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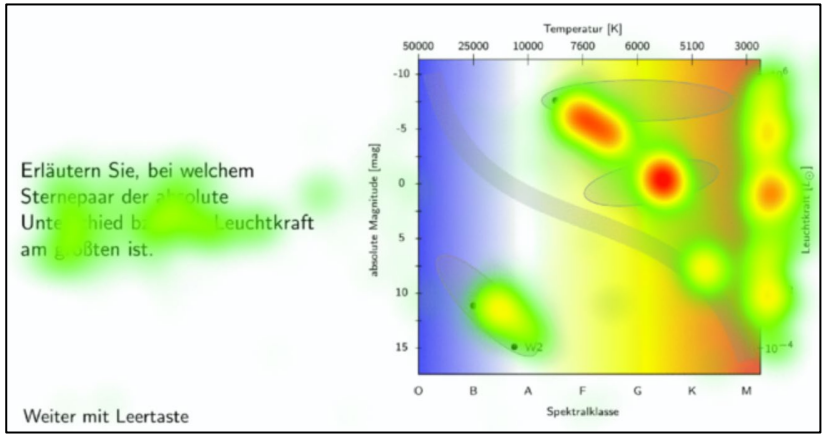
ORIGINS (Physics) Education (Research)

Making the invisible visible

Jochen Kuhn, LMU Munich/Chair of Physics Education

Outline

1. Basic ideas
2. Cosmos visualized: Importance of visualization for communication of ORIGINS research
3. Making the invisible visible: Using cutting-edge-technology to virtually augment our real world
4. Provide the right one for everyone: AI-based personalized science outreach communication
5. Local and global: Implementation of ORIGINS PER



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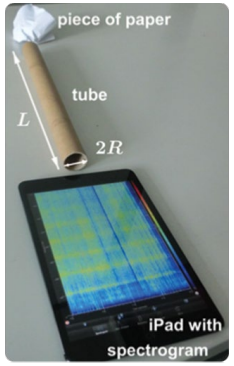
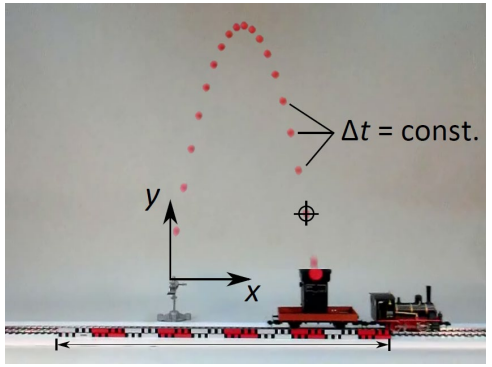
Basic ideas

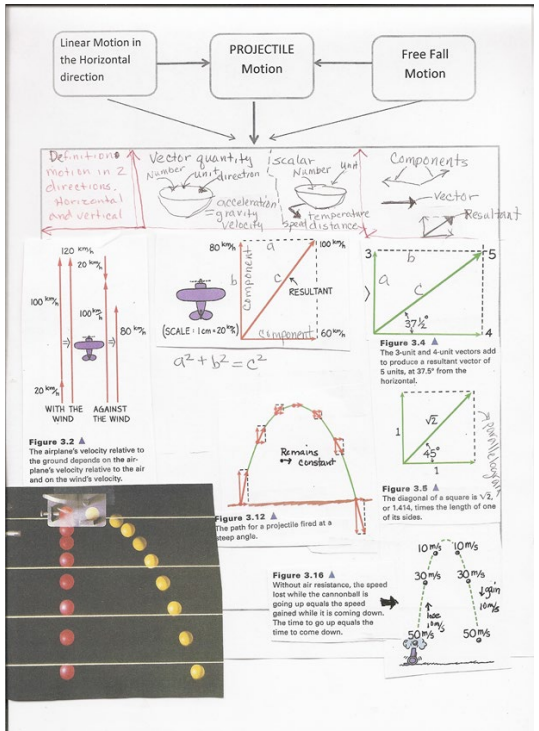
Visualizing scientific phenomena: How, what and why?





