Game-based learning of Petri nets

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Presentation Outline

? Research motivation

📖 Some background

🎮 How to apply games for learning Petri nets?

👨‍🏫 Experiment among students

📊 Results and conclusions

Research motivation

Why to conduct such research?

How to plan the study?

Motivation

- Petri nets are a formal specification technique for modelling of control processes and modern flexible manufacturing systems

- Interpreted Petri nets take into account input and output signals, allowing to apply them in any control system or even in control part of a cyber-physical system

- Due to the fact that Petri nets are not used in the industrial practice, the students sometimes lack motivation to learn them

Some background

Preliminaries:

- Petri nets

- Interpreted Petri nets

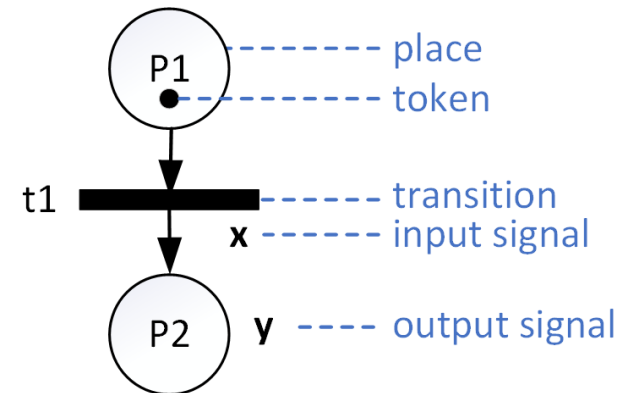- Petri nets in education

- Research methodology

Petri nets

- General mathematical formalism for representation of discrete-event systems

- Widely used for specification of control and manufacturing systems

- Supported by various analysis and verification methods

- Important notions: *live*, *safe*
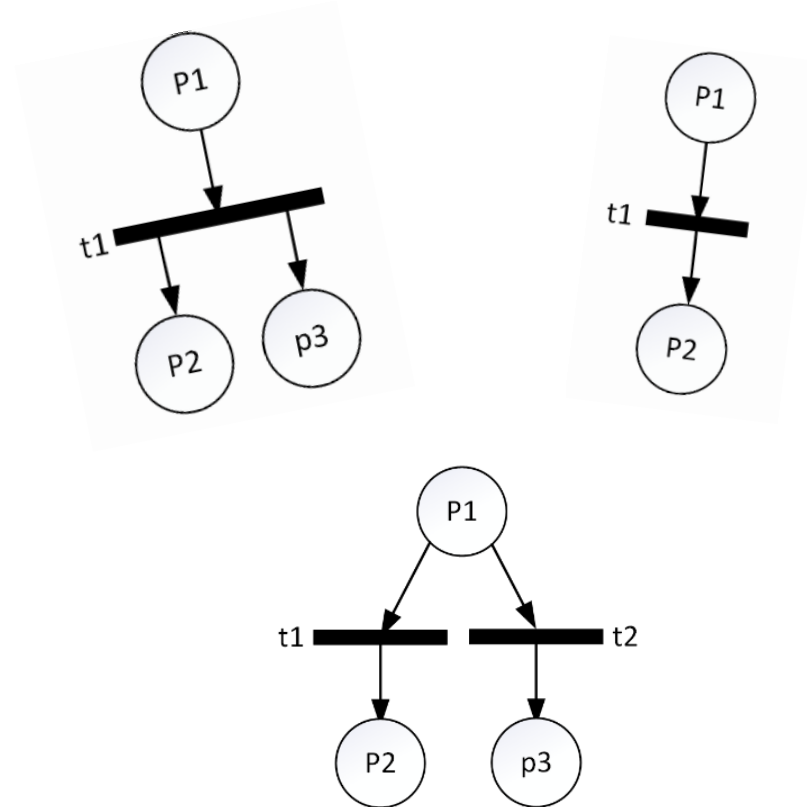
Interpreted Petri nets

- Take into account additionally the presence of input and output signals to communicate with the environment

  - Input signals are assigned to transitions as their guards

  - Output signals are assigned to appropriate places

- It is important to understand the interpretation and behavior of the model, in order to correctly establish a formal specification

Petri nets in education

- Problem of remote education in the pandemia

- Theory is sometimes difficult to be used in practice

- The teaching process of Petri nets considers the combined areas of control systems and mathematics (computer logic)

- Recent challenges in teaching Petri nets clearly indicate the conditions of remote education and the problem of how to fit interdisciplinary aspects into the limited duration of a course

- Existing Petri net tools:

  - Enable drawing the nets and their basic analysis

  - The others are dedicated for education

  - For effective usage of them, it is assumed that the user is already familiar with the basic theory of Petri nets

Research methodology

- Hypotheses:

    1. Creating interpreted Petri net models with Minecraft helps to understand the basic principle

    2. Minecraft makes the course more attractive

- Students were divided into an experimental group (with game-based learning) and a control group (with traditional learning)

- The experimental group filled in a knowledge test twice (on the entry and on the exit) and a questionnaire

- The control group filled in the same knowledge test at the end of the course

The contribution of the conducted research

- We propose how to help students learn interpreted Petri nets with Minecraft as a game-based learning

- We show how interpreted Petri nets can be modelled in Minecraft and how they communicate with the surrounding environment via input and output signals to visualize control processes

- The proposed approach has been validated experimentally among university students

How to apply games for learning Petri nets?

We will cover these aspects:

- Minecraft

- Net structures

- Visualization of control processes

Minecraft

- An open-world survival game with no specific goal of the game

- Players have unlimited possibilities to explore and modify the randomly generated game world

- Main idea behind Minecraft is to build structures consisting of 3D blocks

- Has so far proved to be successful in other domains of education (math, chemistry, computer science, artificial intelligence, etc.)

