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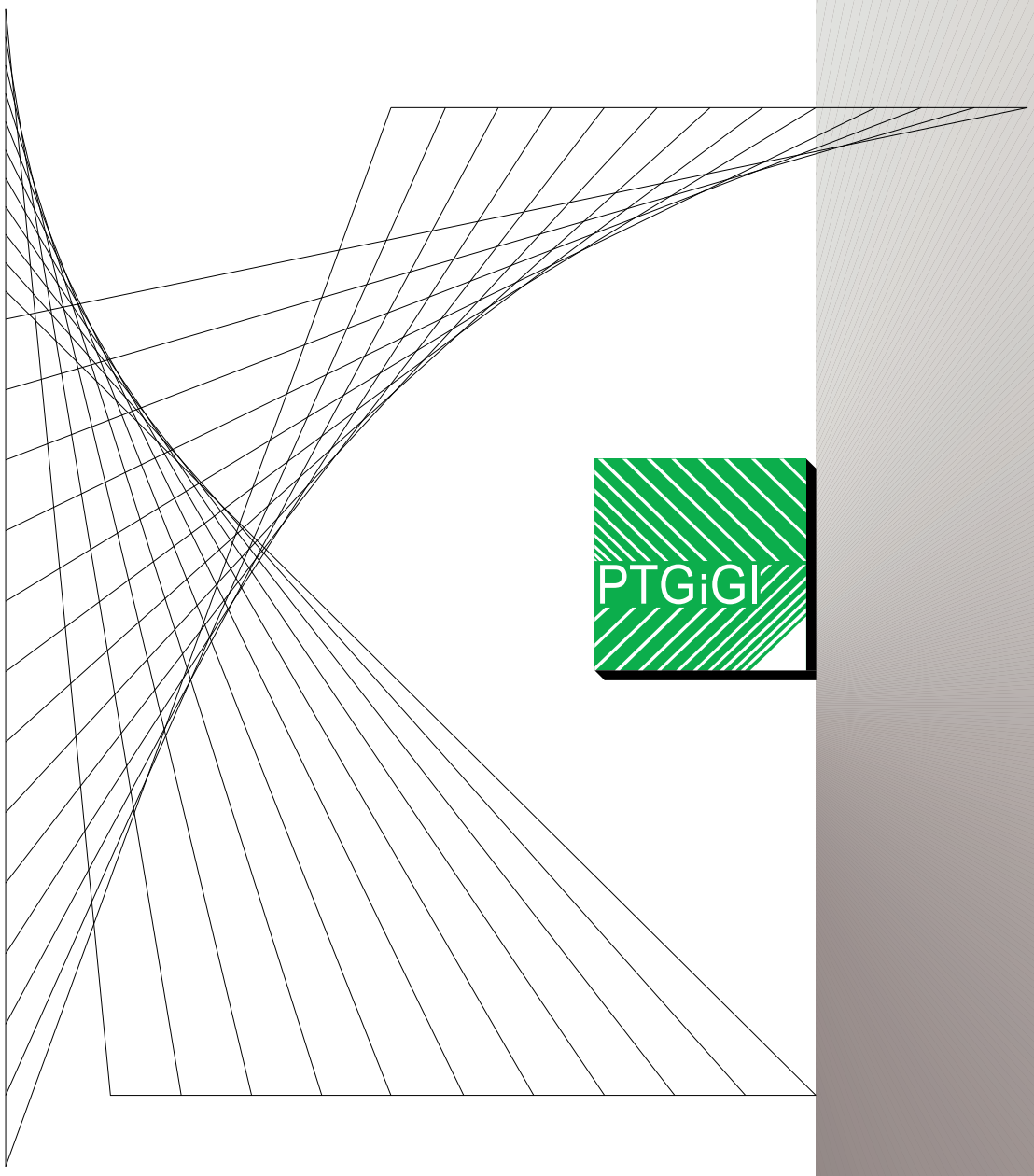

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WHAT CAN TEACHERS LEARN FROM THEIR STUDENT'S HOMEWORK

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Abstract. Homework as a didactic tool is highly useful for students because it makes them practice the acquired knowledge. Simultaneously, it provides the teachers a feedback how the students can understand discussed problems.
In case a homework is processed and evaluated electronically, more data can be collected which gives the teacher wider spectrum of information.
Solving problems in automated systems usually brings the possibility of gaining the data attached to the solution process itself, which – when evaluated – brings information about this process. Such features give the teachers valuable information about students' understanding the lecture topic, provide them with feedback information about laboriousness of a particular homework or test and its most time-consuming problems and tasks. They facilitate differentiation between the various reasons for failure of individual students, help to reveal the critical moments and the most difficult ideas of the task (for students) and thus enable teachers to arrive at conclusions which can help them to form the next steps in the teaching process.
In this paper we present a wide range of information obtained from the data stored in one such system.

Keywords: Learning Management Systems, Learning outcomes, homework assignment evaluation systems and methodology

1 Introduction

Homework assignments are a specific part of any teaching process. They help students to explore and to fix knowledge gained within the lessons. While teachers' explanations lead to Knowledge and Comprehension (the first and the second category of Bloom's taxonomy [1]), then by doing homework assignments the students are subjected to the third category, which is an Application.
Nevertheless, homework can also give specific information to the teacher, too; e.g. about the students' way of executing the specific problems, about the tasks and about the issues that students did not comprehend right.

1.1 Automatic evaluation of homework assignments

Manual evaluation of homework can usually lead to a long time gap between the students' activity and the feedback he/she gets. Thus, it is hard for students to return back to the tasks that have been incorrectly or poorly solved. Return information that is received from the teacher with the delay has usually insufficient impact on the student's creativity if compared to automatic feedback that can be immediately send back after submission, where the student can immediately respond to the evaluation message and try to re-solve the task in another way [3].

What is more, an automatic evaluation of homework can bring some other effects besides this one that the students can correct their answer and therefore bring more tasks to the correct answer: it can provide the teacher with information which would not be possible to get during manual evaluation of the homework. This paper deals with this kind of information.

The examples and all the data which we are presenting in this paper come from the GeoTest (e.g. [4]), and its use by more than 100 teachers and 5000 students on schools of all levels in Czech Republic from 2011 to 2015. Similar data can be obtained from the other LMS systems, such as Moodle [2] or Blackboard.

All the text below has been divided into paragraphs according to particular subjects of acquired information.

