Discovering the bottleneck problems based on automatic time measurements in the GrEta LEGOstics environment

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Abstract

GrEta is an innovative simulation project, what was constructed in Szabó-Szoba R&D Laboratory at Széchenyi University Győr, for modelling the nature of flexible production processes. It is one of the best ways to demonstrate the most commonly occurring logistics phenomena in series of mass production on the learning-by-doing way. The participants are authorised to decide every detail of the production (assembling tasks, layout, material flow), therefore it is really important to have an automatic measurement system built in the plotting board, to register all the data they need to form KPIs, create an adaptable evaluating scheme and support the decision making process.

Index Terms— production process modelling, learning-by-doing, automatic time measurement

CONTENTS

1 LEGOSTICS ENVIRONMENTS

The collective noun LEGOstics is coming from the LEGO and LOGISTICS words: LEGO products are very suitable for modelling such semi-virtual (in most cases non-semi, but real) logistics environments. The bricks and parts are very popular around the world, usually they are considered as high quality innovative products to help in development of constructive skills – from childhood to being a parent, and after. It is important to highlight that we are using these products in totally new applications, new forms like planned by the producer.

What is really innovative in LEGOstics Laboratory: “How to use?”, not “Which type of products to use?”, so in our environments we could use also metal construction boards or any other wood-bricks – the reason why LEGO products were chosen was: the students are very familiar with, and these modelled environments are also “mobile” applications, we can bring them to several formal and non-formal education situations and special circumstances (the first successful DotSCan application was provided in a prison for training prisoners becoming warehouse assistants).

In this creative learning environment all the actions are provided by participants – with flexible, dialectic (learning-by-doing) ways, focusing on evaluation results and the whole process of performance measurements (Bajor, Bódis 2011).

We are developing all these environments on the same platform: analysing and developing the processes according to the technology and real nature of logistics processes (warehousing, material handling, production and transportation).

The LEGOstics environments are the best for training students and experts on the field of logistics, where we can provide all the critical factors of „Self-regulated learning“.

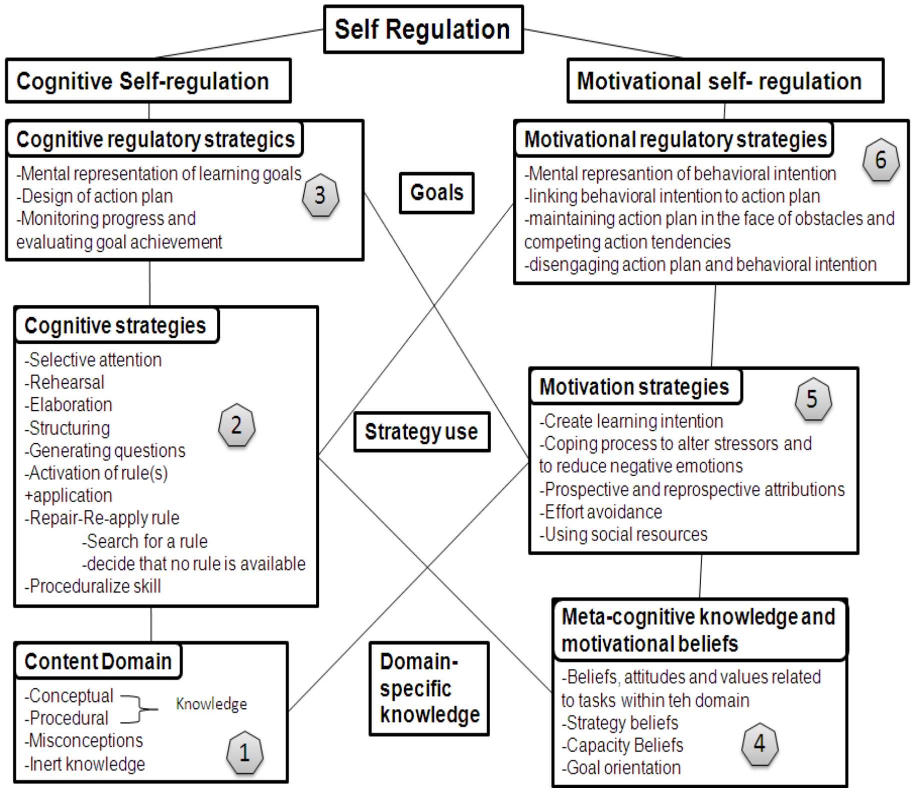

Fig. 1. Self-regulated learning (Broekaerts, 1997)

2 THE GRETA ENVIRONMENT

2.1 GrEta car

GrEta is a self-developed, non-official LEGO product, based on our intention to construct a relatively simple model, what is possible to build up different and totally flexible ways. The result is a nice car: GrEta (E is a capital letter, like Eta means “effectivity, or efficiency”, the productivity related to the invested resources).