General description

- The schematic presentation of the proposed idea - both the Petri net models as well as the visualization of control processes can be realized in one game, introducing some animation to the theory

- The structure of the interpreted Petri net is realized with redstone

- The input signals may be related to levers or buttons, while the output signals to redstone lamps or other activators

- It is also possible to model the physical plant that visualizes the control process


Interpreted Petri net

Realization in Minecraft
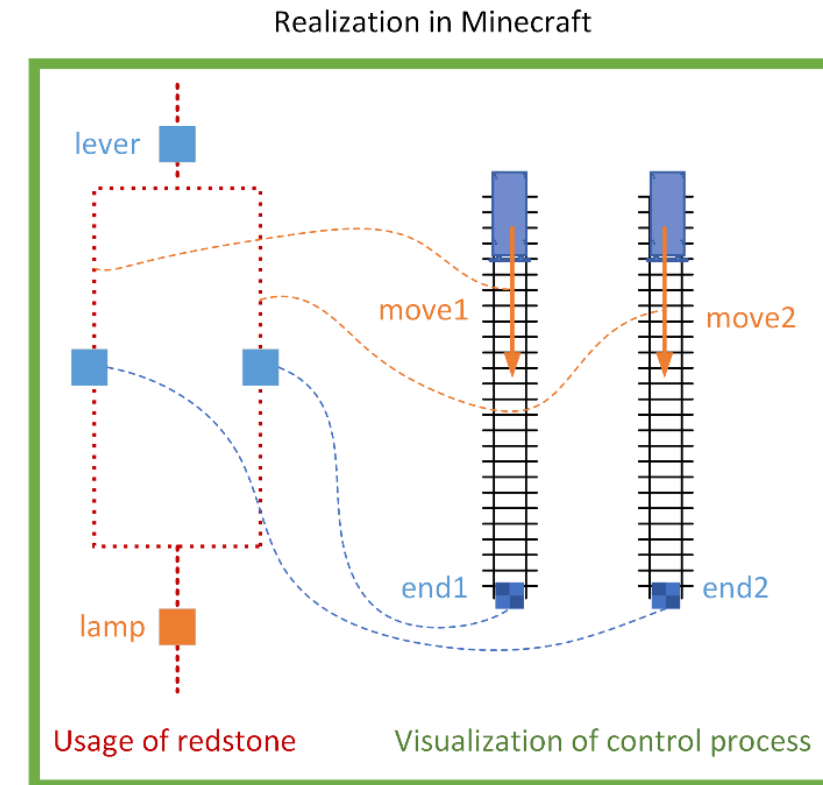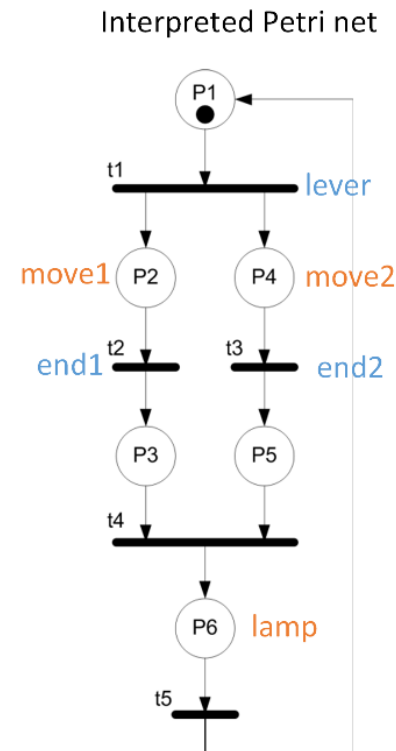
Modelling the sequentiality

- A simple realization: using only redstone

- A more complex realization: with additional piston elements
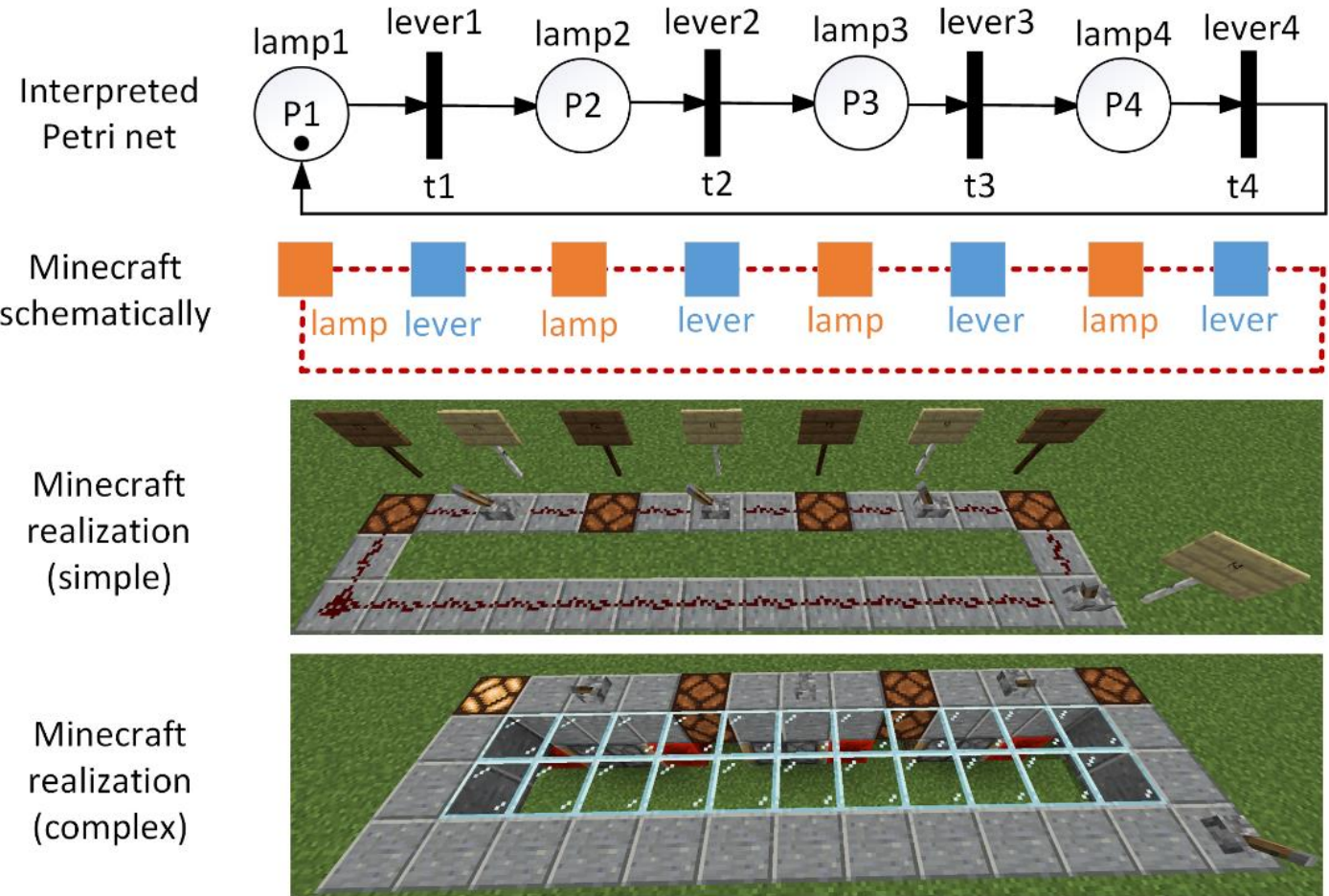
Modelling the choice