2 Information on specific solution

The first piece of information we will talk about now, is not much different from information that a teacher can get by correcting the homework manually. While examining the students' answers, the teacher can spot the mistakes and can easily compare the answers given individually by all the students.

An electronic form of answering procedure can bring different views on particular solutions. In case of geometric constructions we have to do with the following elements which are the parts of a solving process: a drawing, a construction protocol and a structure of the construction process, which is represented by a graph showing all the solving process in subsequent steps which have been executed. The graph can show the complexity of the construction and also can reveal all unnecessary steps and the elements that have been unnecessarily used or simply useless in a construction process (see in Figure 1: line *b* and points *Ps*, *A*2 in the second and the third constructions; *s*1, *s*2 are the expected answers).

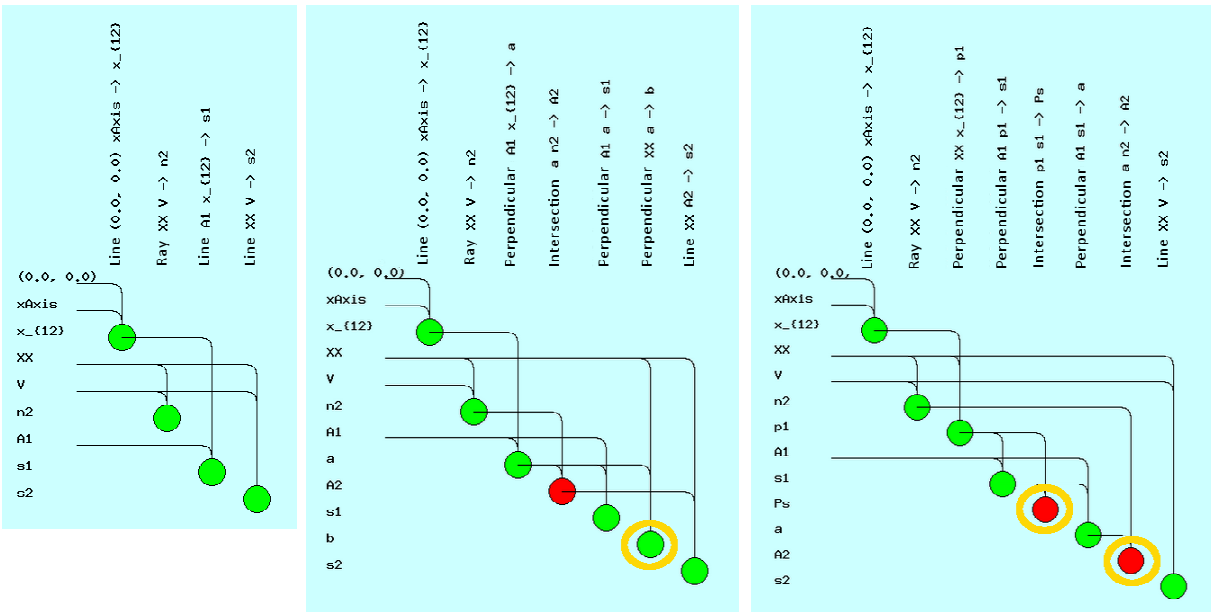
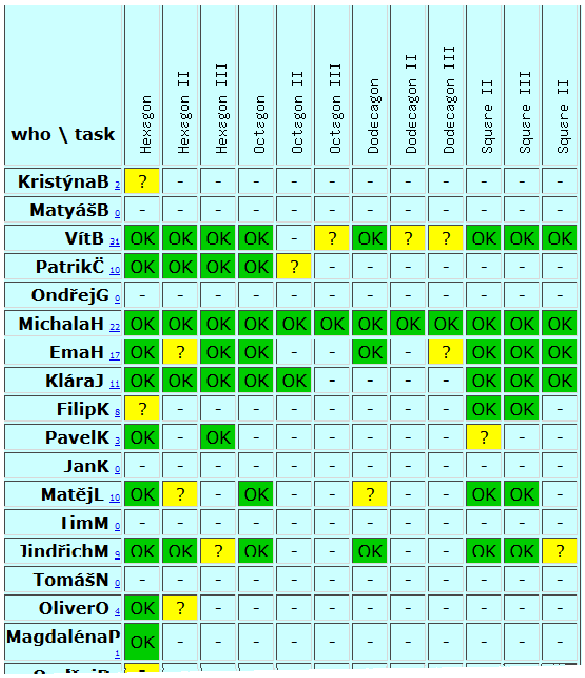
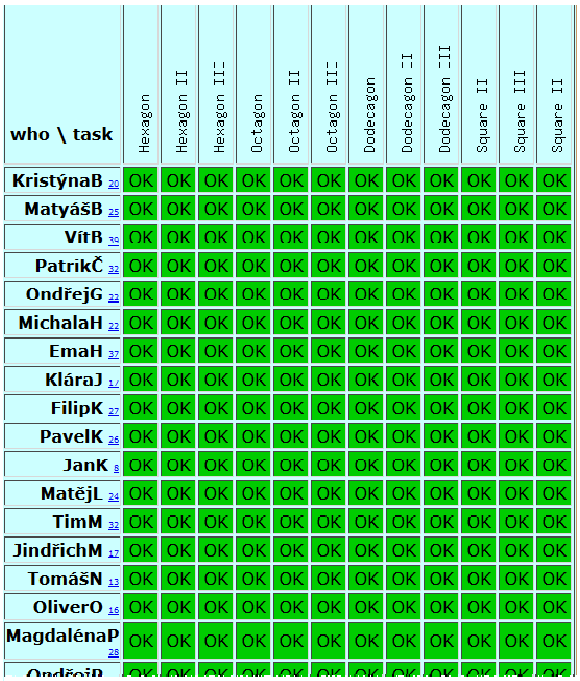


