# On the design of security games: From frustrating to engaging learning

**2016 USENIX Advances in Security Education Workshop**

August 9, 2016

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KYPO
BY CSIRT-MU

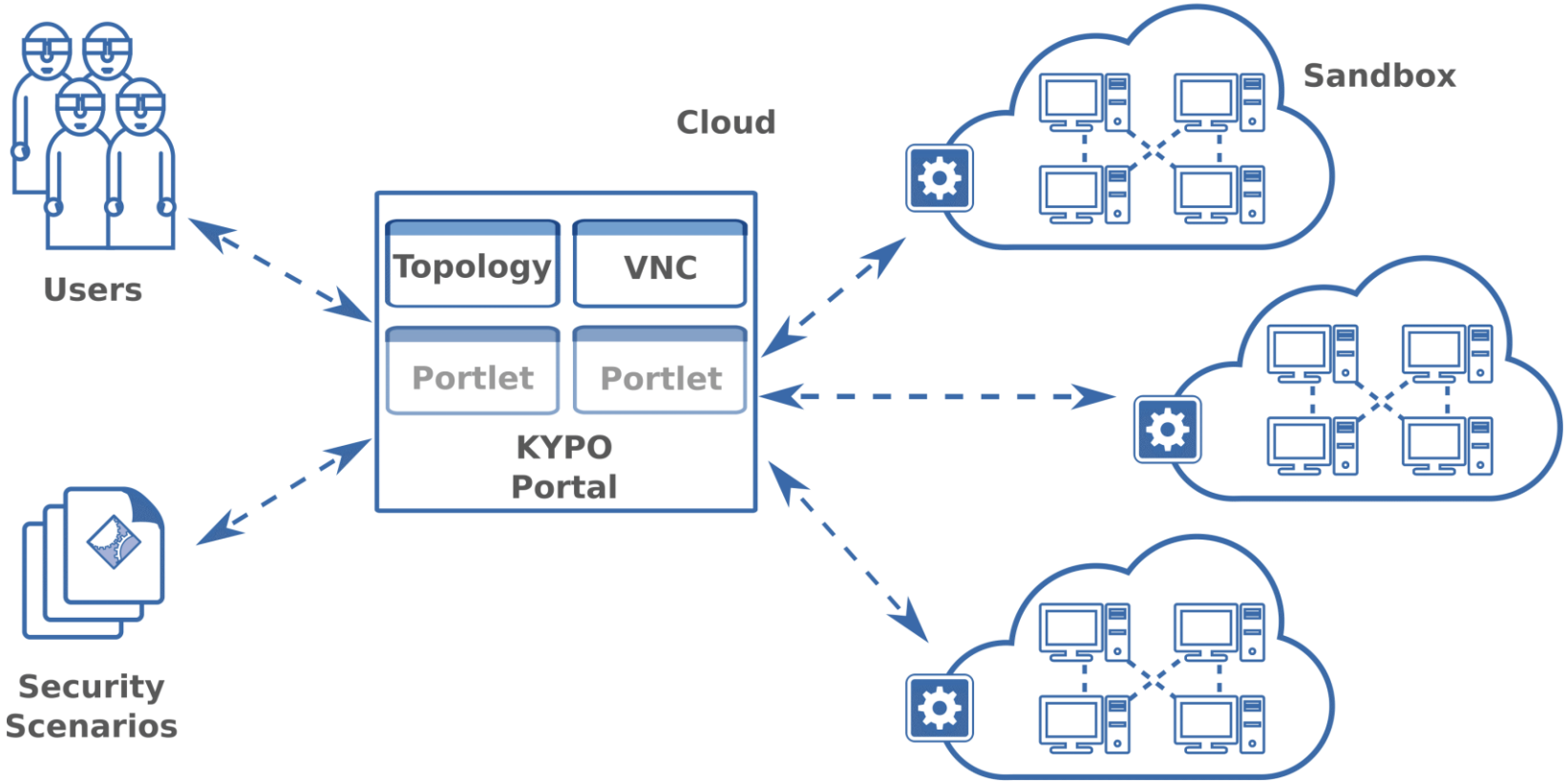
# Who am I?

- Ph.D. graduate in flow-based intrusion detection.
- Founder and head of a university CSIRT in the Czech Republic.
- Researcher with KYPO – academic cloud-based cyber range.
- Coordinator and designer of hands-on training at KYPO platform, e. g. Czech national cyber defence exercise.

