil of the first class of the elementary school unknowing negative numbers or changing operations of the calculation won't be able to determine the intermediate result for „5 - 8" and therefore not calculate such the example, in spite of the fact that examples of „5 + 4 - 8" or „8 - 5 + 4" would not be problem for him/her.

[4] E.g. when only one decimal point is being set and the „0.5 * 0.5" example assigned, then the 0.3 value will be considered as the right result and eventually wrought up, however, when a student has assigned the more accurate result of 0.25, then also this value shall be rounded and even after it compared, so that both options shall be considered right.

[5] E.g. it is not possible to think out more than one example even with all operations, no decimals, two members in range 1–10 and with a result in range 100–200.
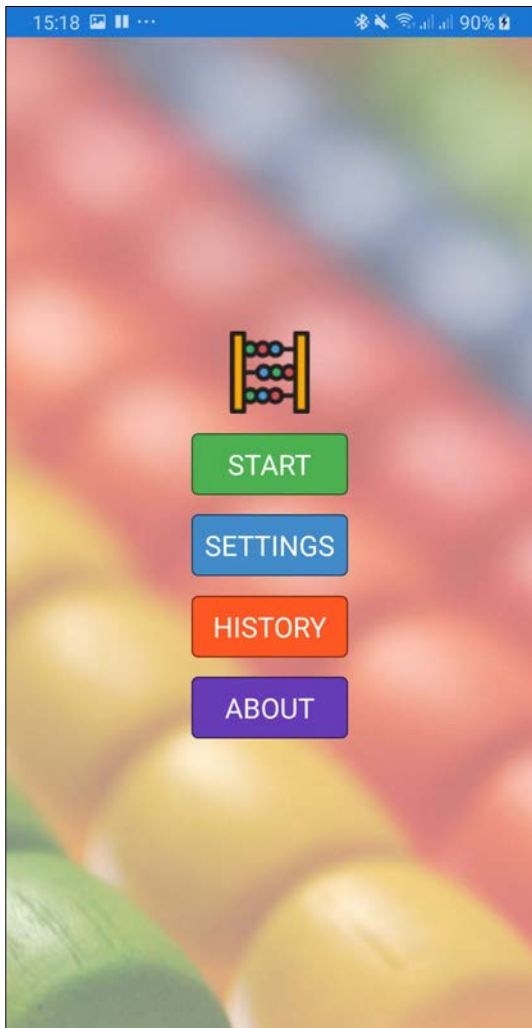
Figure 9. The application introduction display with the main menu.
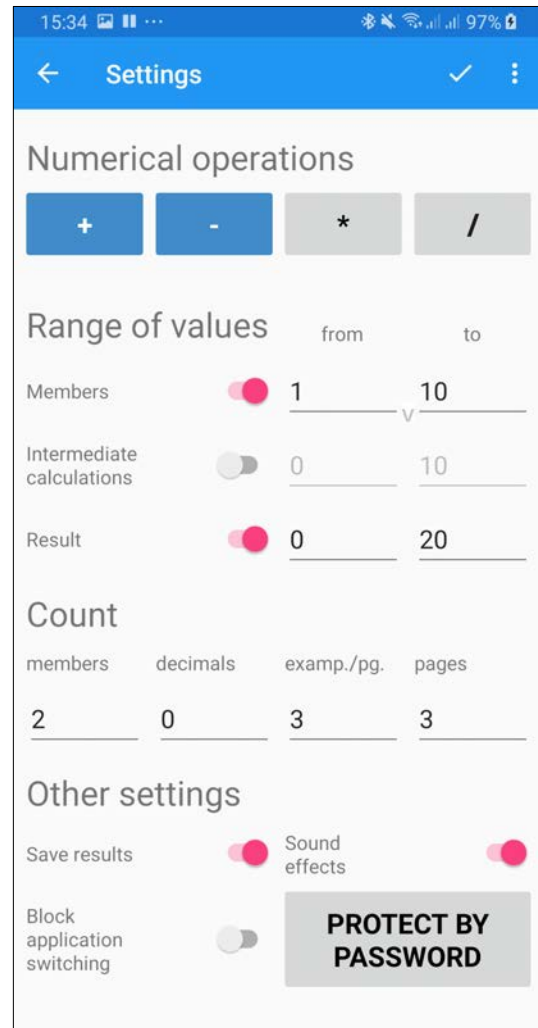

Figure 10. The page with setting the examination parameters.