Figure 1: Structure of the construction – comparison of three different solutions of the same task



who \ task	Hexagon	Hexagon II	Hexagon III	Octagon	Octagon II	Octagon III	Dodecagon	Dodecagon II	Dodecagon III	Square II	Square III	Square II
KristýnaB 2	?	-	-	-	-	-	-	-	-	-	-	-
MatyášB 0	-	-	-	-	-	-	-	-	-	-	-	-
VítB 21	OK	OK	OK	OK	-	?	OK	?	?	OK	OK	OK
PatrikČ 10	OK	OK	OK	OK	?	-	-	-	-	-	-	-
OndřejG 0	-	-	-	-	-	-	-	-	-	-	-	-
MichalaH 22	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
EmaH 17	OK	?	OK	OK	-	-	OK	-	?	OK	OK	OK
KláraJ 11	OK	OK	OK	OK	OK	-	-	-	-	OK	OK	OK
FilipK 8	?	-	-	-	-	-	-	-	-	OK	OK	-
PavelK 3	OK	-	OK	-	-	-	-	-	-	?	-	-
JanK 0	-	-	-	-	-	-	-	-	-	-	-	-
MatějL 10	OK	?	-	OK	-	-	?	-	-	OK	OK	-
TimM 0	-	-	-	-	-	-	-	-	-	-	-	-
JindřichM 9	OK	OK	?	OK	-	-	OK	-	-	OK	OK	?
TomášN 0	-	-	-	-	-	-	-	-	-	-	-	-
OliverO 4	OK	?	-	-	-	-	-	-	-	-	-	-
MagdalénaP 1	OK	-	-	-	-	-	-	-	-	-	-	-



who \ task	Hexagon	Hexagon II	Hexagon III	Octagon	Octagon II	Octagon III	Dodecagon	Dodecagon II	Dodecagon III	Square II	Square III	Square II
KristýnaB 20	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
MatyášB 25	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
VítB 30	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
PatrikČ 32	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
OndřejG 23	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
MichalaH 22	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
EmaH 37	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
KláraJ 17	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
FilipK 27	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
PavelK 26	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
JanK 8	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
MatějL 24	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
TimM 32	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
JindřichM 17	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
TomášN 13	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
OliverO 16	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
MagdalénaP 28	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

Figure 2: Overview of solved tasks – initial grading

Figure 3: Overview of solved tasks – final grading

3 Information on student

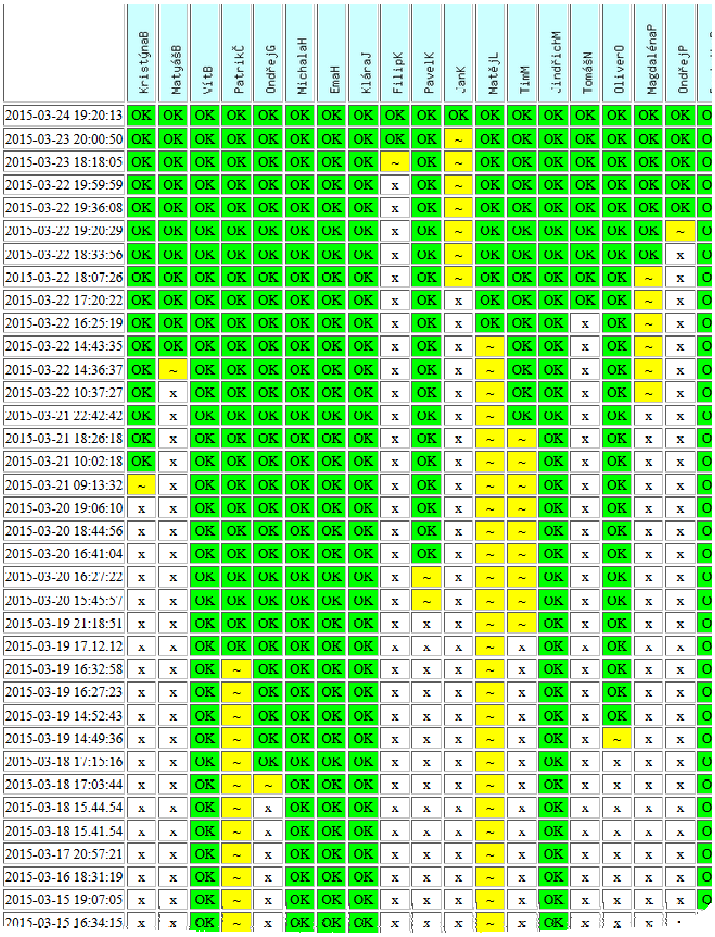
3.1 Solving the tasks

After a teacher (or computer) has evaluated all the answers of a given homework, the result can be shown in a table presenting what tasks were solved correctly or incorrectly or else if some were left unsolved by a particular student. In Figure 2, the columns are assigned to subsequent tasks, the rows to particular students, and the three colors have been used as the cell's infill. These colors are as follows: green is used for correctly solved tasks, yellow for incorrectly solved problems, while light blue if no solution has been submitted by a student.

3.2 Process of solution I

When the students get information on their mistakes and if they have enough time to correct their answers, then they all have a chance to improve their solutions. Thus they have a chance to have all the tasks correctly solved. This situation is awarding in context of reaching the goal of a teaching process, but it gives no information on the learning progress and learning outcome to the teacher (see Fig. 3).

The advantage which gives an electronic system (for solving homework) is that we can display the status of the solution process at any time within a solving process. To give an example, let us analyze the table presented in Figure 4. In the columns we have the names of the students, the rows show the date and time of solution. Proper color has been assigned to the "state of art" of a particular problem (correct, incorrect, no answer) achieved by student for at least half of tasks. In the topmost row we can see that finally all students solved at least 50 percent of the tasks – the teacher can choose the number – and later he/she can see which student solved the homework sooner and which solved it later.