# Outline

- KYPO game
  - Generic module of KYPO cyber range for running CtF games
  - Prototype game
  - Lessons learned
- Extensions of KYPO game
- Research questions
- User study – setup and results
- Conclusion and future work

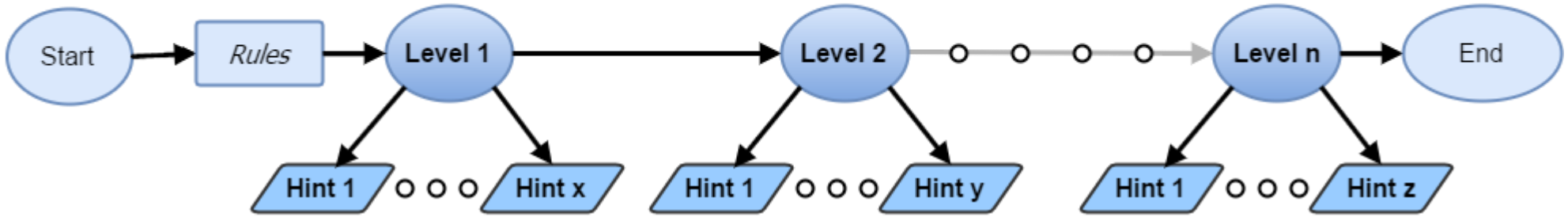
# KYPO cyber range



# KYPO game - design

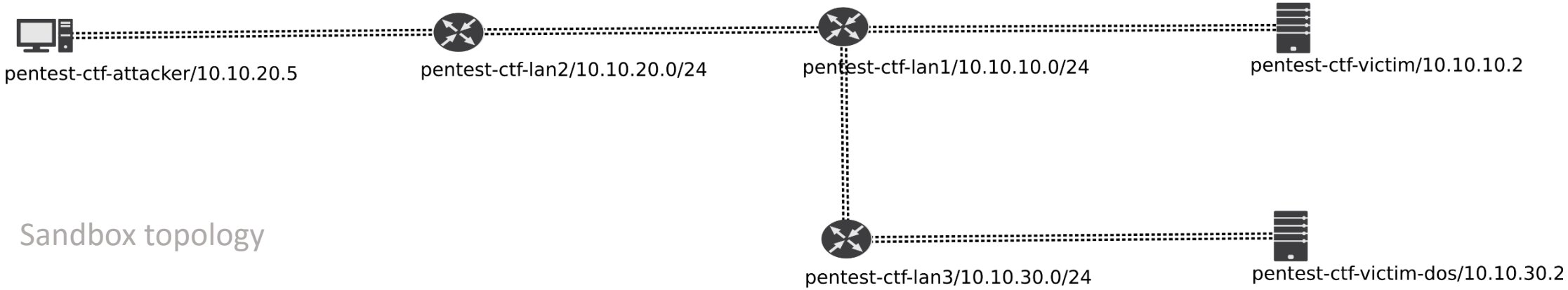
- One educational use case of KYPO cyber range, implemented as a portlet.
- Framework for creating and running *attack-only* capture-the-flag games.

- Each game is split to several levels, players search for correct answer (flag).
- Each level offers hints that can be displayed in exchange for penalty points.



# KYPO game – prototype

- Prototype game for teaching penetration testing.
- Four levels with the ultimate objective of NTP DoS amplification attack.
- Each player has own sandbox with a machine under control.