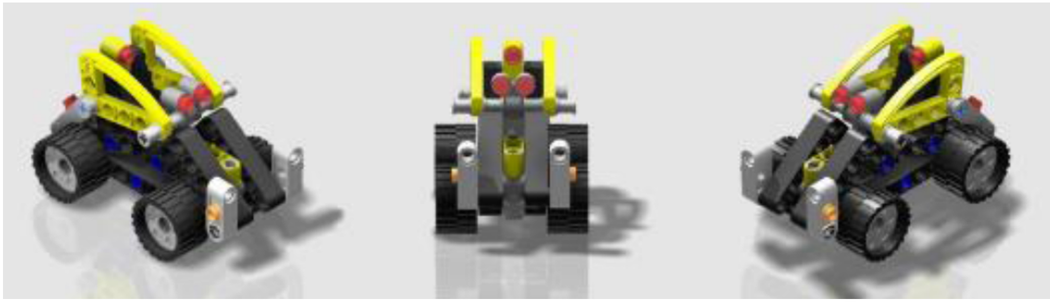

Fig. 2. GrEta car design

GrEta car has 8 separate functional parts: chassis, wheels, engine, engine hood, seat, computer unit, cabin, lamps. The parts also can be assembled on some ways. The participants have a lot of possible strategies and production system structures, according to the decisions of the team based on the different personal attributes. On the next figure we can see the elements and one possibility for parts assembling:

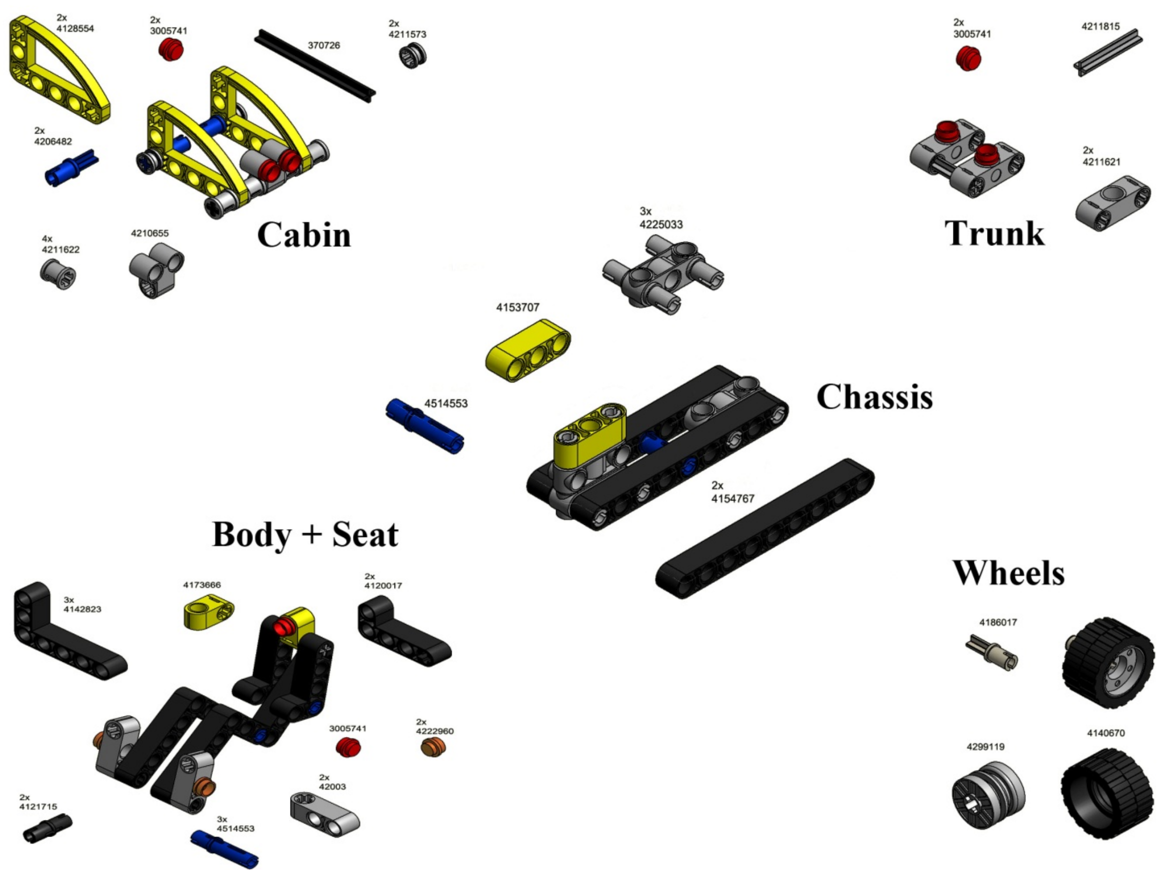

Fig. 3. GrEta main parts

2.2 GrEta plotting board

The plotting board is basically a regular wooden board, which has been separated into four workstations. Between the workstations we situated four drawers for transportation. In the game the transportation has the highest priority, when a box (shipment) comes it always have to be unloaded and sent back to the previous participant to provide the possibility for the continuous material flow.

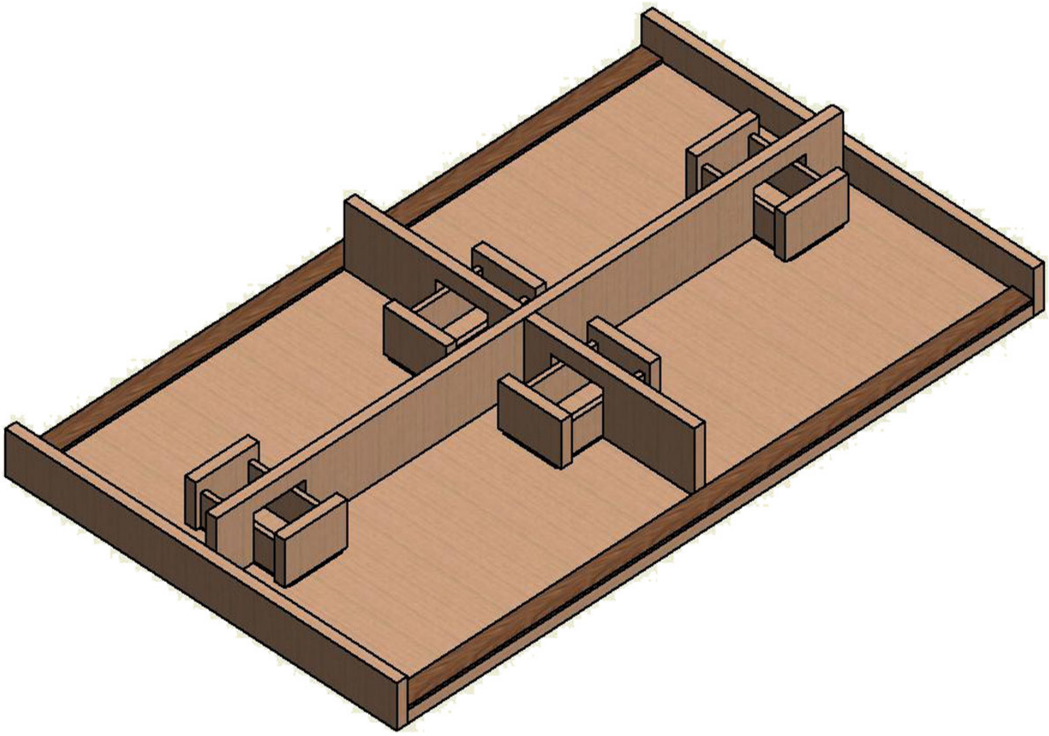

Fig. 4. The GrEta plotting board

3 TRAINING SCENARIO/GUIDE

The GrEta training was constructed for four participants, but it also can be played by eight or more people. At a training situation we can never know the exact number of the participants, so that we created a flexible training method. With eight people we create two groups, four people sitting and assembling, the rest stay close to observe and measure, then they change positions in every round. It is very effective, because all assembling positions have a worker and an observer, every participant can practice the tasks and also see through the whole process.

When the participants are situated around the table they need to be clear with the rules, which are the following:

- the tasks should be performed independently
- no element changes between the positions (they have to follow the previously discussed scenario in each round)
- priority of the transportation (unloading and returning the boxes)
- documentations (register every detail which is considered to be relevant)
- quality checking
- discussing remarks, problems, ideas round-by-round
- decision about the layout

It's not enough to know the rules, the participants must practice the whole assembling procedure before the first round. We prepared a step-by-step presentation about assembling GrEta, with this the participants usually are able to acquire the tasks. In the instructions guide we separated the assembling tasks into four different steps, which we use later as the first layout in the game.