	KristýnaB	MatyášB	VítB	PatrikČ	OndřejG	MichalaH	EmaH	KláraJ	FilipK	PavelK	JanK	MatějL	TimM	JindřichM	TomášN	OliverO	MagdalénaP	OndřejP	
2015-03-24 19:20:13	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	O
2015-03-23 20:00:50	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	~	OK	OK	OK	OK	OK	OK	OK	O
2015-03-23 18:18:05	OK	OK	OK	OK	OK	OK	OK	OK	~	OK	~	OK	OK	OK	OK	OK	OK	OK	O
2015-03-22 19:59:59	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	~	OK	OK	OK	OK	OK	OK	OK	O
2015-03-22 19:36:08	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	~	OK	OK	OK	OK	OK	OK	OK	O
2015-03-22 19:20:29	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	~	OK	OK	OK	OK	OK	OK	~	O
2015-03-22 18:33:56	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	~	OK	OK	OK	OK	OK	OK	x	O
2015-03-22 18:07:26	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	~	OK	OK	OK	OK	OK	~	x	O
2015-03-22 17:20:22	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	x	OK	OK	OK	OK	OK	~	x	O
2015-03-22 16:25:19	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	x	OK	OK	OK	x	OK	~	x	O
2015-03-22 14:43:35	OK	OK	OK	OK	OK	OK	OK	OK	x	OK	x	~	OK	OK	x	OK	~	x	O
2015-03-22 14:36:37	OK	~	OK	OK	OK	OK	OK	OK	x	OK	x	~	OK	OK	x	OK	~	x	O
2015-03-22 10:37:27	OK	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	OK	OK	x	OK	~	x	O
2015-03-21 22:42:42	OK	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	OK	OK	x	OK	x	x	O
2015-03-21 18:26:18	OK	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-21 10:02:18	OK	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-21 09:13:32	~	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-20 19:06:10	x	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-20 18:44:56	x	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-20 16:41:04	x	x	OK	OK	OK	OK	OK	OK	x	OK	x	~	~	OK	x	OK	x	x	O
2015-03-20 16:27:22	x	x	OK	OK	OK	OK	OK	OK	x	~	x	~	~	OK	x	OK	x	x	O
2015-03-20 15:45:57	x	x	OK	OK	OK	OK	OK	OK	x	~	x	~	~	OK	x	OK	x	x	O
2015-03-19 21:18:51	x	x	OK	OK	OK	OK	OK	OK	x	x	x	~	~	OK	x	OK	x	x	O
2015-03-19 17:12:12	x	x	OK	OK	OK	OK	OK	OK	x	x	x	~	x	OK	x	OK	x	x	O
2015-03-19 16:32:58	x	x	OK	~	OK	OK	OK	OK	x	x	x	~	x	OK	x	OK	x	x	O
2015-03-19 16:27:23	x	x	OK	~	OK	OK	OK	OK	x	x	x	~	x	OK	x	OK	x	x	O
2015-03-19 14:52:43	x	x	OK	~	OK	OK	OK	OK	x	x	x	~	x	OK	x	OK	x	x	O
2015-03-19 14:49:36	x	x	OK	~	OK	OK	OK	OK	x	x	x	~	x	OK	x	~	x	x	O
2015-03-18 17:15:16	x	x	OK	~	OK	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-18 17:03:44	x	x	OK	~	~	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-18 15:44:54	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-18 15:41:54	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-17 20:57:21	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-16 18:31:19	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-15 19:07:05	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x	x	O
2015-03-15 16:34:15	x	x	OK	~	x	OK	OK	OK	x	x	x	~	x	OK	x	x	x		

Figure 4: Progress of individual students

3.3 Solving after finishing correct answer

As the electronic system keeps the data on all submissions and answers, the teacher is able to notice that some of the students keep up to continue submissions even though their homework has already been correctly solved. Also, when the teacher looks on a specific answer, he/she can see that the student tried to solve the same task in another way.

3.4 Total time of homework

At the end of this chapter we are going to report how much time his/her student spent on doing the homework.

Two factors are surprising in the discussed above context: 1) the total time spent on a task by the specific student and 2) the differences between the students. Figure 5 presents the total amounts of time per each student spent on the homework (for each student it is the sum of time needed for individual tasks). The data provided here are given in seconds. The fastest student needed slightly more than half an hour while the slowest one almost six times more.

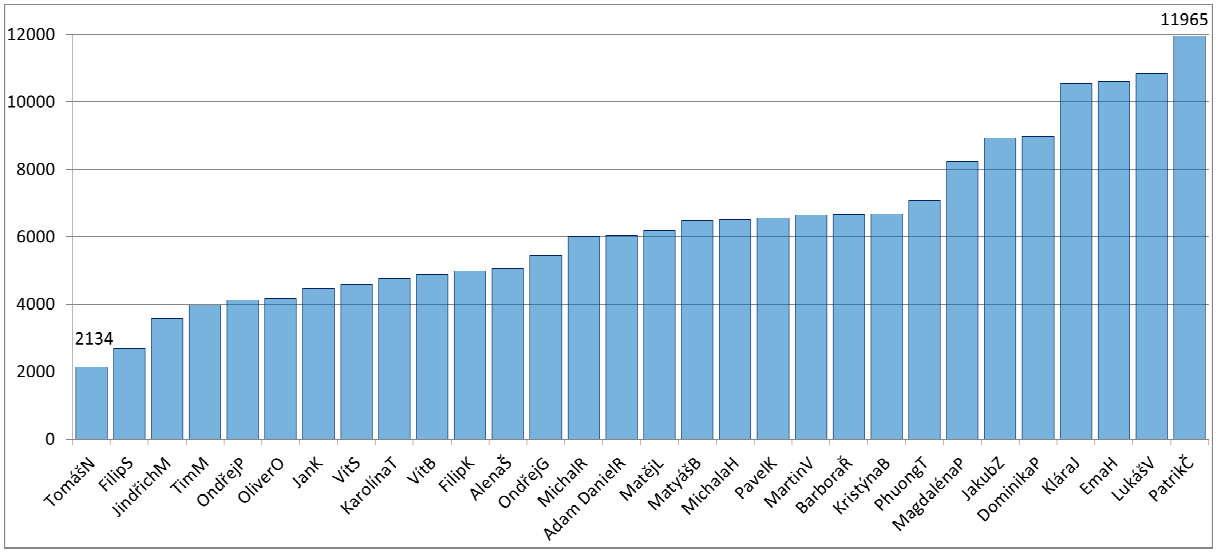


Figure 5: The overall time of individual students

4 Information on the specific student and the specific task

Solving homework with the help of online system can provide the teacher with information how long it takes for the specific student to solve the specific task. Such information relates to the skills and knowledge of a particular student.

In Figure 6 we can see a boxplot of time needed to solve one task of a given homework – outliers, minimum, maximum, quartiles and median of time needed for each student. Figure 7 shows the time-span that the student needs to solve individual tasks.

