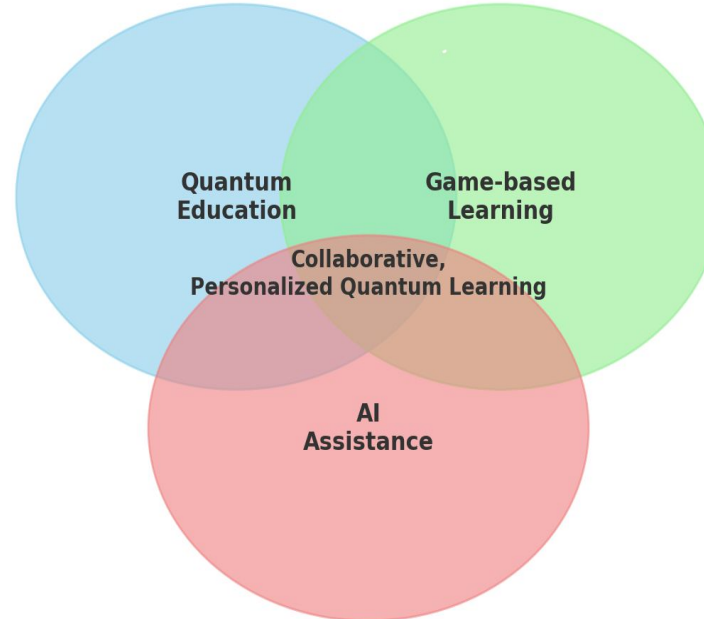# Game-based and AI-assisted Learning about Quantum Science

Dr. Fabian Schrodt

Quantum Gaming GmbH

Tübingen, Germany

- **Rising need for quantum literacy** as quantum technologies expand across science & industry

- **Limitations of traditional teaching**: abstract concepts, low engagement, accessibility gaps

- **Educational innovation required**: engaging, adaptive, and intuitive learning frameworks

- **Game-based learning** provides interactivity, motivation, and context for abstract ideas

- **AI-assisted education** enables personalization & adaptivity

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- **G**ame-based and **A**I-assisted **L**earning **a**bout **Q**uantum **S**cience = **Galaqsci**

- **Goal of Galaqsci**: combine games and („classical!") AI to create scalable, collaborative learning experiences in quantum science

Quantum
Education

Game-based
Learning

Collaborative,
Personalized Quantum Learning

AI
Assistance

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- **Research consortium**

- **Qookies** – A Quantum Quest
  - Story-driven point- and click adventure
  - Escape room elements
  - E-learning elements
  - For pupils and students
  - Release 2026
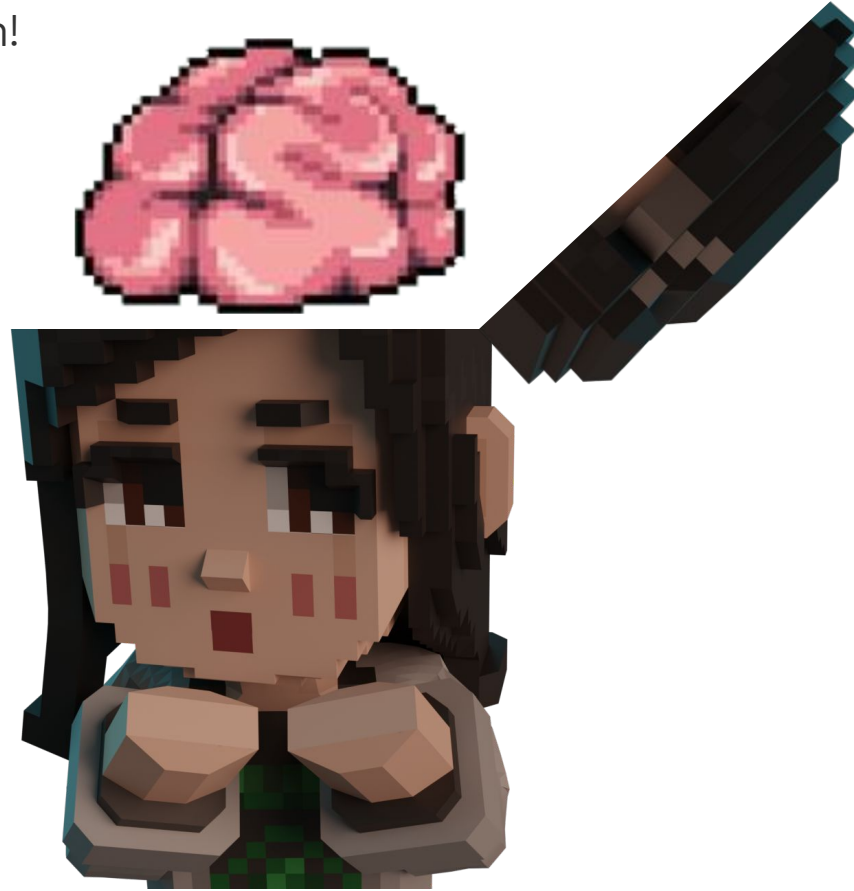 - For Android and iOS (and Chromebook)