Fig. 5. First individual assembling of GrEta by following the presentation

After the practice they get one car assembled for sample, one in parts at each position as the sample of the given task regarding to the predetermined layout. The groups start to assemble sequentially the cars four times, while they change the positions each round. On this way every player gets experience about each tasks, and also they are able to observe the adequate and the insufficient points in the procedures.

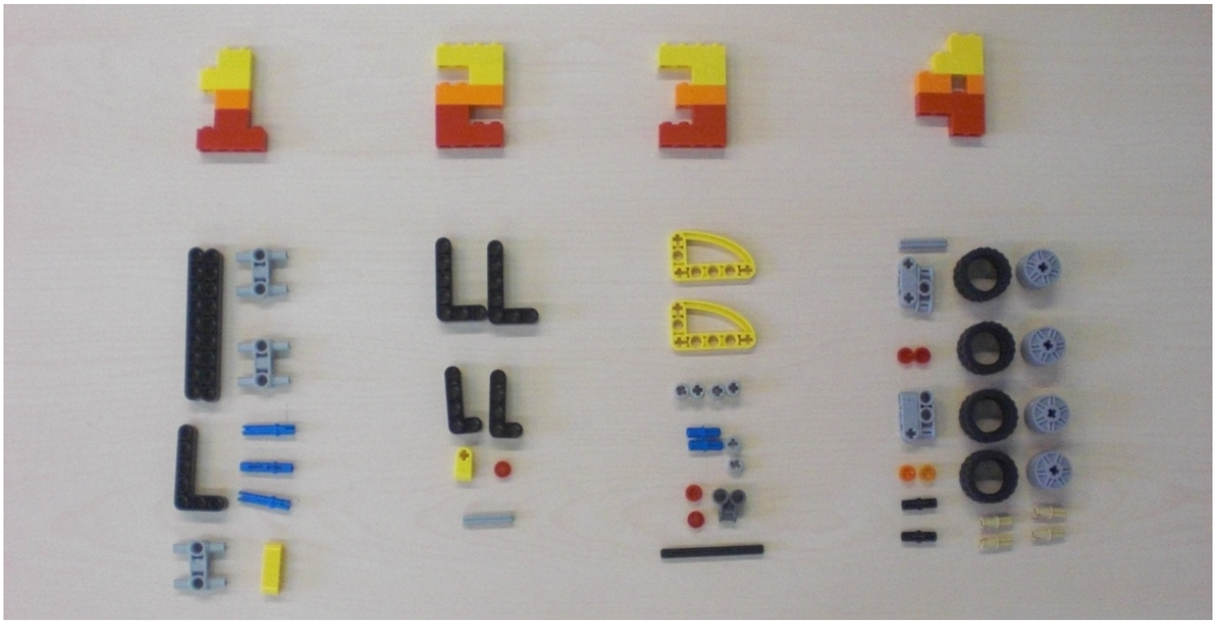

Fig. 6. The initial layout

After the four rounds of practising and observing they can start the real work. They have to choose a boss from the group who will be responsible for the layout, the tasks and the whole process. In the first round of parallel assembling the participants use the basic layout, that can be changed after the discussion.

The most important part of this round is the measurement. They also have to decide what to measure, and how to measure, because this will be the base of the following optimization.

The training usually takes two and half an hour, thus it ends after at least the second optimized round.

During the training they can get experience about production teamwork (allocate procedures according to different features of a given workstation – speed, accuracy, quality checking, etc.) and also in process analysis (after a round they discuss their observations, make some changes, do it again, evaluate the consequences, etc.) The main questions are: What is the real meaning of efficiency at a given case? What to measure and how to measure? How to improve capacity utilization? How to fit different processes following each other on the best way?

Fig. 7. Discussing problems

The participants not compete with each other – theirs job to improve productivity and provide high-level quality checking at the same time (measurements, quality check points, etc.)

The main points of the discussions:

- optimization of the strategy – better sharing of the assembling tasks
- flow control – better management of material flow (prior actions, match-mismatch of concurrent tasks)
- improving the individual assembling speed, parallel assembling

During spontaneous discussions a lot of theoretical knowledge is coming into practice:

- controlling viewpoint – not just financial, but time-based indicators
- sensing viewpoint – automatic detection of bottlenecks and inactive times

4 DISCOVERING THE BOTTLENECK

To record every measurement data we made a simple but easily understandable data sheet.

During the optimization participants need to take into consideration that assembling small parts is more time (skills needed) than assembling easier and bigger parts.

In addition they need to notice that the addiction of the material flow is very important. The sequence of the assembly stations is important too. Above all information after they saw our measurement sheet they knew that where the changes are needed. Participants almost all time recognized that where was the bottleneck and how can they solve it.