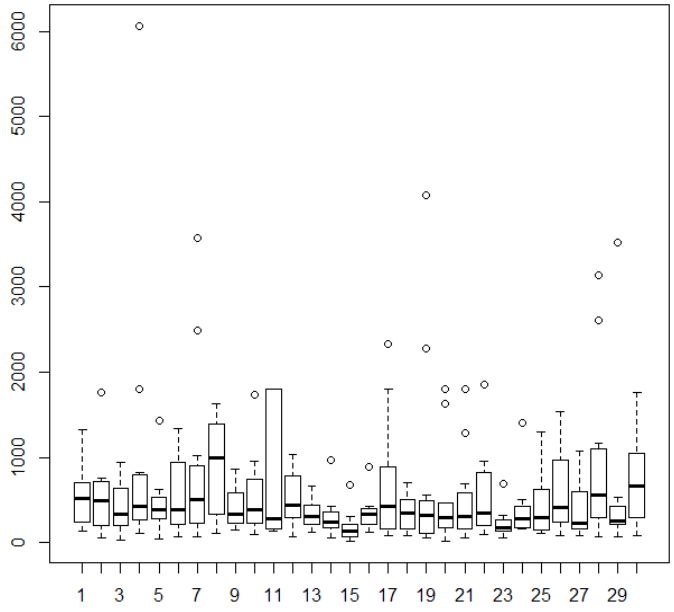


Figure 6: The time spent by individual students per task (there are numbers instead of the names here)

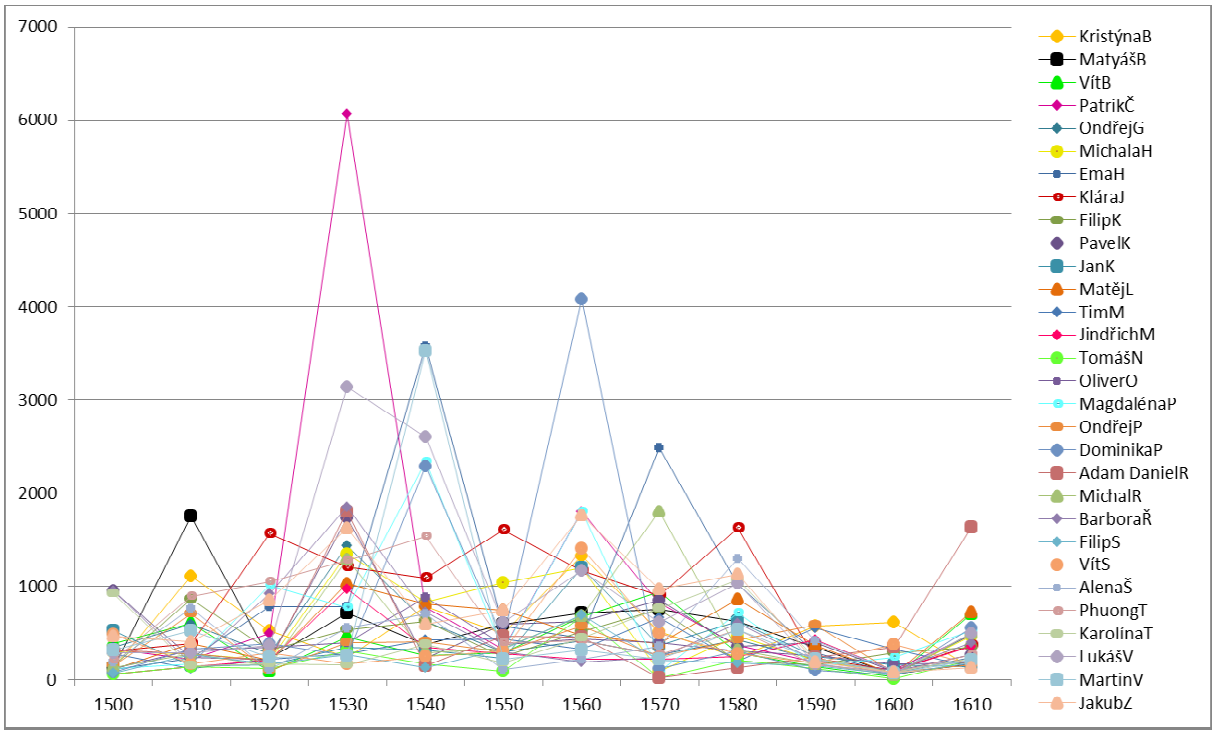


Figure 7: The time needed for each of given tasks by individual students

When we present a sum of times instead of a simple time chart, we can see more clearly in which case the time is determined by the global skill and quickness of the student and when it is determined by the ability to solve the specific task – see Figure 8 where one particular student's time sequence is highlighted. On the vertical axis is time in seconds, on the horizontal axis are numbers of individual tasks.

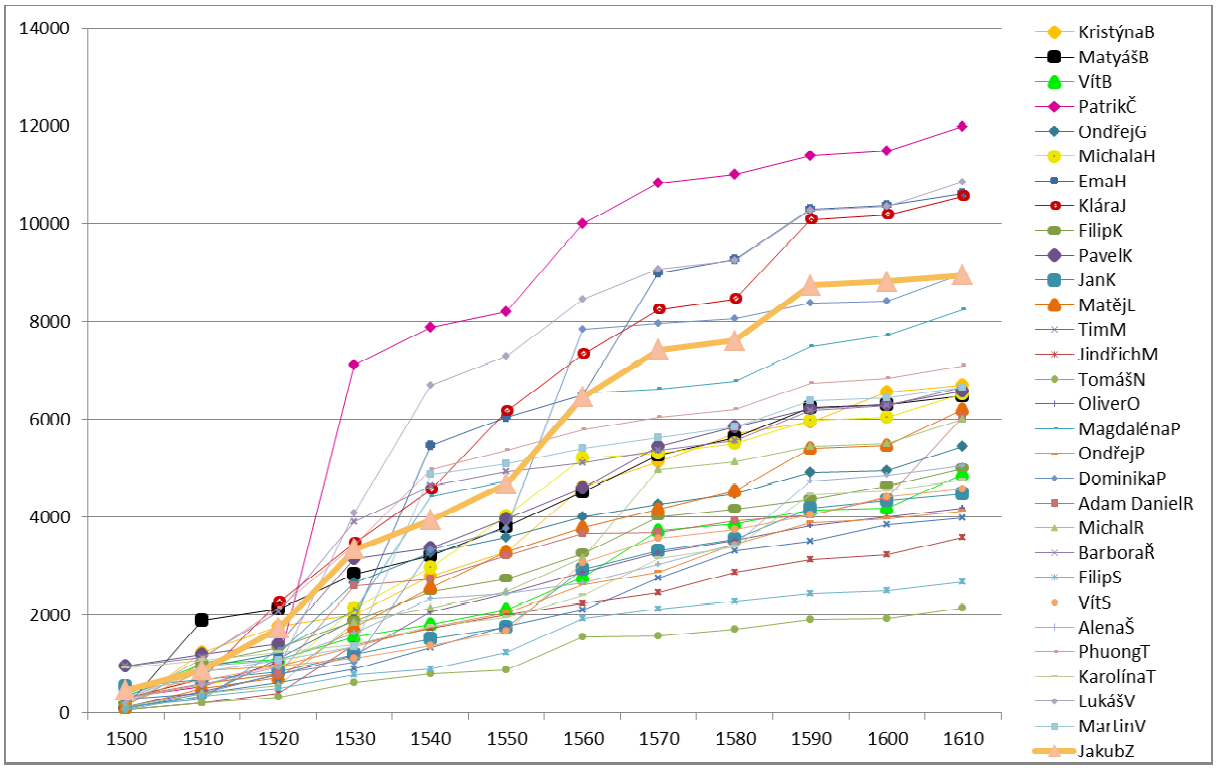


Figure 8: The total time needed for solving given tasks (cumulative)