- In interpreted Petri nets, these transitions are usually guarded to ensure the determinism of the model

- It is important that the guards are mutually exclusive

- Here also the places correspond to lamps in Minecraft, while the transitions to levers

- Again – two possible realizations –
a simpler one & a complex one

Interpreted Petri net

Minecraft schematically

Minecraft realization (simple)

Minecraft realization (complex)
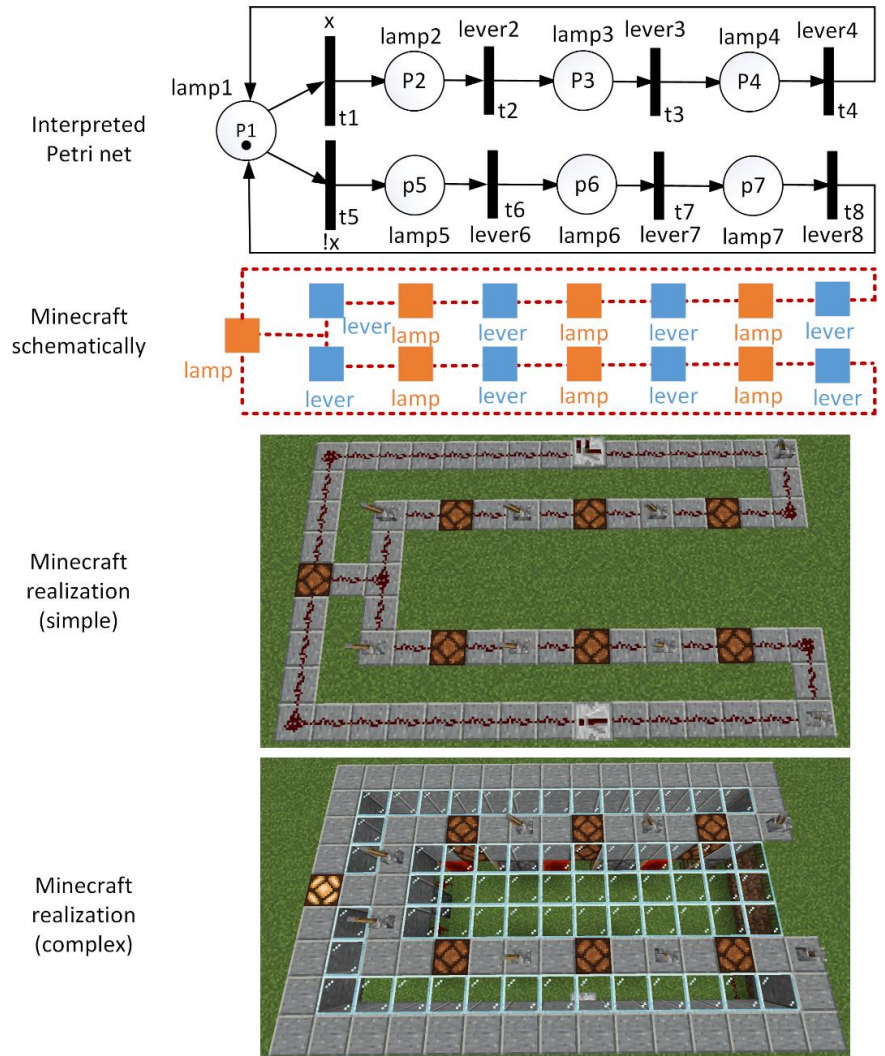
Modelling the concurrency

- Of special interest in control systems

- The usage of an AND gate is required to synchronize the processes

- The flow proceeds if all processes come to the end, so all inputs to the AND gate are *TRUE*
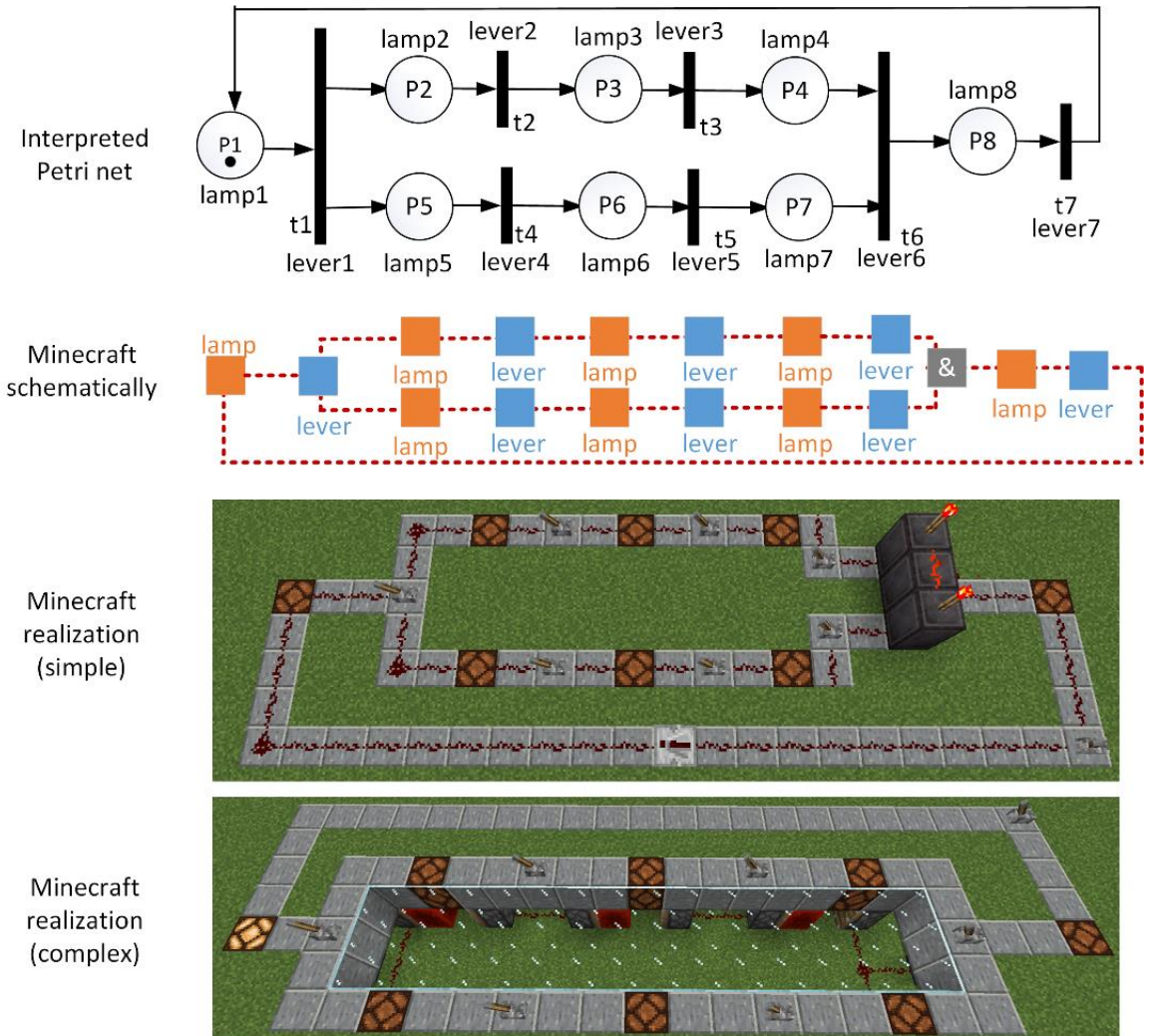
Connecting an interpreted Petri net model with a physical plant