- **Yuki:** AI-controlled co-player

- Let's take a look into Yuki's brain!

- Let's take a look into Yuki's brain!

- **NPC Requirements:**

  - Limited initial domain knowledge (just as the player)

  - Shared gameplay with the player

  - Incremental learning from
    - Observation
    - Instruction
    - Dialogue

  - Close coupling to game mechanics

  - Co-learning experience

Yuki: I don't know exactly how we can solve this, but I have a few ideas!

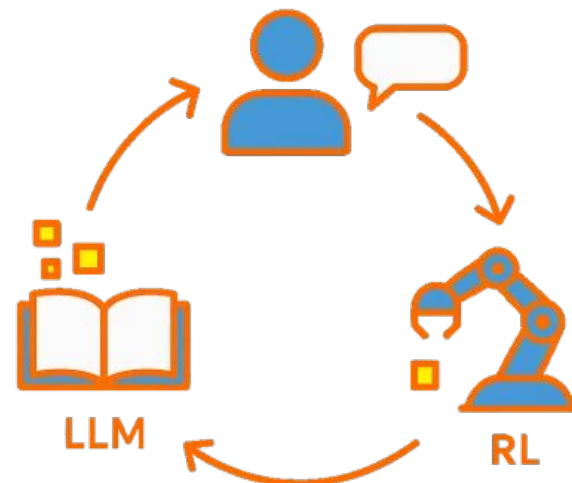- **Technological approach:**

Large language models (LLM)
(Llama 3.1 70B)