Sandbox topology

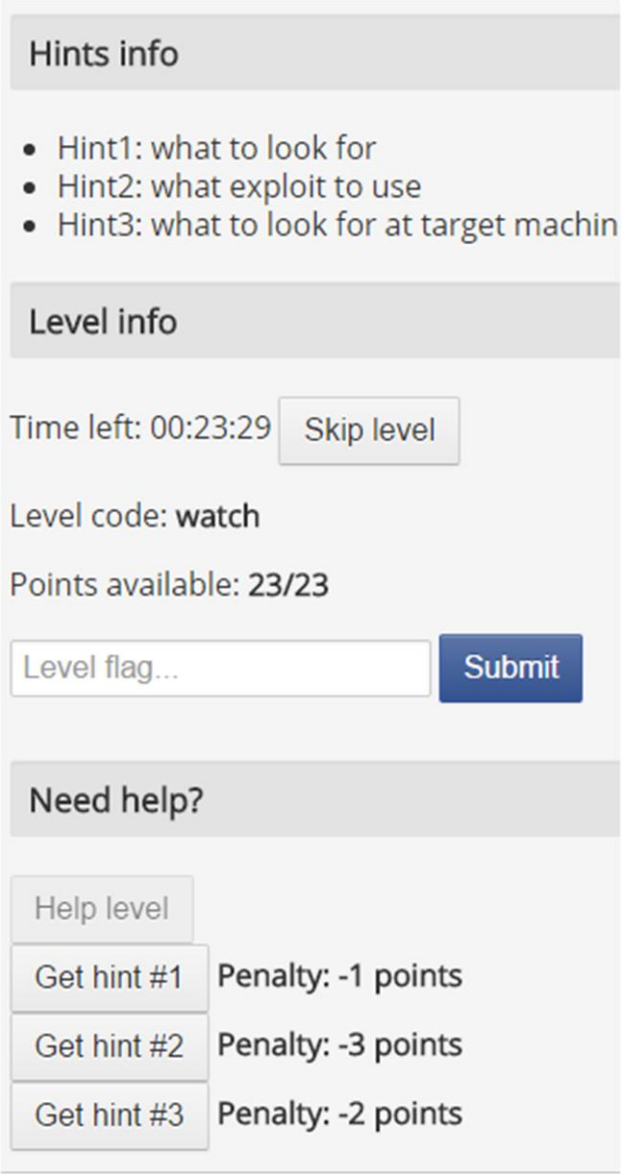
# KYPO game – extensions I

**Lessons learned:**

- Difficulty of levels is not balanced.
- Learners are hesitant whether the hints will help them.
- Game-related information provided outside the platform are inconvenient.

**Extensions:**

- **Improved hint system**
  - Hints about hints available
    *what tool to use, how to use the tool, …*
  - Players can now choose hints in arbitrary order.
- **Embedded level solutions**
  - Step-by-step tutorial for each level.



# KYPO game – extensions II

**Lesson learned:**

- Teacher has no information about the learners' performance and progress in the ongoing event.

**Extension:**

- **Logging the learner's actions**
  - Generic approach **in**dependent on specific game and its sandbox (hosts, network connections).
  - Captures only the interaction of the player and KYPO portal.
  - Does **not** capture any events or states from sandbox.

```
Aug 9, 08:00, Participant_1:
Game started

Aug 9, 08:00, Participant_1:
Level 1 entered

Aug 9, 08:05, Participant_1:
Incorrect flag submitted

Aug 9, 08:07, Participant_1:
Hint 1 taken

Aug 9, 08:15, Participant_1:
Level 1 completed (correct flag)

Aug 9, 08:20, Participant_1:
Level 2 entered

...
```

# Research questions

1. **How helpful are the hints and solutions for the learners?**

How do they contribute to completion of the level?

2. **What can be predicted from the participants' actions?**

What do game logs tell about the game and progress of the players?

# Evaluation of extensions – setup I

- Experiment with a new game using the new features
  - More levels
  - Used improved hint system
  - Level solutions available.

- 21 participants in total - a diverse mix of players
  - Various level of experience and work positions (students, IT staff, researchers, experts).
  - Various European nations.
  - Various experience with hands-on training in cyber security.

# Evaluation of extensions – setup II

- Self-assessment questionnaires for players
  - before the game,
  - after each level,
  - after the game.

  - *How was the level difficult?*
  - *Were the hints helpful?*
  - *Was the time limit sufficient?*
  - *What have you learned?*
  - *Would you like to play another game?*

- Game events of all players logged – a complement to self-assessment data.