- The main difficulty is how to correctly connect the particular elements of the process with the model of interpreted Petri net

- The earlier realization of basic structures just with lamps and levers simplifies the understanding

- Appropriate signals must then be connected with the corresponding actuators or sensors, e.g., leading from a redstone torch to a powered rail in order to move the carriage or from a button to a door (an element needed to enable token flow)
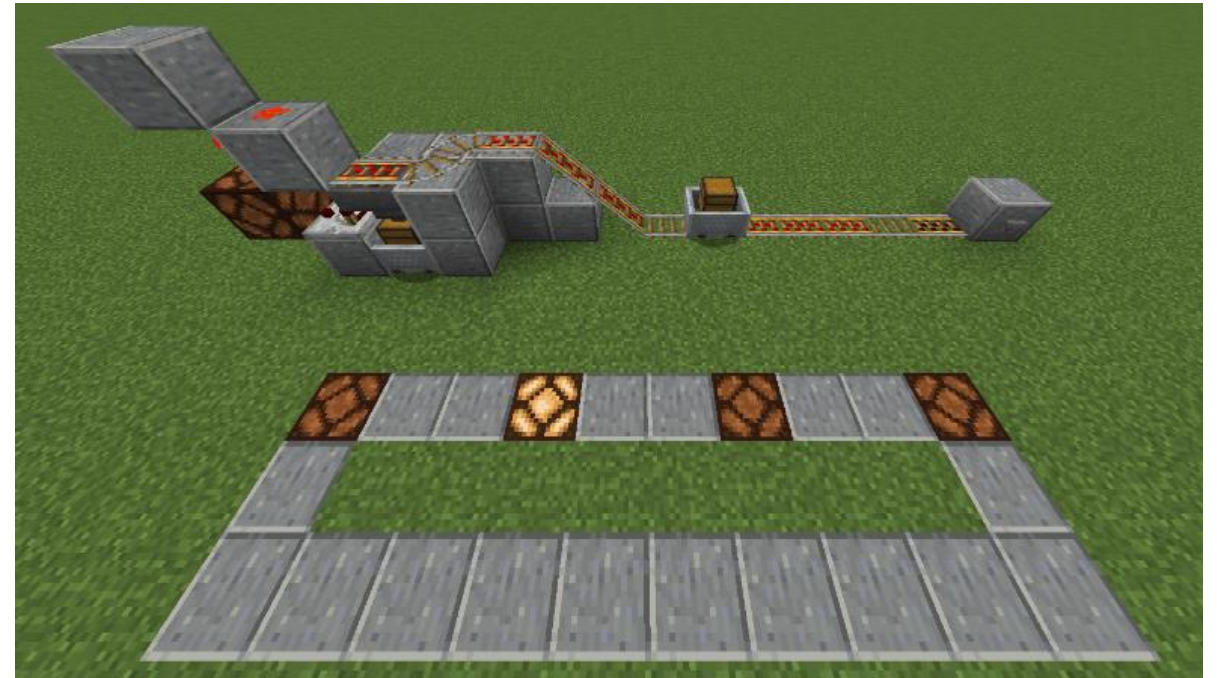
Experiment among students

We will cover these aspects:

- Experimental groups
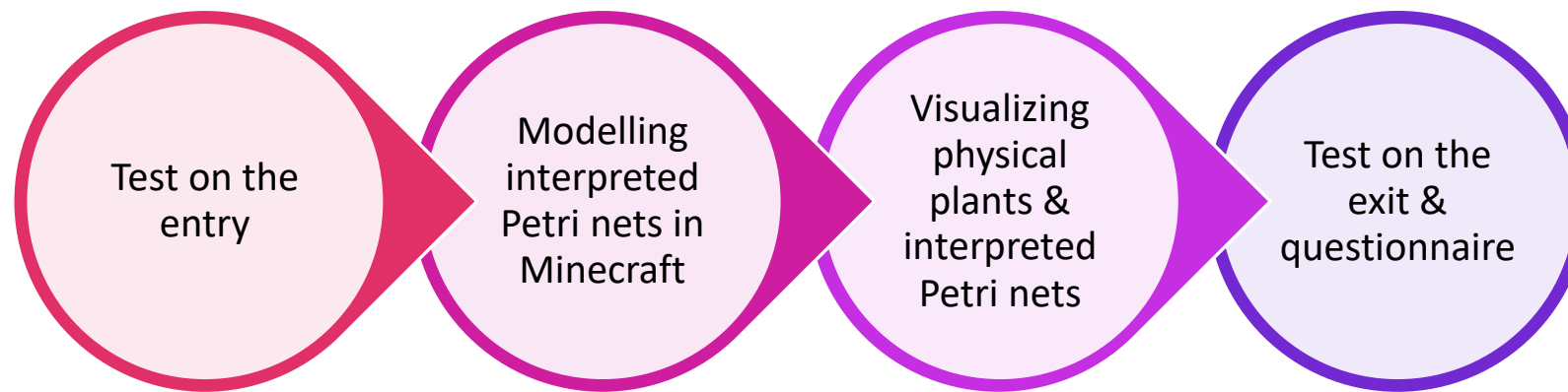- Stages of experiment
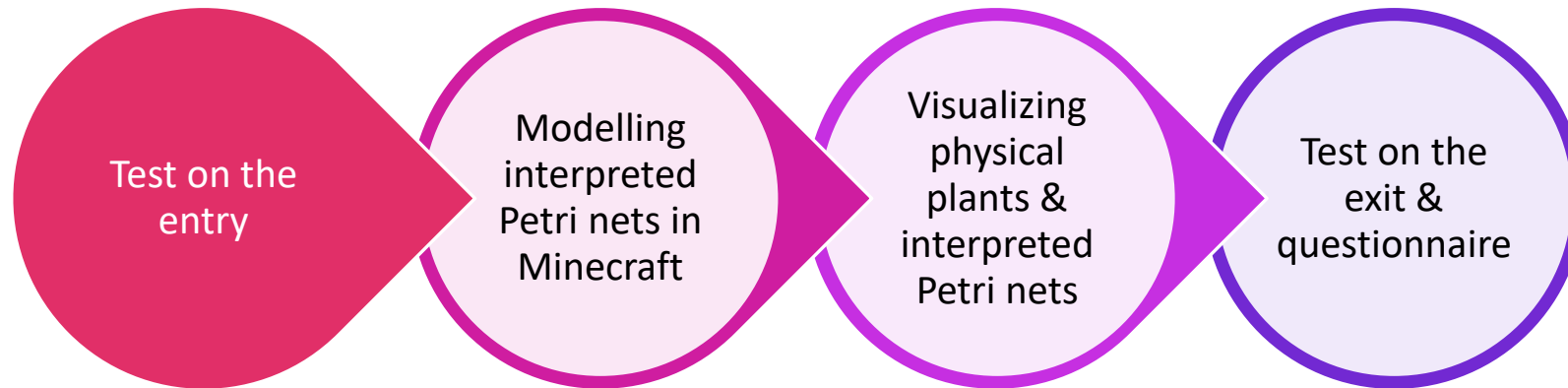- Sample student projects

Experimental groups

- The study on 51 students in the courses of Discrete Control Systems and Modelling of Cyber-Physical Systems at the University of Zielona Góra in the academic year 2021/22

- The enrolled students were divided into an experimental group with game-based learning and a control group with traditional learning

- The control group trained the concepts taught previously in the lecture class using conventional methods

- The experimental group used additionally the Minecraft game

- All participants have been playing Minecraft before and have known the basic rules regarding the game. Just before the experiment, they have also been introduced to the theory and practice of general Petri nets and interpreted Petri nets.
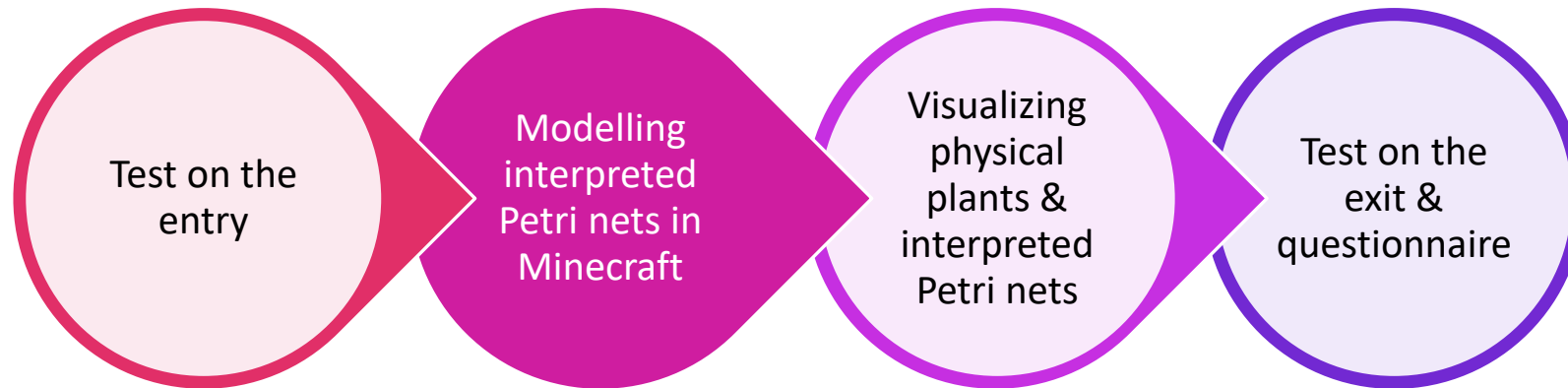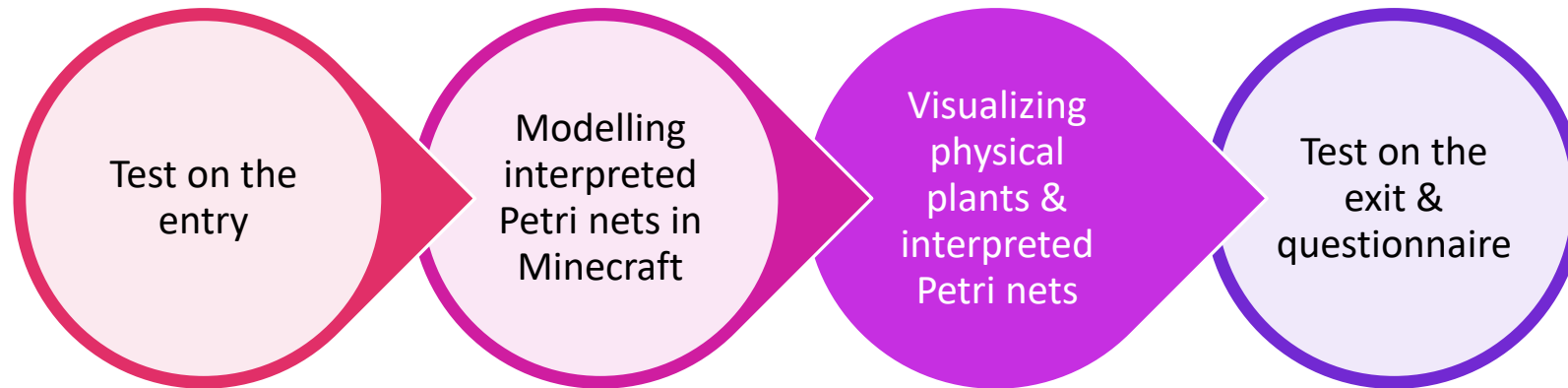
Parts of the experimental study