Through activating the function intended for lockout of switching the applications over it can be accomplished that during the examination this application can't be simply switched to another one, e.g. to a calculator or to any chat. Switching the application itself over can't be prevented because of the operating system characteristics (e.g. the application switches over automatically when someone will be called), however, the application itself can response to that switching over in a certain way. In this case, the current page with examples is be covered with a red panel, in which a countdown from 10 to zero is running, and there is also the *Continue* button here (Fig. 11). If the pupil manages to switch back to the Basic Numbers application and click this button immediately, then he/she can continue the current examination. If the pupil fails to click in time, the test shall be stored after these ten seconds (when this function is not off in the setting) and finished automatically. (This solution is similar as at [7, pp. 48-53].)

This protection is working in case of the application version for Windows 10. Here the applications themselves are not switched over, but their windows only, which can be arranged on the screen even in such a way that they will be visible at the same time. That the application can't prevent, nevertheless by the focus change (switching over) to another window it occurs the same effect immediately (red cover, countdown, button) as at the version of the mobile phone (Fig. 12).
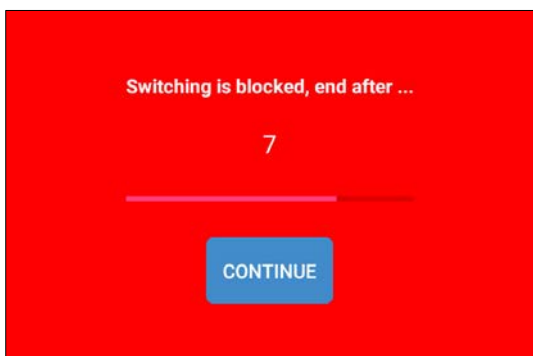
Figure 11. Protecting against switching applications over – the window with countdown the premature test termination (Android version).
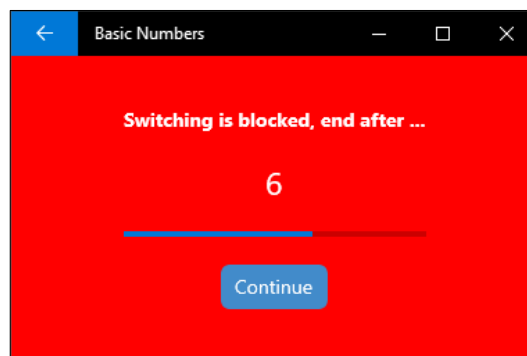

Figure 12. Protecting against switching applications in UWP version of the app for Windows 10.

Examination's parameters can be also essentially affected in the setting. When pupils use this application for practicing spontaneously, it naturally depends on them only, how much demanding settings they will select. If the examination is assigned by someone else (a teacher or a parent), then he/she will certainly appreciate a function which prevent an arbitrary adaptation of setting parameters by the pupil in an unguarded moment before the examination.

There is a possibility to lock the whole setting by means a password. This procedure can start by click the *Protected by password* button, which opens a dialog for entering the password (Fig. 12). After entering and confirming the lock of settings, the button turns red (Fig. 13), which means that the setting has been locked and any of its parameters can't be changed. It is enough for unlocking to click on the now red button again, to enter the same password as during locking and the setting will unlock again. The password is not stored in the setting as a plain text, but its hash[6] it is stored only, so that even an experienced user is not able to cheat a good selected password.
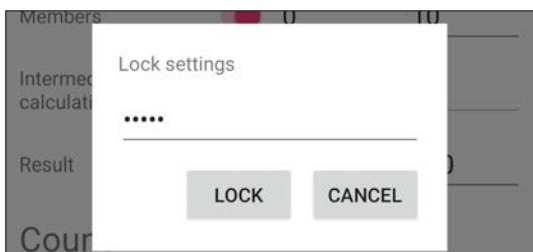

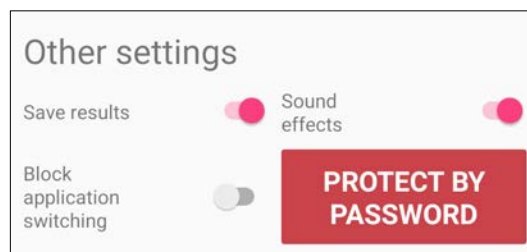*Figure 12. The dialog for entering the password intended for locking the setting.*

Figure 13. The red button indicating the locked setting.