# Evaluation of extensions – hints

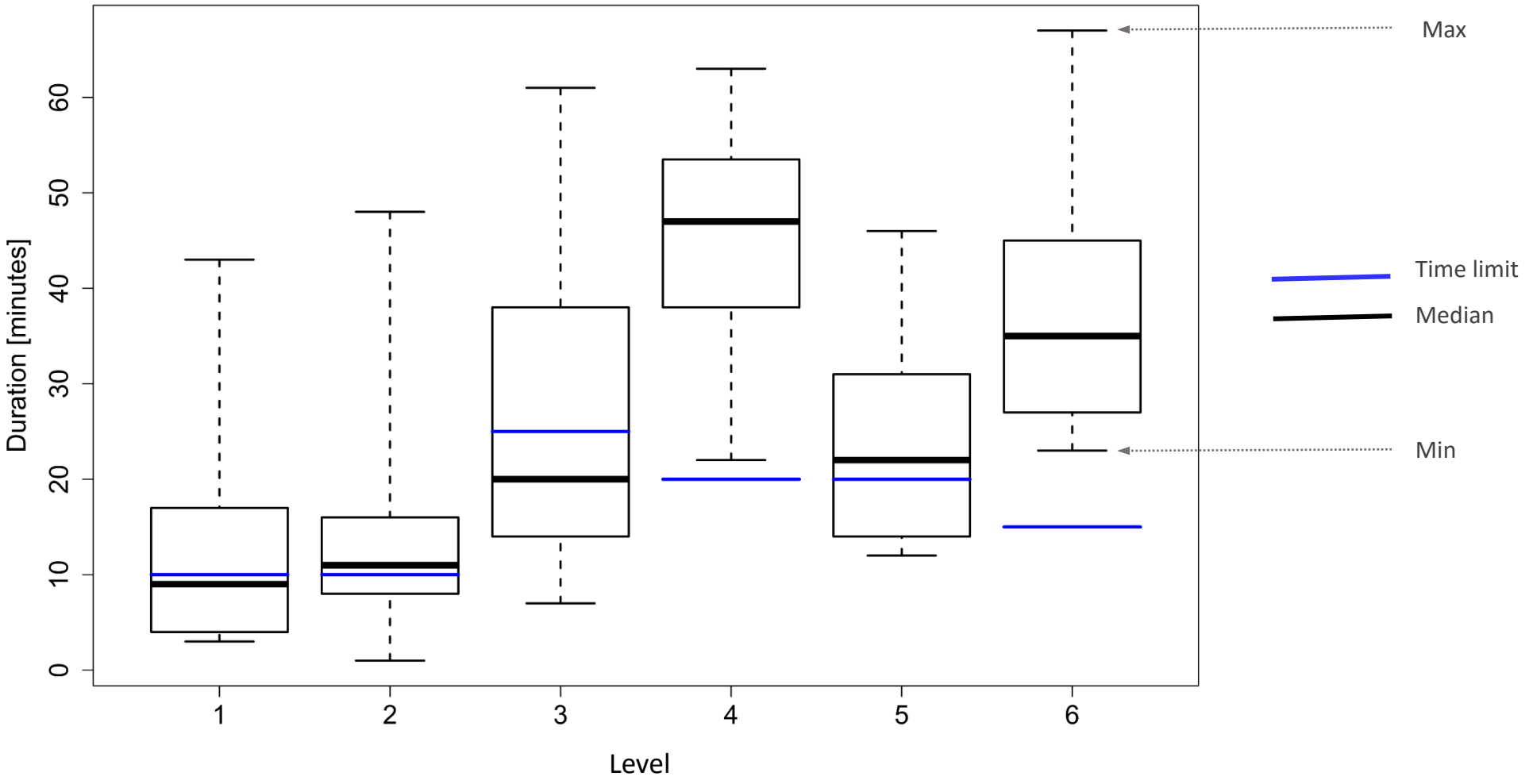
| Level | Learners | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | X | X | | | | | | | | | | | | | X | | X | |
| 4 | | | | | | | | X | X | | | | | | X | | X | X | | X | |
| 5 | | | | | | | | | X | | | | | | X | | X | X | | X | |
| 6 | X | | | | X | | | X | X | | | | | | X | | X | X | | X | |

- New hint system used in 28 % of cases (arbitrary order of hints = green boxes).
- 77 % of all levels where learners opted for a hint(s) were then accomplished.
- **Mismatch of game logs and self-assessment** (double checked).