Test on the entry

Modelling interpreted Petri nets in Minecraft

Visualizing physical plants & interpreted Petri nets

Test on the exit & questionnaire

Parts of the experimental study

Test on the entry → Modelling interpreted Petri nets in Minecraft → Visualizing physical plants & interpreted Petri nets → Test on the exit & questionnaire

- 15 questions with a single response
- Students not informed about the correct answers
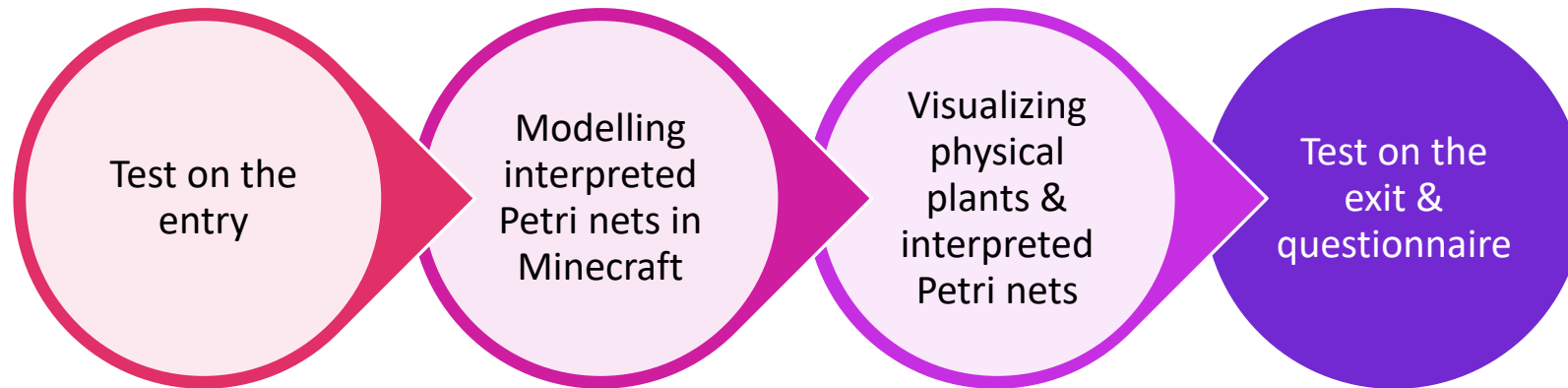- Time limit: 15 minutes

Parts of the experimental study

Test on the entry → Modelling interpreted Petri nets in Minecraft → Visualizing physical plants & interpreted Petri nets → Test on the exit & questionnaire

- Introduction to the proposed approach
- Presentation followed by self-realization of the basic structures
- Then – playing in free time

Parts of the experimental study

Test on the entry → Modelling interpreted Petri nets in Minecraft → Visualizing physical plants & interpreted Petri nets → Test on the exit & questionnaire

- Introduction to the approach
- Presentation followed by self-realization of a basic scenario
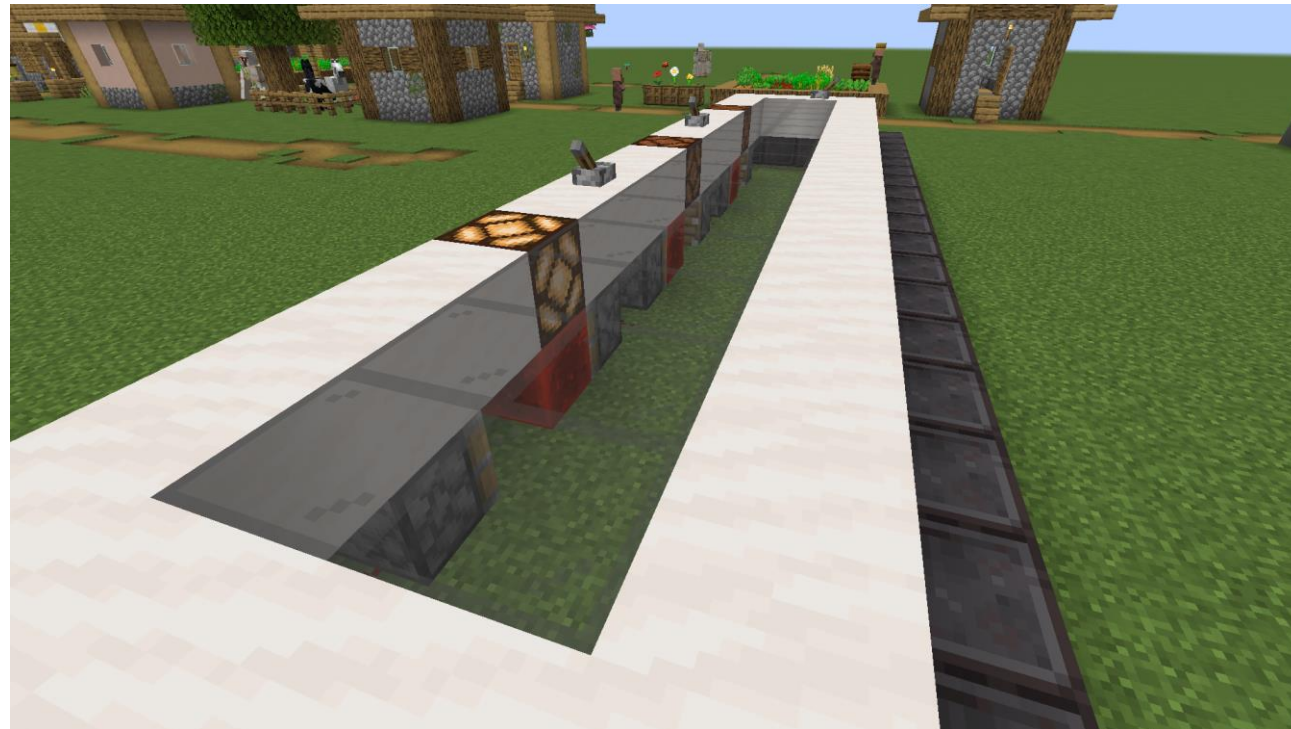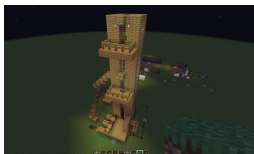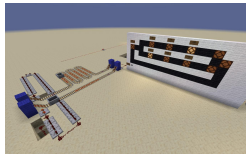- Then – playing in free time