Since there are comparatively enough parameters for settings, an option to store particular setting configurations and to read them again later has been added. This function is hidden under the button with three dots, where the buttons are situated for saving, for reading or for deleting the previous saved setting (Fig. 10 on the right above). Saving the setting is always available, reading and deleting only if the setting has not been locked by the password. For the saving it is only necessary to enter a name of the configuration under which the setting shall be stored, and through which can be found to read again. If the setting protected with a password has been stored, then it is saved including this option, however during loading, this fact shall be announced and a version of setting without a password protection offered for load. It could happen by a mistake that some older setting locked by a lost password be loaded therefore any further setting will be impossible.

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[6] *The hash representing one-way (irreversible) computationally efficient function mapping binary strings of arbitrary length to strings of a fixed length is called the hash-value.* [8]

3.3 Records of Tests

Records of all performed examinations/tests are stored into an internal application storage facility as independent files in the XML format, provided that this function is not switched off in the setting. Each of them contains in its title basic information about test results, i.e. date and time of the test's start, number of examples on a page and number of pages, time period devoted to the test's solution and a total percentage result. A summary of these records (Fig. 14) can be shown by the History button in the main menu (Fig. 9).

Figure 14. The list of records of performed tests.

Figure 15. The page of analysis of a selected test.

The page of the records summary also contains their rolling list which basic information concerning each of them is evident from. This summary can be filtered according to the date for the time period of the last day, week, month, year, respectively to display everything. Particular items can be marked and the selected record is possible to either delete (if the setting is not locked by a password) or load.

The complete analysis can be loaded by opening the record. It will be displayed an equivalent of every page which an examinee could see before switching to another one (Figures 2, 4, 6, 7, 8) with all his/her mistakes and progressively assigned results. The arrangement is slightly different (Fig. 15).

There is always a right result in the non-active editor, namely as it has been determined by the application, and after it on the right there are an examinee's particular attempts (entered numerical values). They can be in a count from 1 to 3. Behind them there is an icon describing a correctness of each entered result. It this result was right, other attempts did not follow logically (except the first possibility, when even a right result could be "corrected" to a wrong one) and the example was considered right at the first step. A wrong result (whether with changes or still the same) can however stay till the end, i.e. to the third attempt.

It is necessary to bear it in mind at evaluating particular results in the test's analysis, under which circumstances the examinee assigned each of the attempts. The first attempt was in the complete clear screen with assignment of examples only (Fig. 1), the second solution could be changed by the

examinee after an announcement that there was some mistake in these examples (Fig. 3), and at the third attempt there were even marked the examples containing the mistake (Fig. 5).

It can be seen on each of the pages, how many asterisks the examinee obtained, the order number of the page from its total count and there are two buttons intended for switching between the *Previous* and *Next* pages over here. The label of the *Next* button is changed to *Close* on the last page, because it closes the test analysis and returns to the examination records list. The analysis as any other page can be leaved by the system *Back* button regardless if the hardware or software one.

4   CONCLUSIONS

The Basic Numbers application provides a new interesting option intended for both study and education of mathematics at the primary school. It can be either a useful aid for practicing and automation of basic mathematical operations themselves intended for pupils, a funnier alternative for parents at the assignment of examples for the purpose of improving their children, but also a tool of teachers for the sake of variety of the education or examination of the knowledge level of their pupils.

The application itself contains elements of gamification. Examples are marked by means of coloured icons, every step of the evaluation is accompanied by sound effects and there are even not the progressive help, which however decreases number of asterisks at the evaluation in particular pages with examples. All these details, occurs in various games which however are not beneficial in all cases, motivate children to obtain the best results and to repeat the examination till obtaining "the best results".

This application is fully configurable, and it is possible to set individual conditions of the examination for every pupil's level. These settings can be also saved under own names and protect by a password against unauthorized changes of parameters. An interesting option especially for using the application to pupils' examinations represents the function of lockout of switching over among applications, which increases the relevance of obtained results.

A development of the application continues permanently, but it has been even proved during its pilot operation as a first-rate and useful aid for an advanced way of the effective education in the field of basic mathematics at the first grade of primary school.

ACKNOWLEDGEMENTS

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