+
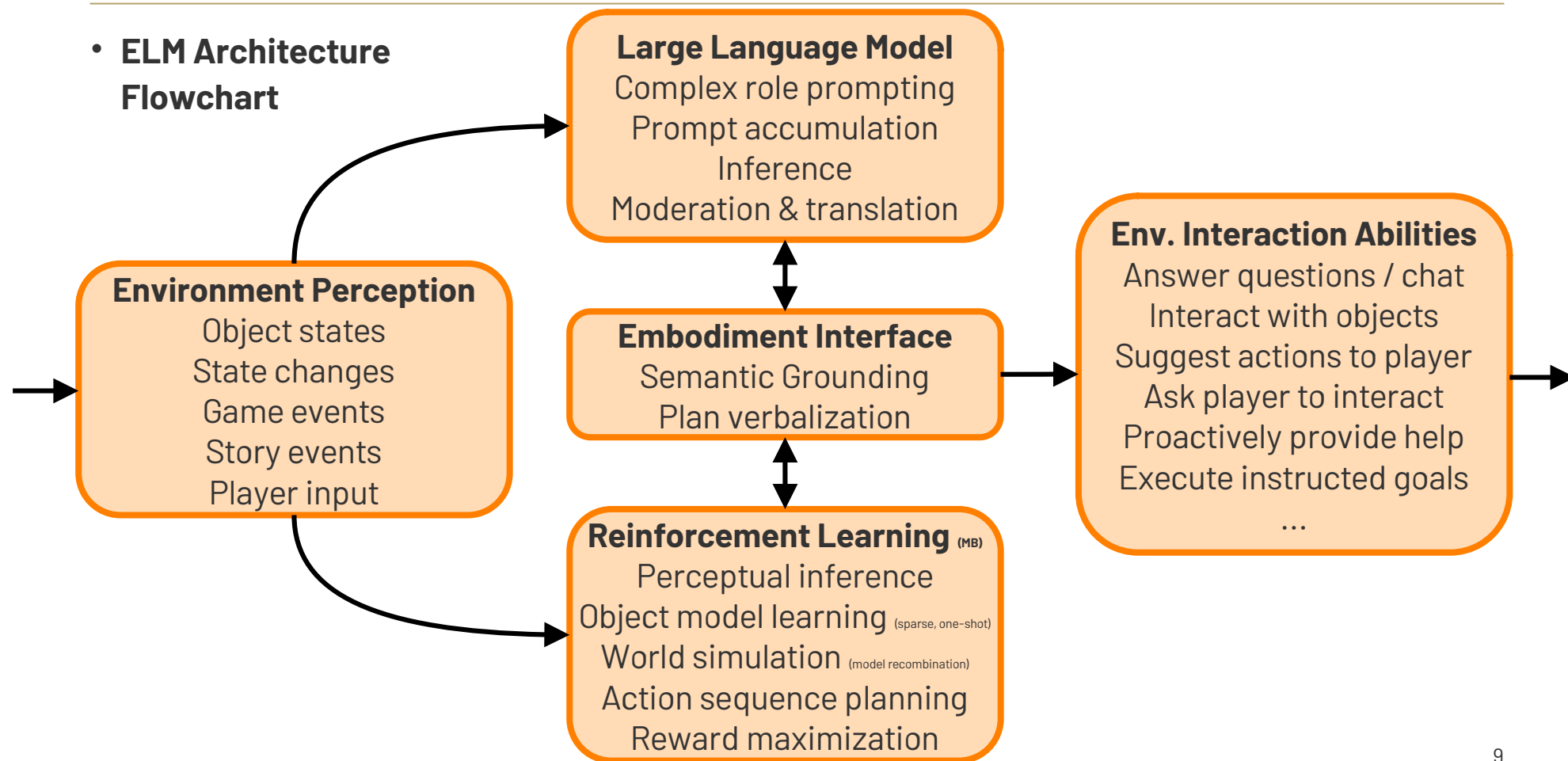
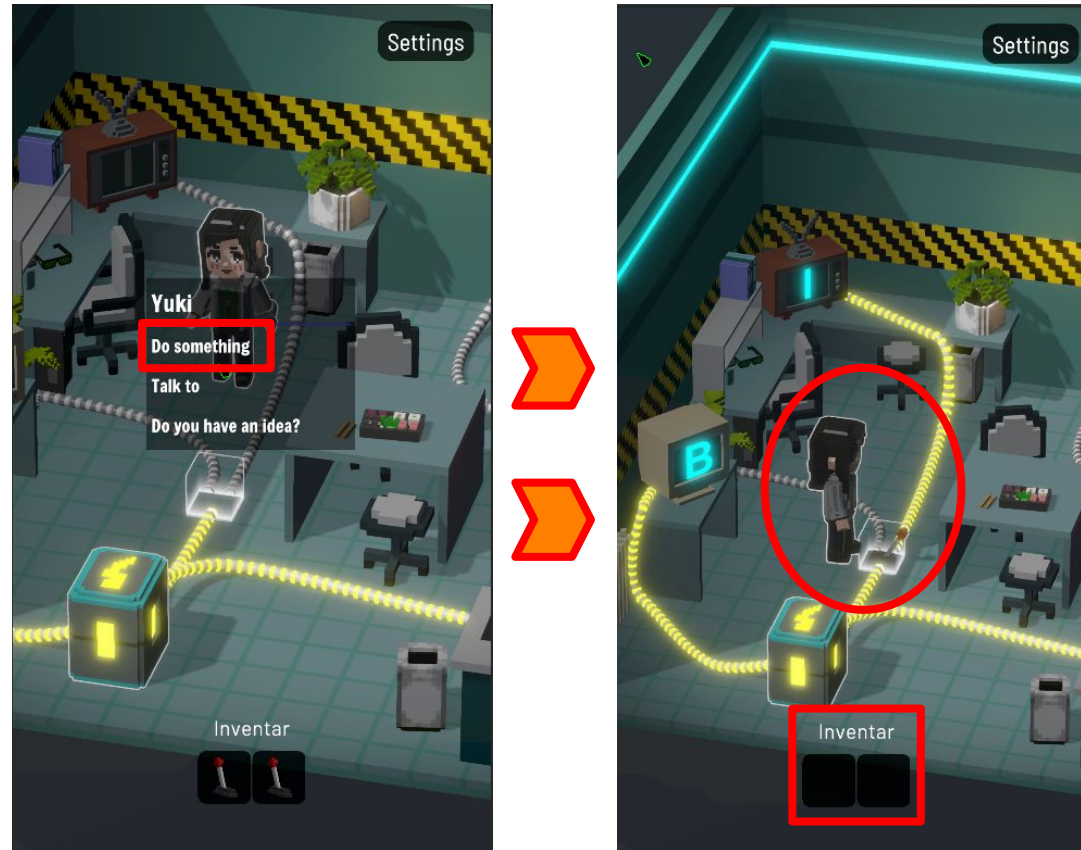Model Based Reinforcement learning (MB RL)
(proprietory)