After this lesson their homework is to analyse the process, searching for the reasons of the bottlenecks, the idle times and the possible solutions and prepare a presentation. Their other task is to propose – if possible – an optimal layout, which they can measure on the next lesson. We can see the results below:

Team	A	B
1st	1:43	1:41
2nd	2:09	2:35
3rd	2:35	3:06
3 pcs of GrEta		

Team	A	B
Player 1	chassis and wheels (the chassis had the priority)	chassis and one set of wheels (the chassis had the priority)
Player 2	seat and computer unit	seat and two sets of wheels (the seats had the priority)
Player 3	cabin	cabin
Player 4	lamps	lamps

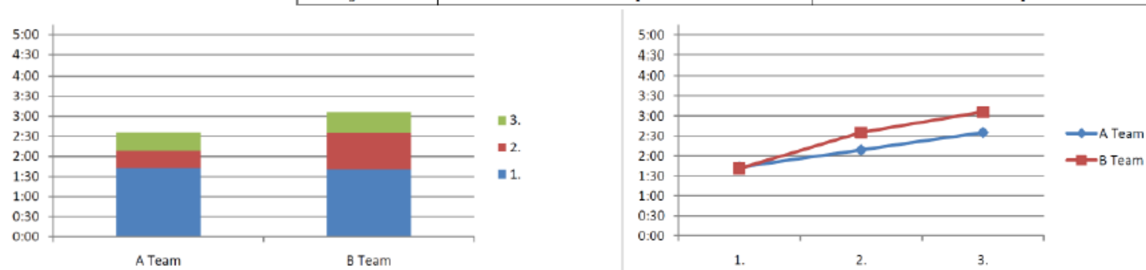

Fig. 8. Time results for 3 model

In this round the first player said the task was simple, but mainly because he was the first to start the assembly line. The second player felt this task was very easy but for the third player it was difficult and laborious. The fourth player said it was hard to assemble, because of the high number of tiny pieces.

After this round we gave them 2 more cars, to try the layout with 5 cars.

Team	A	B
1st	2:28	1:19
2nd	2:51	2:10
3rd	3:24	3:17
4th	3:46	3:52
5th	4:10	4:57

Team	A	B
Player 1	chassis and wheels (the chassis had the priority)	chassis and two sets of wheels (the chassis had the priority)
Player 2	seat and computer unit	seat and three sets of wheels (the seats had the priority)
Player 3	cabin	cabin
Player 4	lamps	lamps

5 pcs of GrEta

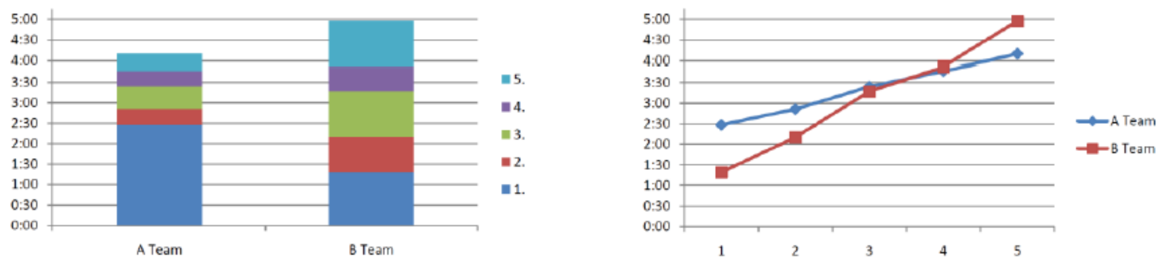

Fig 9. Results of 5 Greta car

The first group had same layout as the three car assembling, which was the following with the five cars:

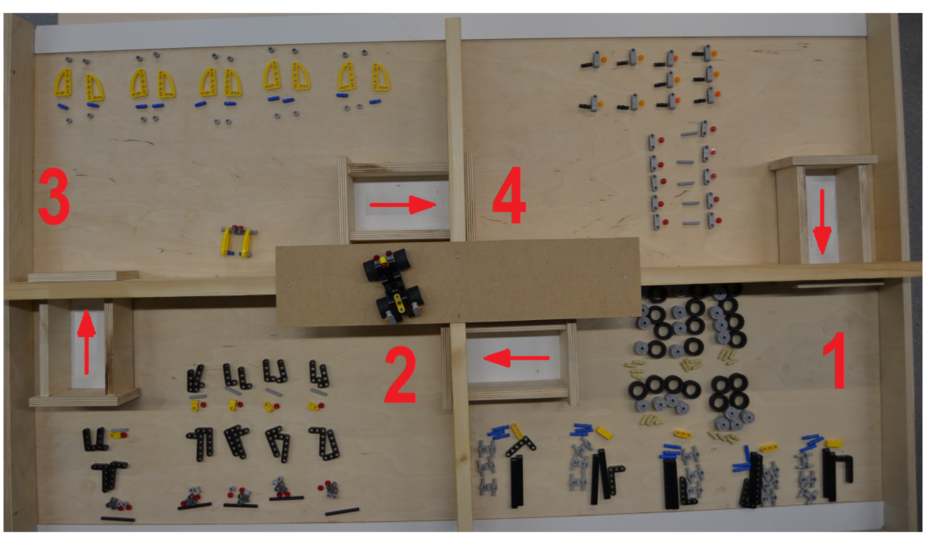

Fig 10. 5 Greta layout with work flow direction

Then they had the possibility to optimize the mass production with 5 cars:

Team	A	B
1st	2:10	1:22
2nd	2:37	2:25
3rd	3:03	3:02
4th	3:33	3:40
5th	3:48	4:28

5 pcs of GrEta

Team	A	B
Player 1	chassis and four sets of wheels (the chassis had the priority)	chassis and one sets of wheels (the chassis had the priority)
Player 2	seat, computer unit and one set of wheels	seat and three sets of wheels (the seats had the priority)
Player 3	cabin	cabin
Player 4	lamps	lamps and one set of wheels

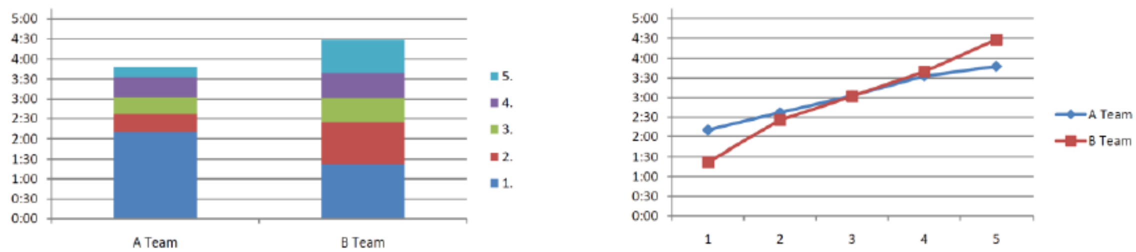

Fig 11. Time results for 5 greta after re-engineering

The first group in this round changed the assembly of the wheels: the first player gave one set of wheels to the second.

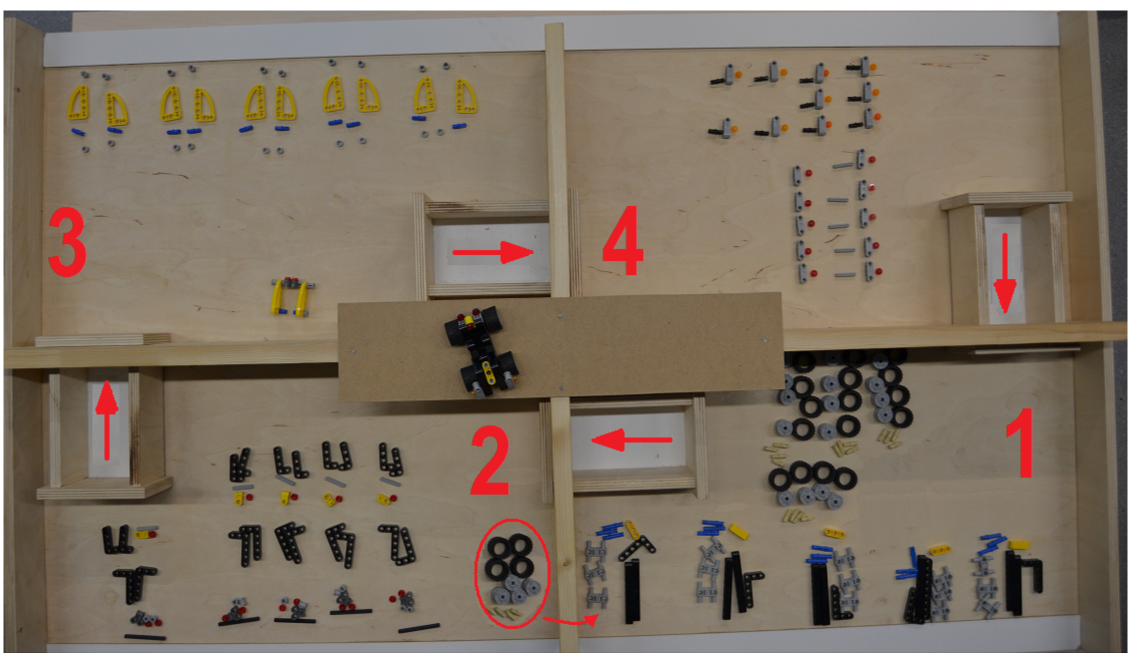

Fig 12. 5 Greta layout with work flow direction after the re-engineering

In the optimized layout the second group decided to pass one set of wheels from the first player to the second:

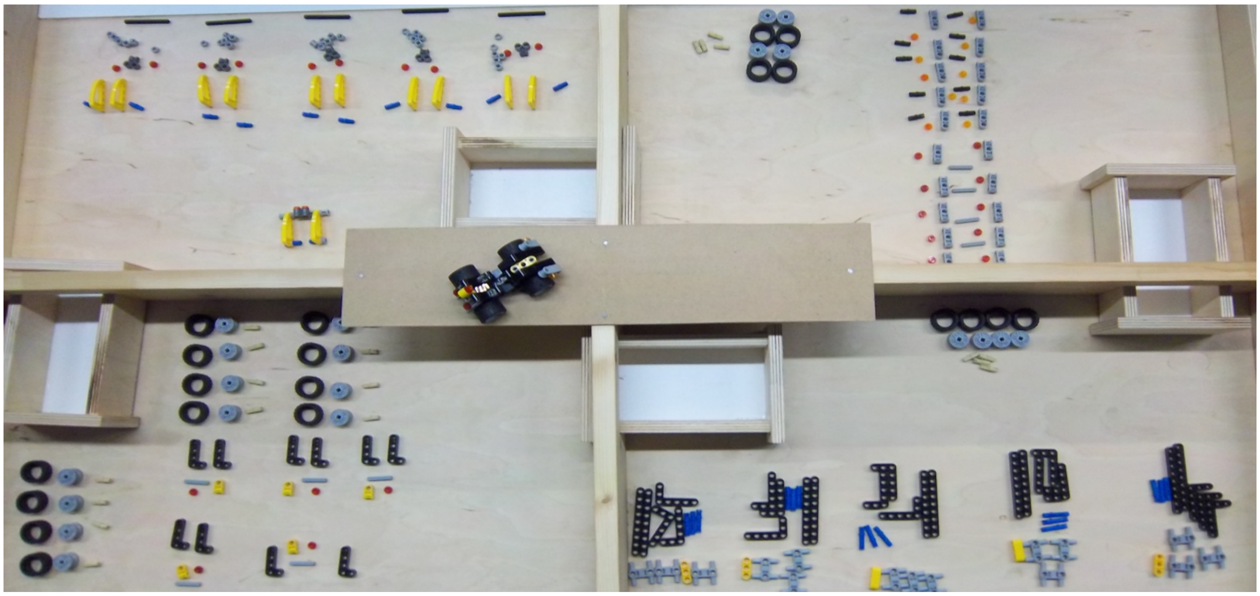

Fig 13. Optimized layout

Their proposition to improve the process:

- the first player gives all the wheels to the fourth, so the last position assembles two sets of wheels on GrEta

Each student was measuring the performance of one student from the other group. This way every action was measured. Unfortunately we don't have always this numerous group so we realized the need of a better solution: an automatized measurement system.

5 USING AUTOMATIC MEASUREMENTS

The most important measurement function is the detection of inactive periods at each player. We are using 2-hands buttons (if both series-wired button is pushed, the logical value at the microcontroller is 0, otherwise it is 1). At the end it is possible to compare not only the lengths of inactive periods, but the distribution of inactivity in space and time as well.