5 Information on tasks

Next piece of information that the teacher can be interested in and that can help the teacher to accommodate his/her teaching refers to the levels of difficulty of the individual tasks for students.

5.1 Process of solution III

By analogy, as the teacher can retrospectively see the process of solving homework by individual students (Fig. 4), he/she can also see how students dealt with particular tasks (Fig. 9).

Columns of the table are assigned to particular tasks. In the cells we assign specific colors as it is described in 3.1. The color corresponds to the result obtained at least one half (or given percent) of all students.

	Hexagon	Hexagon II	Hexagon III	Octagon	Octagon II	Octagon III	Dodecagon	Dodecagon II	Dodecagon III	Square II	Square III	Square II
2015-03-21 19:44:03	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
2015-03-21 18:26:11	OK	OK	OK	OK	OK	OK	OK	-	OK	OK	OK	OK
2015-03-21 18:26:18	OK	OK	OK	OK	OK	OK	OK	~	~	OK	OK	OK
2015-03-20 18:50:13	OK	OK	OK	OK	OK	~	OK	~	~	OK	OK	OK
2015-03-20 16:02:16	OK	OK	OK	OK	~	~	OK	~	~	OK	OK	OK
2015-03-20 15:35:18	OK	OK	OK	OK	~	~	OK	x	~	OK	OK	OK
2015-03-19 19:45:55	OK	OK	OK	OK	~	~	OK	x	~	OK	OK	~
2015-03-19 19:38:56	OK	OK	OK	OK	~	~	OK	x	x	OK	OK	~
2015-03-19 17:44:40	OK	OK	OK	OK	~	x	OK	x	x	OK	OK	~
2015-03-19 16:16:11	OK	OK	OK	OK	~	x	~	x	x	OK	OK	~
2015-03-18 17:33:49	OK	~	OK	OK	~	x	~	x	x	OK	OK	~
2015-03-18 17:00:44	OK	~	OK	OK	x	x	~	x	x	OK	OK	~
2015-03-18 15:44:54	OK	~	OK	OK	x	x	x	x	x	OK	OK	~
2015-03-18 15:43:39	OK	~	OK	OK	x	x	x	x	x	OK	~	~
2015-03-17 20:36:43	OK	~	OK	OK	x	x	x	x	x	~	~	~
2015-03-17 17:27:49	OK	~	~	OK	x	x	x	x	x	~	~	~
2015-03-15 17:20:28	OK	~	~	~	x	x	x	x	x	~	~	~
2015-03-15 17:18:18	OK	~	~	~	x	x	x	x	x	~	~	x
2015-03-15 15:35:20	OK	~	~	~	x	x	x	x	x	~	x	x
2015-03-15 15:31:54	OK	~	~	~	x	x	x	x	x	x	x	x
2015-03-14 15:10:31	OK	~	x	~	x	x	x	x	x	x	x	x
2015-03-14 14:29:27	OK	x	x	~	x	x	x	x	x	x	x	x
2015-03-14 10:19:35	OK	x	x	x	x	x	x	x	x	x	x	x
2015-03-09 21:48:01	~	x	x	x	x	x	x	x	x	x	x	x
2015-03-06 16:03:08	x	x	x	x	x	x	x	x	x	x	x	x

Figure 9: Progress of solving individual tasks

In this example we can see that majority of the students solved the first task in the first run, then started to solve the second task but lot of them have postponed solution and switched to a subsequent task or tasks. One may want to notice that the problem which is positioned in the fifth column from the right side has not been approached by the majority of students for a long time. We may want to conclude here that this problem was a pain to majority of students.

When the teacher receives such information, he/she must explore the task in context of its complexity and the reasons for the failure in getting a correct solution. It is also probable that the problem should be explained more thoroughly, sometimes again

or otherwise modified. Sometimes it would be required to change the strategy of his/her teaching approach.

5.2 Comparison of the time of solving the task

Data on the time that a particular student needs to solve a particular task are shown in Figure 6.

In Figure10 we have shown the boxplots for particular tasks performed by all the students: outliers, minimum, maximum, quartiles and median of time needed for each task of the homework.

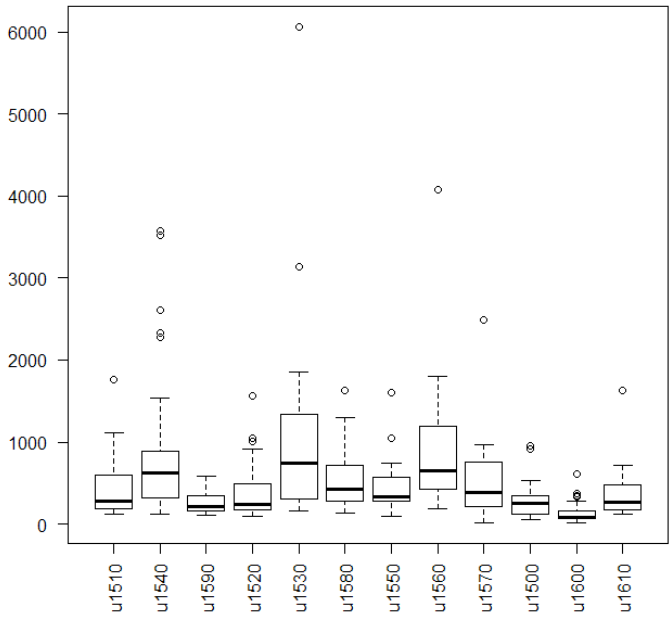


Figure 10: The time spent on individual tasks per student

We can get other view observing the time as a sample of random variable and evaluating the hypothesis about particular couple of tasks that first tasks requires more time than second task.