Parts of the experimental study

Test on the entry → Modelling interpreted Petri nets in Minecraft → Visualizing physical plants & interpreted Petri nets → Test on the exit & questionnaire
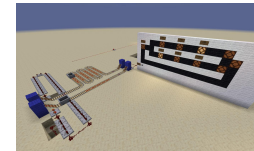
- The same test as on the entry (time limit: 15 minutes)
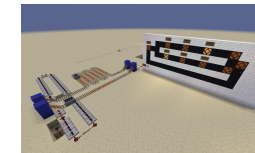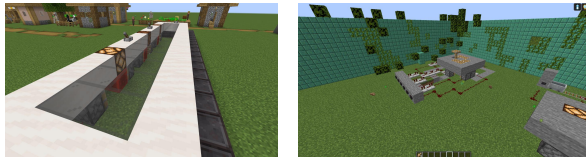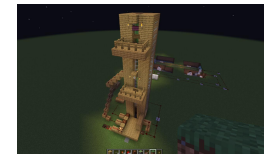- Questionnaire for rating the subjective experience
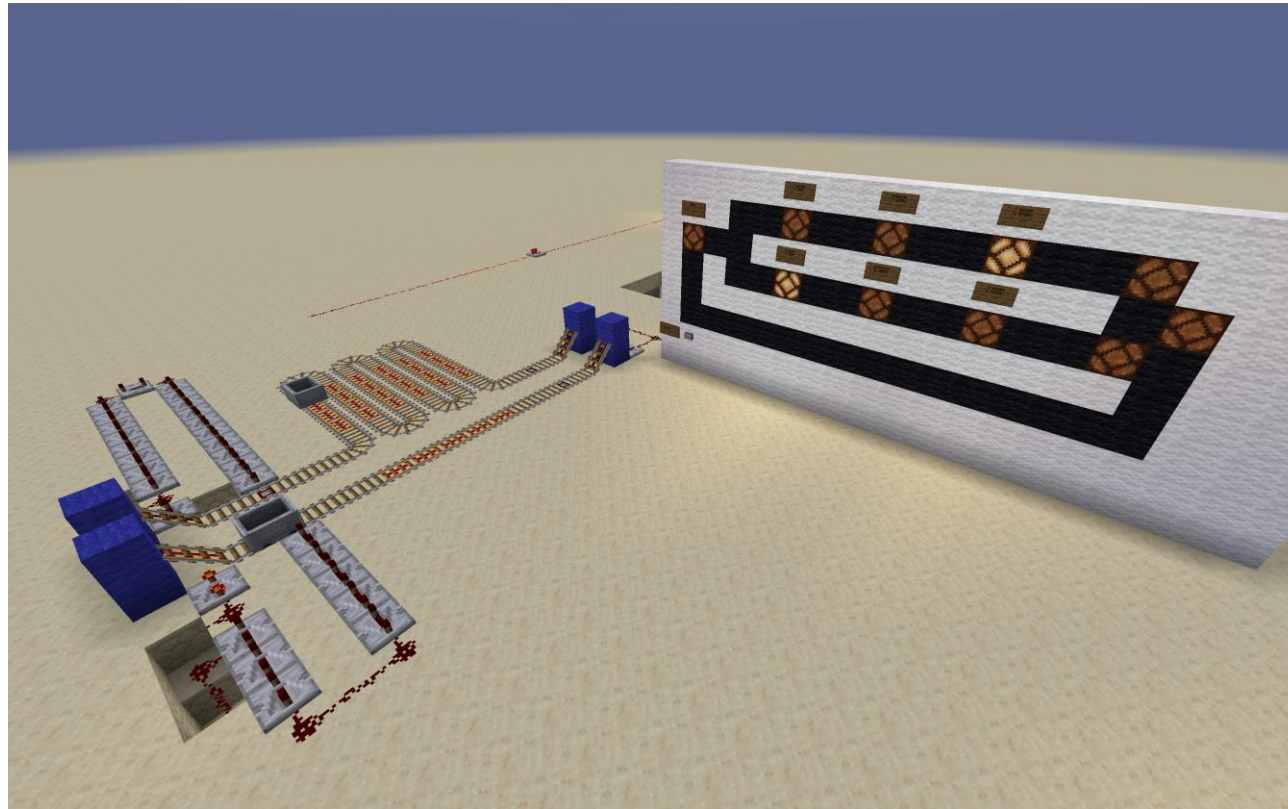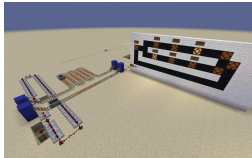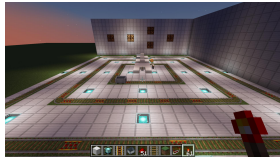- Additional comments

Students projects
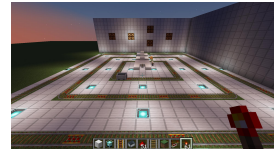
Students projects

Students projects

Students projects

Students projects

Results and conclusions

We will cover these aspects:

- Evaluation of the tests
- Subjective opinions of the students
- Comments on the experiment written by students

Results of the tests

- Comparing the results of the test on the entry and on the exit, we observed that the arithmetic average value has been increased by ca. 4 points (i.e. about 50%)

- At the same time, both the lowest value and the median value have increased by 5 points

	Arithmetic average	The lowest value	Median value
Test on the entry	7,86	3	7
Test on the exit	12,02	8	12
Difference	+4,16 (+53%)	+5	+5
Control group	11,125	8	11