=

Embodied Language Model (ELM)
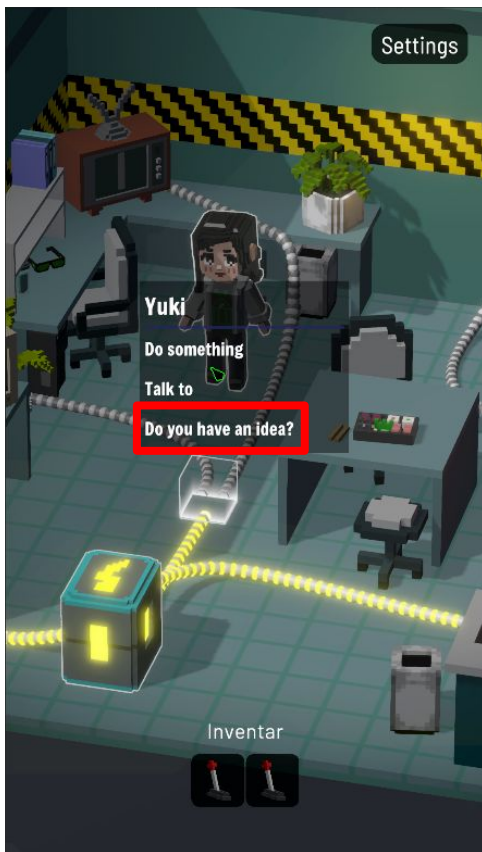
- **ELM Architecture Flowchart**

Large Language Model
Complex role prompting
Prompt accumulation
Inference
Moderation & translation

Environment Perception
Object states
State changes
Game events
Story events
Player input

Embodiment Interface
Semantic Grounding
Plan verbalization

Reinforcement Learning (MB)
Perceptual inference
Object model learning (sparse, one-shot)
World simulation (model recombination)
Action sequence planning
Reward maximization

Env. Interaction Abilities
Answer questions / chat
Interact with objects
Suggest actions to player
Ask player to interact
Proactively provide help
Execute instructed goals
...

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- **Player makes Yuki try to do the next steps in the level:**

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- **Player chats with Yuki:**

- **Player asks for a hint:**

RL based reply:

Yuki: Pair this Item slot with a ClassicSwitch.

OR

LLM based reply:

Yuki: Place the beam splitter to divide the laser beam, then use mirrors to redirect the beams towards the detectors.

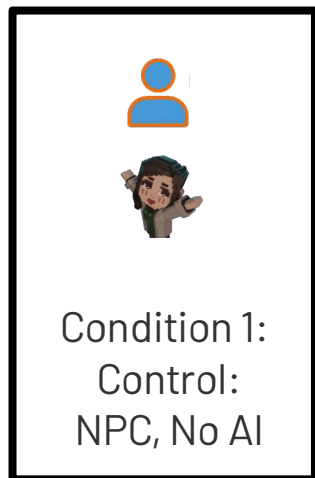- **Yuki asks the player to interact with an object that is out of her reach:**

Design Choice / Tech	Expected Educational Outcome
Game-based learning	↑↑ engagement, motivation, and context for abstract concepts
Shared & cooperative gameplay, adaptive support	↑↑ Bonding, attachment, social presence, engagement
Co-learning: Limited initial knowledge & incremental learning	↑↑ reflection and active participation
Context-aware chat + prompt accumulation	↑↑ personalized interaction, narrative continuity
Close coupling between AI and game mechanics	↑↑ seamless integration of play and learning, less prone to hallucinations

**Overall**: Improved **conceptual understanding**

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- **Study design (LMU Munich):**
  - Conducted with **early version** of the game („Prof. Unknown")
  - 3 Groups:

Condition 1:
Control:
NPC, No AI

Condition 2:
LLM:
Chat

Condition 3:
ELM:
Chat+Interact.
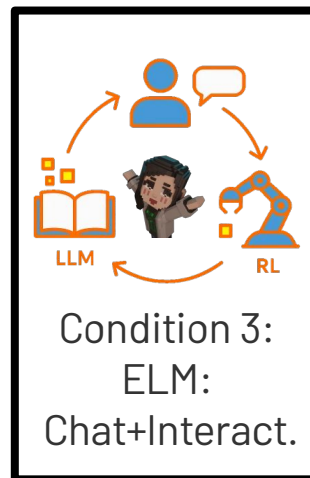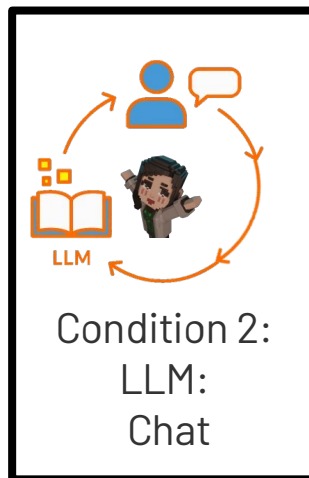
  - 152 participants (47 + 50 + 55)
  - Questionnaire: pre- and post tests on **conceptual understanding**

- **Conceptual understanding** = points in questionnaire on quantum science
- **Significant gain in points** achieved pre- to post-test in all groups → game effect (and reflection period)
- No significant difference between the groups → players didn't learn significantly more with AI.