For evaluation of this hypothesis we can use **Paired t-test** or **Welch Two Sample t-test** and present the results in the form of a graph (Fig. 11). The edge is directed from the more difficult (more time required to solve) to the easier (less time) task.

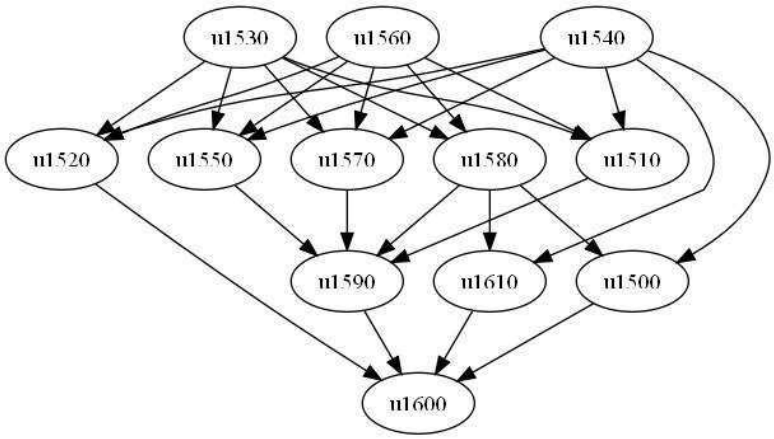


Figure 11: Partial ordering of tasks by the time needed

5.3 Comparison of the difficulty of the tasks (percentage of successful attempts)

We can also try to measure the difficulty of the task by counting the number of successful/unsuccessful students' attempts to answer it. Usually, the comparison complies with the experienced teacher's expectation. However, it happens that the result goes across his/her expectations.

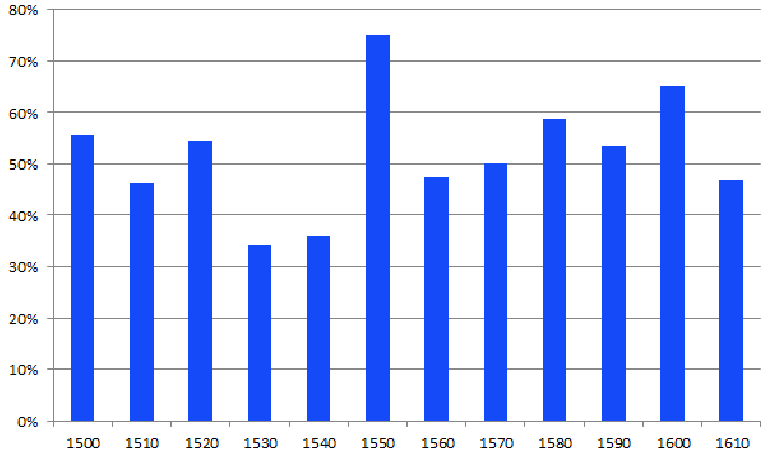


Figure 12: Percentage of successful attempts per task

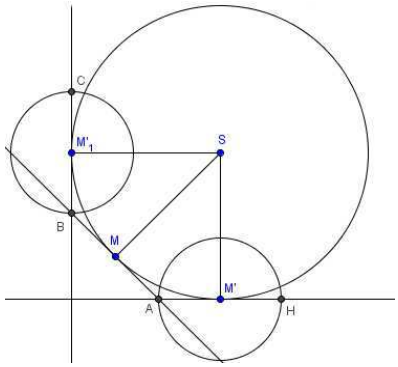


Figure 13: Example of task

In the graph (Fig. 12) we can see the success rate in solving tasks from the examples discussed above. The most unsuccessful task was to construct an octagon given by its center *S* and midpoint *M* of the side *AB* (Fig. 13). Only rotation, ruler and compasses are allowed in this construction.

Let us now have a look on one thematic group taken from descriptive geometry. Graph in Figure14 shows the success rate in solving tasks the goal of which is to construct the slope line in a given plane (Monge's Projection). Some of the tasks are simple and some are more complicated and require students to construct additional lines.

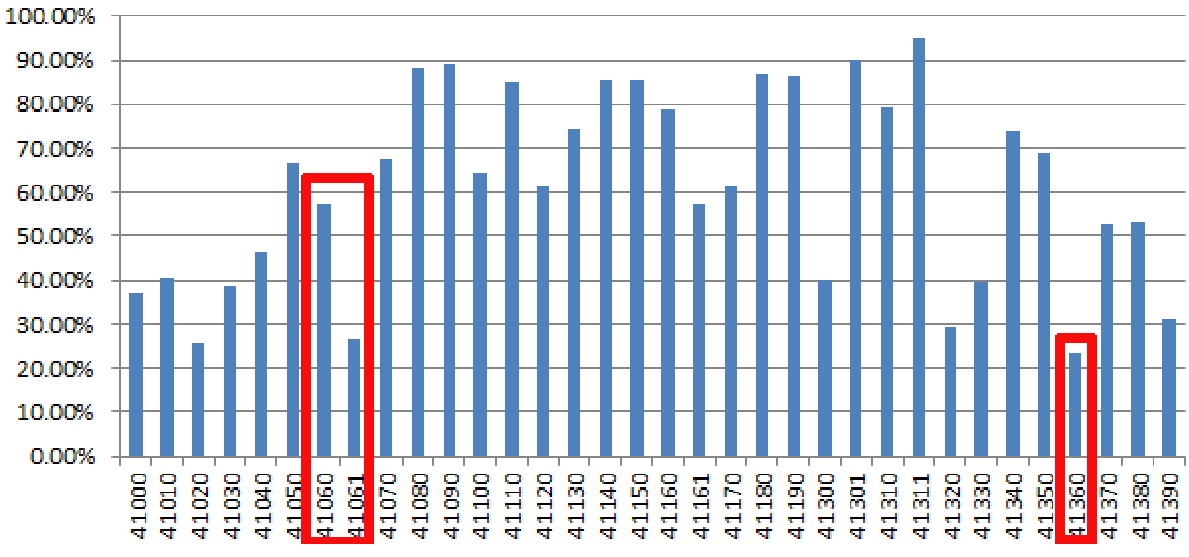


Figure 14: Percentage of successful attempts per task (Monge's Projection)