- The results obtained by the experimental group were better than for the control group
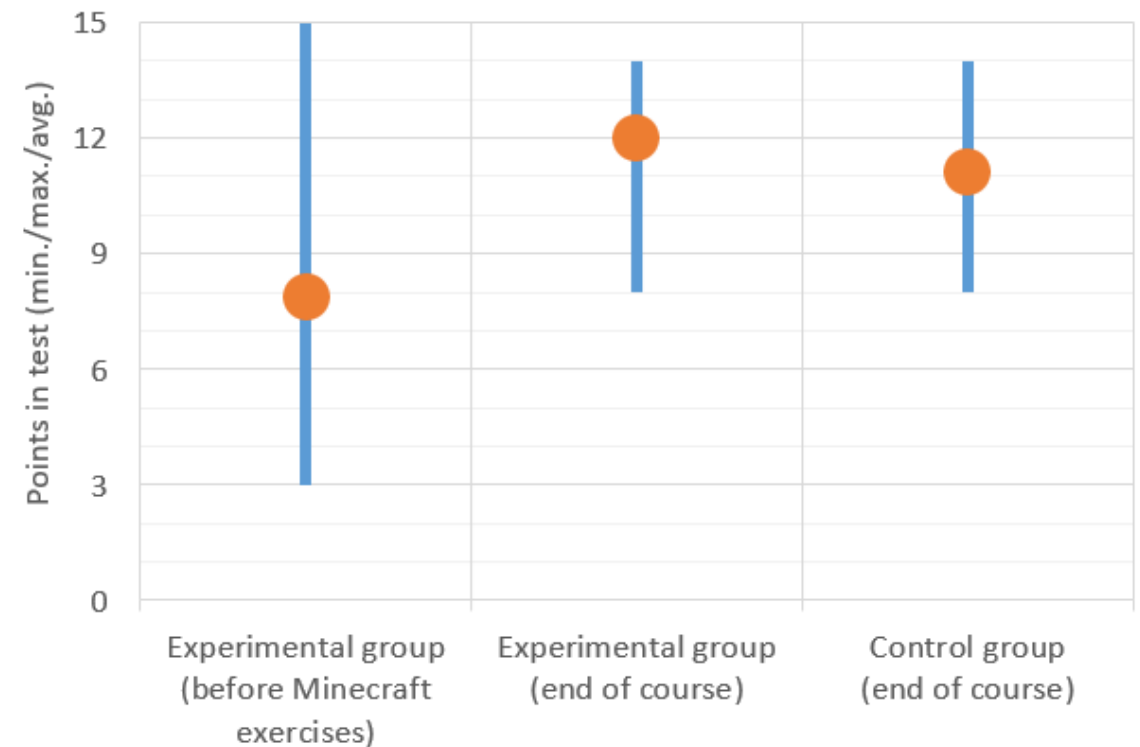
Hypothesis 1

- Based on the test results we can conclude that the knowledge of the students has been enriched with game-based learning

- The first hypothesis is confirmed: "*Creating interpreted Petri net models with Minecraft helps to understand the basic principles*"

Results of the questionnaire

ID	Question	Arithmetic average	Median value
1	How do you rate the attractiveness of Minecraft classes?	4,67	5
2	How has Minecraft contributed to a better understanding of token flow in Petri nets?	4,18	4
3	How has Minecraft contributed to a better understanding of concurrency modelling in Petri nets?	4,42	5
4	How has Minecraft contributed to a better distinguishing between input and output signals?	4,36	5
5	How do you rate your Minecraft skills?	3,48	3

Results of the questionnaire

- to evaluate how the so-far experience in playing Minecraft influence the results, we have separately analyzed two groups of students
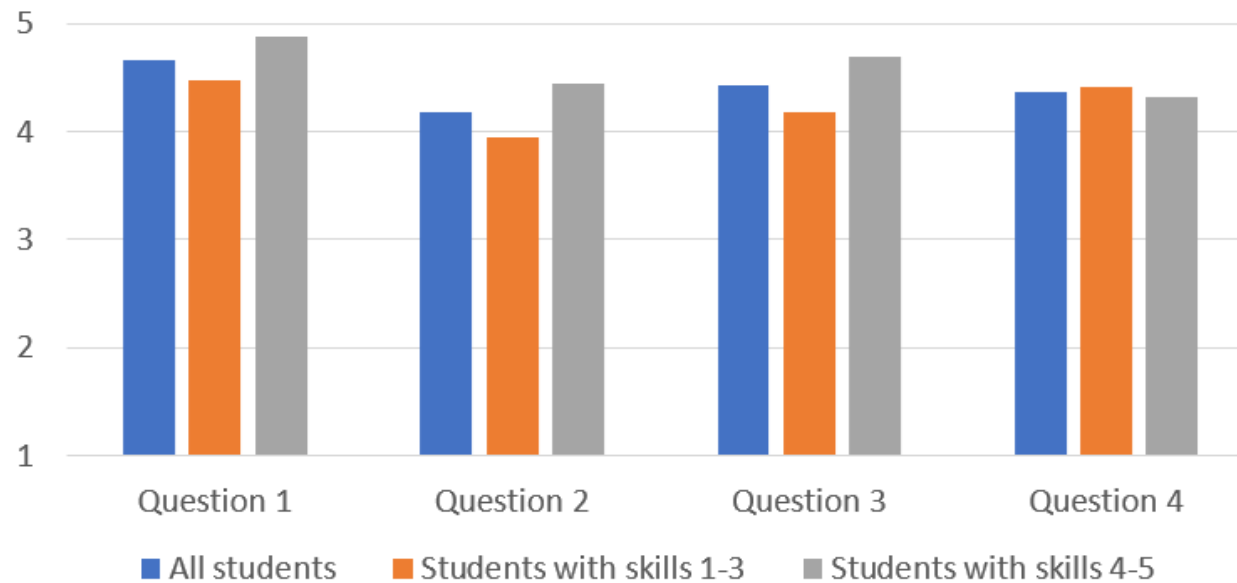
general feelings were slightly better by students with higher Minecraft skills

Comments on the experiment written by students

Minecraft classes helped to improve the knowledge of Petri nets. During this type of classes, it is much easier to understand a given topic, because we create these nets by ourselves and it is a kind of practice.

It is a very interesting and inspiring form of getting to know the functioning of a Petri net. A very good idea to combine "fun" with a very important issue.

A pleasant surprise, a much more pleasant form of teaching. I hope for more such surprises.

Instead of imagining a Petri net in our head, we can easily construct it in the game and on-the-fly analyze the entire process, which is very helpful in case of a mistake. It will take less time to find the errors, because they will be immediately noticeable on implemented Petri net model.

Hypothesis 2

- We can conclude that the experimental learning of interpreted Petri nets was successful

- The second hypothesis is confirmed:
„Minecraft makes the course more attractive".

Findings
The observations confirm that the Minecraft-based teaching of interpreted Petri nets allows to gain better results in final tests, making at the same time the course more attractive and enjoyable.

For more information
📄 Help students learn interpreted Petri nets with Minecraft, I. Grobelna, M. Mazurkiewicz, D. Janus, *Informatics in Education*, Volume 22, Issue 2 (2023), pp. 257–276, June 2023, DOI: 10.15388/infedu.2023.13

Experiment Summary

Here is what we learned

Thank You!