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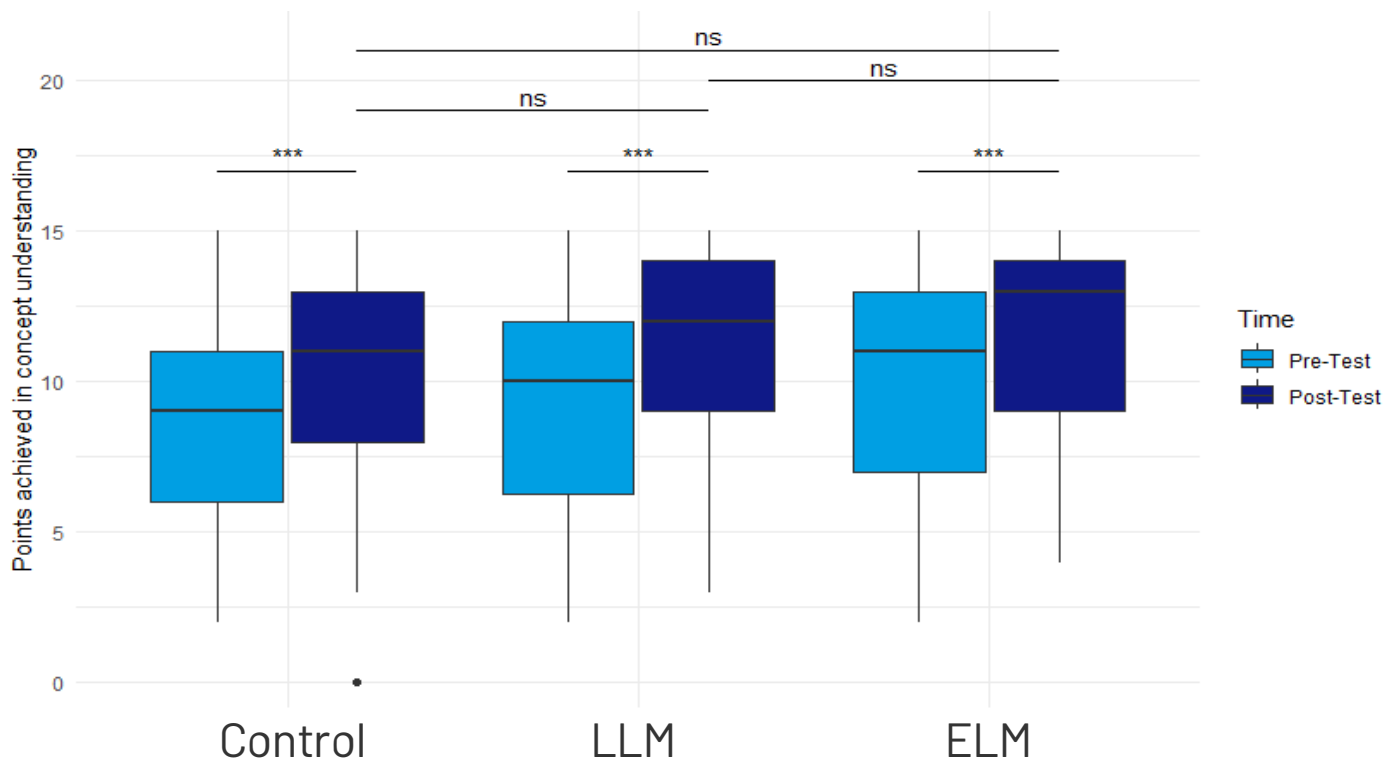
- **Intrinsic Cognitive Load** = mental effort due to number of elements and degree of interdependence
- **Significant decrease of ICL with Embodied Language Model** over LLM alone → learning was **easier**.
- No significant decrease of ICL comparign ELM with Control → LLM seems to increase ICL?
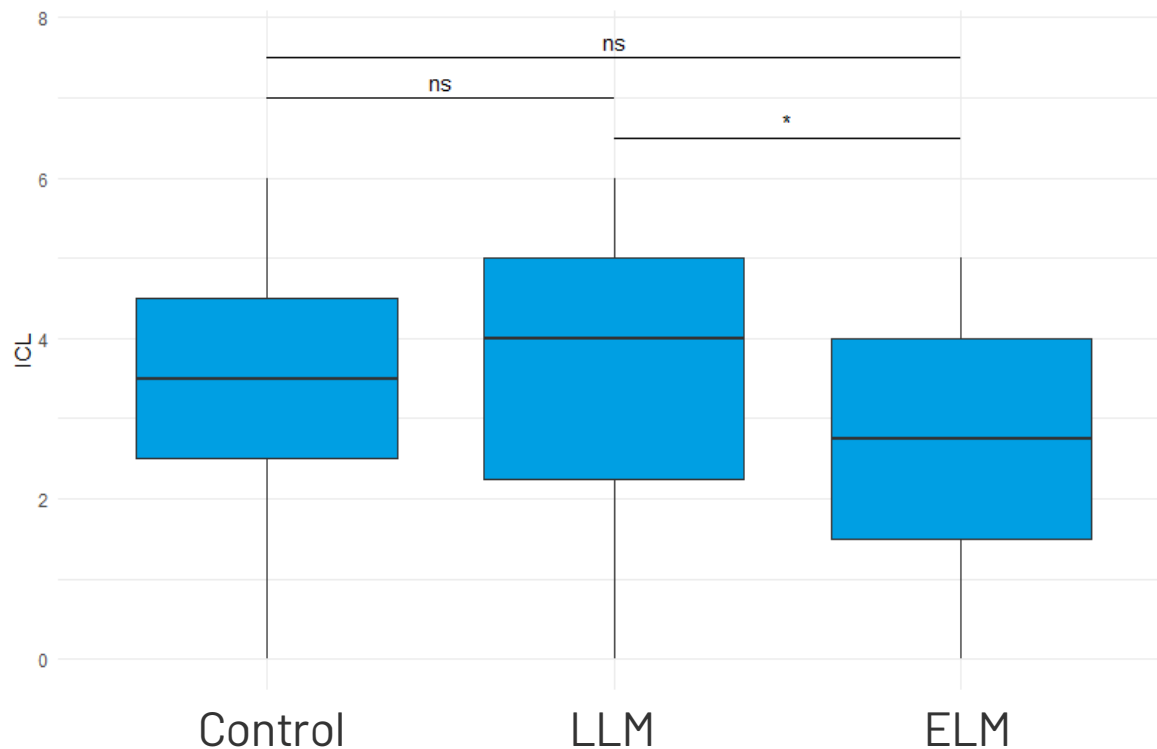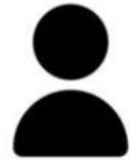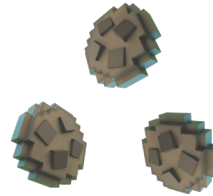
- **Quantum literacy is urgent** – Engaging, adaptive teaching methods are needed to make complex quantum concepts accessible.

- **Game-based learning boosts engagement** – Interactive, story-driven gameplay helps contextualize abstract ideas.

- **AI co-player enables co-learning** – Yuki's incremental learning fosters reflection, collaboration, and active participation.

- **Embodied AI reduces intrinsic cognitive load** – ELM makes learning easier by grounding language models.

- **Galaqsci is scalable & innovative** – Combining games and AI provides a flexible, immersive framework for education in general.

- **Future work:** Additional studies; AR-mode; Transfer of Galaqsci to other teaching domains.

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We are **Quantum Gaming** — we create AI for gaming and learning

Get in touch and visit our booth!

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- Discuss your project ideas
- **Get FREE COOKIES!!!**

Hall 2, booth 2E31

vCard

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