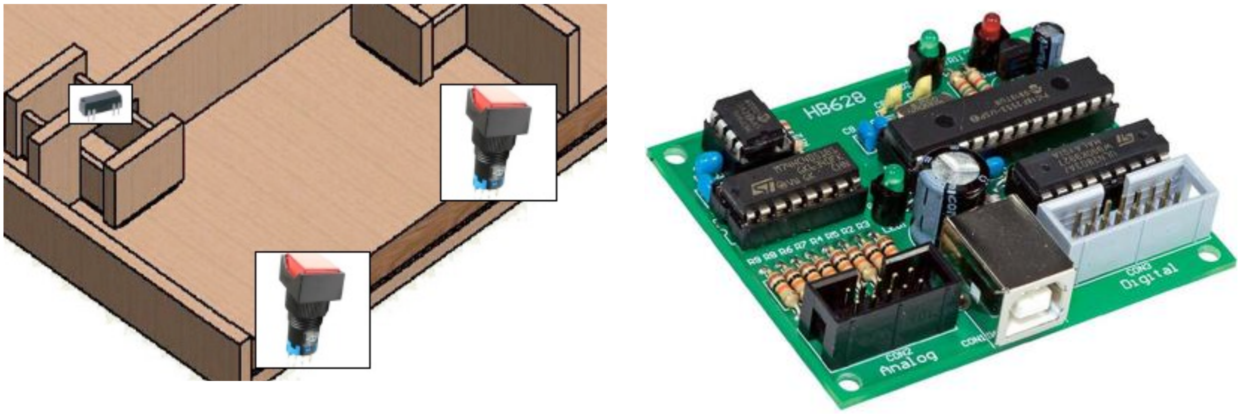

Fig. 14. Automatic measurements with an 8-inputs microcontroller unit

We are using magnets and reed-relays for the monitoring of transport activities. We put a magnet at the bottom of one side of each transport box, and a reed-relay under the box – the logical value is 1 when the magnet is closed to the reed-relay, if it is far the value is 0.

It is possible to import the results into a CSV file, where we can easily make graphs, and analysis.

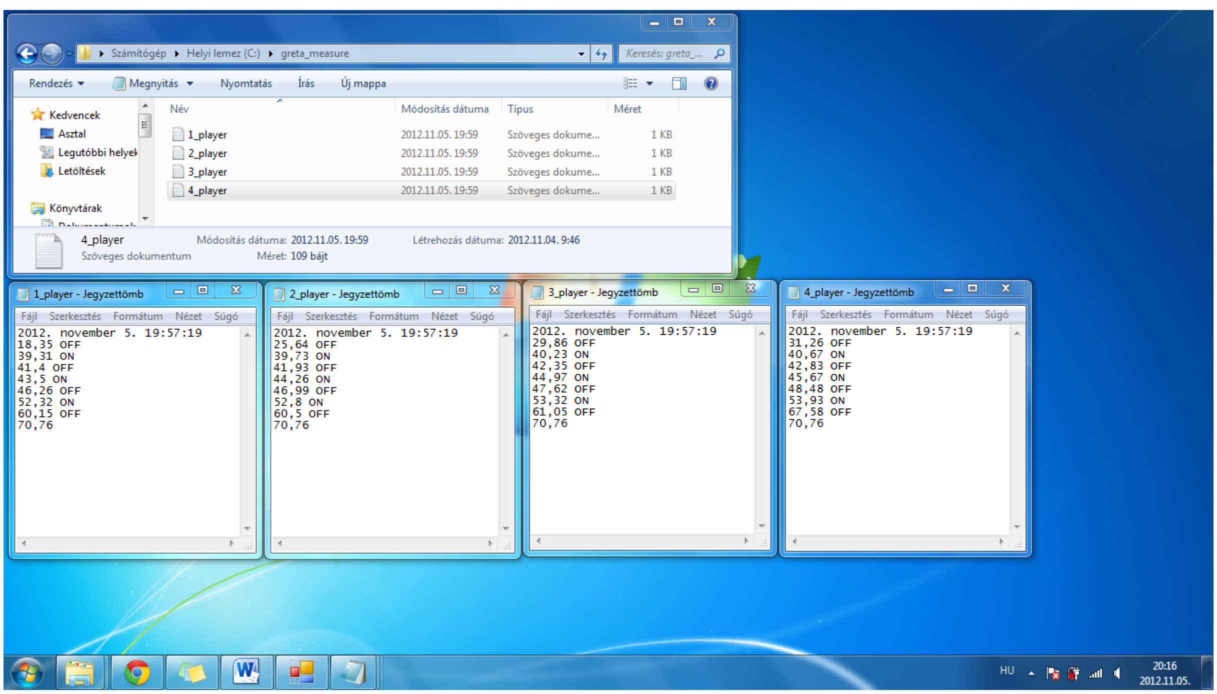

Fig 15. GrEta .csv files

6 CONCLUSION

Laboratory of LEGOstics is an innovative (low-cost) learning-by-doing environment for students, experts and researchers from the field of logistics. In the GrEta manufacturing environment all the assembling and re-engineering actions are provided by participants according to the goal: reduce the time request and improve the productivity rate of the mass-production system.

During the training it is possible to highlight the importance of logistics process re-engineering and develop the critical skills of participants to be able to:

- recognize the critical factors of production processes
- construct appropriate performance measurement systems
- support the decision making process of system developments

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