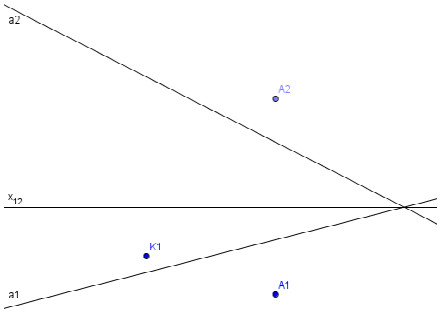


Figure 15: Given elements in the task 41060

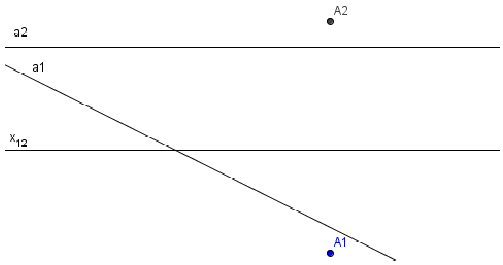


Figure 16: Given elements in the task 41061

Surprising observation results from comparison of the success rate of task 41060 and 4061. In 4060, the slope line at point *K* (Fig. 15: the plane is given by a line and a point) is to be constructed. More than 57 % of students completed this task correctly. On the next task, which was practically the same (Fig. 16: the line at given point *A* is required to construct) 41061 has reached only 27 % of correct answers although this task should be much easier to solve. It is most probable that the line parallel to the horizontal picture (horizontal line) confuses the students.

Similarly, a horizontal line is forming element of a plane in the task 41360 where the success rate is only 23 %.

6 Information on working mode of students

Last piece of information focuses on observation about the time of a day when the students do their homework. We are examining the subsequent days in a series of a week and a time of a day. Observation utilize the number of submitted answers, it includes not only homework solutions but also answers submitted during school lessons (individual activity in lessons, tests).

For each hour we show the number of correct and incorrect submitted answers. Figure 17 displays those data for school years 2012/13 and 2013/14.

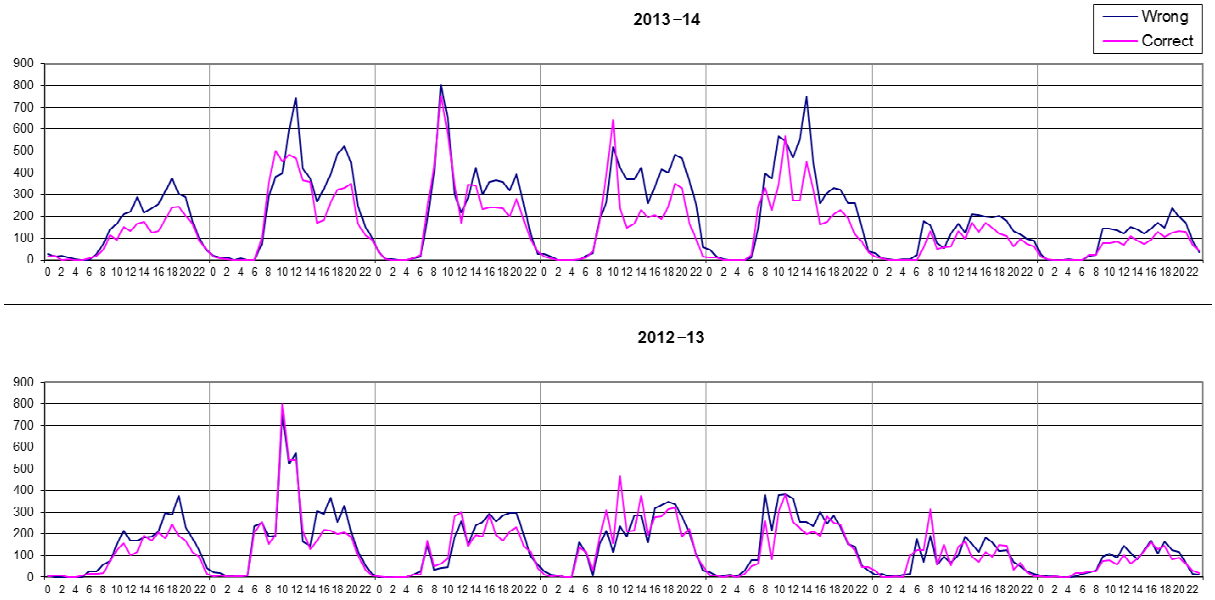


Figure 17: Number of correct and incorrect answers during the week (starting Sunday)

7 Conclusion

Homework is an integral part of teaching for centuries. When students prepare and submit their answers using electronic system, teacher can obtain some additional information on both task and students. Both of them he/she can afterward apply to enhance his/her teaching and increase its impact.

References

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[2] *Moodle.org.* Retrieved May 29, 2015: https://moodle.org
[3] Gergelitsová Š., Holan T.: *Using GeoGebra applets for homework assignments.* The Journal Biuletyn of Polish Society for Geometry and Engineering Graphics, Volume 26 (2014), 21–25.
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ZADANIA PROBLEMOWE W SYSTEMIE ZDALNEGO NAUCZANIA – WIELOPARAMETROWA ANALIZA EFEKTÓW NAUCZANIA

Zadania domowe odgrywają niezwykle istotną rolę w procesie dydaktycznym, umożliwiając zrozumienie i ugruntowanie wykładanego materiału. Jednocześnie, dostarczają informacji wykładowcom, w jakim stopniu materiał przedstawiany na wykładach jest przyswajany przez studentów. W przypadku nauczania za pomocą środowiska zdalnego nauczania, jakim jest np. system GeoTest, można nie tylko zadawać poszczególne problemy do rozwiązania, ale też dokonywać analizy wielu parametrów związanych z procesem rozwiązywania zadań. Autorzy niniejszego projektu, nie tylko przygotowali zestaw zadań w systemie GeoTest z zakresu geometrii dwuwymiarowej, jak również rzutów Monge'a, ale także dokonali analizy matematycznej i statystycznej otrzymanych wyników pod kątem różnorodnych parametrów, a to: stopnia trudności poszczególnych zadań, czasu rozwiązywania, pory dnia w jakiej najchętniej studenci przystępują do zadań, itd. Analiza taka daje cenne informacje zwrotne dla wykładowcy i pozwala na rozwijanie kolejnych etapów przygotowania ulepszonego systemu testów. W niniejszej pracy przedstawiono wyniki badań przeprowadzonych w Uniwersytecie Karola w Pradze (Republika Czeska).