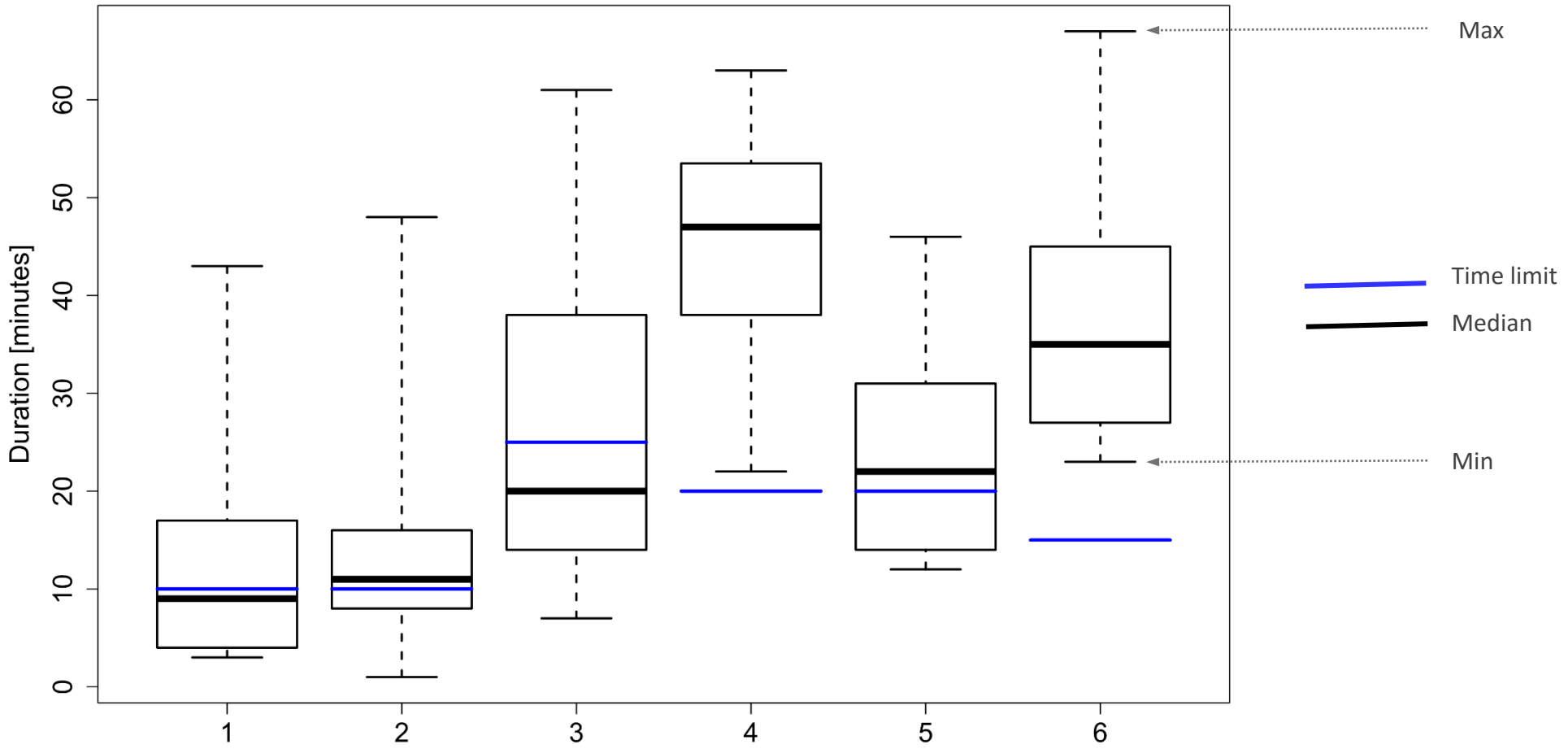
# Evaluation of extensions – level solutions

- If the hints do still not help, and participants cannot proceed further, they can access the solution of the level.
- Contribution of solutions to accomplishment of the level was **weaker than expected**
  - Solution displayed and then the **correct flag submitted** – 60 % (17x)
  - Solution displayed and then the **level skipped** – 40 % (11x)
- Some participants might be frustrated and just wanted to enter the next level(s).

# Evaluation of new features – game logs



# Evaluation of new features – game logs




**Level difficulty** 1.6 → 2.7 → 3.6 → 4.2 → **3.8** → 4.5

1 – easy, 5 – very hard

# Conclusions

- Logging the game's events provide useful data for analysis of game sessions to make them more engaging and fun.
- It is also useful for teachers to monitor ongoing session.

- Learners did use redesigned hint system and recommended solutions.
  - Evidence found in collected game events and the supplemental user survey.
- Learners' answers neither confirm nor disprove the benefit of the hints and solutions used.

- Other games events matched the learners' assessment (level difficulty and duration).

- Future work: **Do user surveys represent reliable tools for designing and evaluating hands-on training?**

# QUESTIONS?

# THANKS FOR YOUR ATTENTION!

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