Basic ideas:

- Physics is considered "dry" and abstract, mostly theoretical and invisible => bridge these tensions using (cutting-edge Ed)Tech.
- Augmenting **real world phenomena with virtual information** for inquiry-based learning in physics
- Using Apps to **visualize physical variables, processes** and **relationships => Making invisible** phenomena/processes/… **visible**



Theoretical links: Learning with Multiple (External) Representations (MER)

- important role of competent handling of MER for STEM education (e.g. Verschaffel et al. 2010) – considering their design opportunities and different functions (DeFT; Ainsworth, 2006)
- Representational competence as domain-specific prerequisite for conceptual understanding, reasoning, and problem solving(e.g. Rau, 2017)
- BUT: learners of each age often struggle with MER (Scheid et al., 2019).

…and:

- Visualizations must be individualized and personalized.

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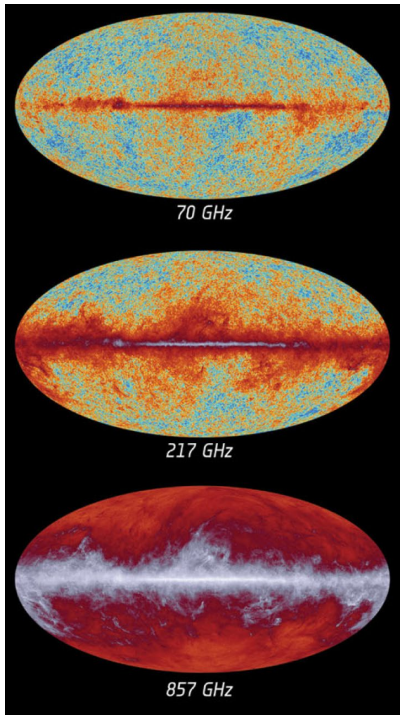
Cosmos visualized

Importance of visualization for communication of ORIGINS research

Cosmos visualized: Importance of visualization for communication of ORIGINS research



PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH **17,** 013104 (2021)

Cosmos visualized: Development of a qualitative framework for analyzing representations in cosmology education

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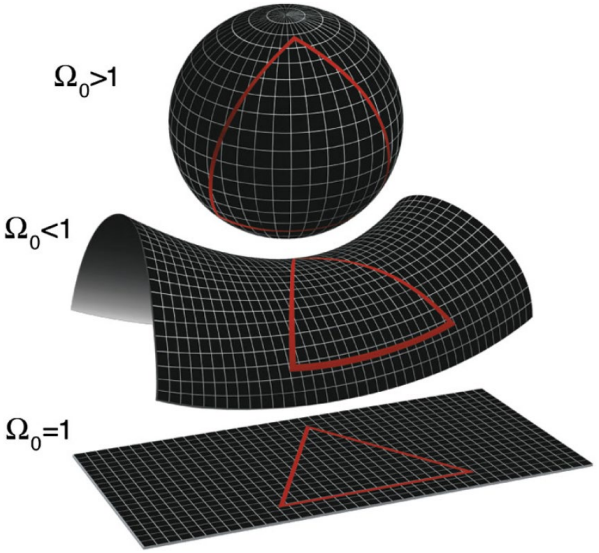
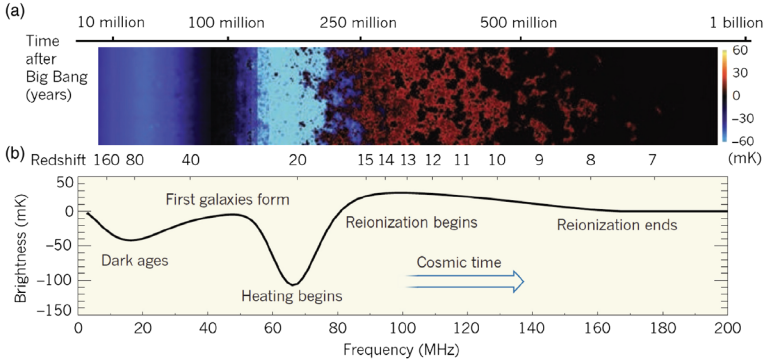
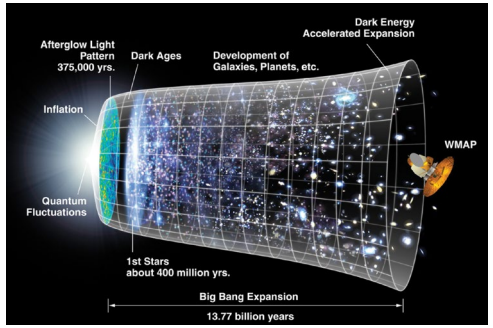
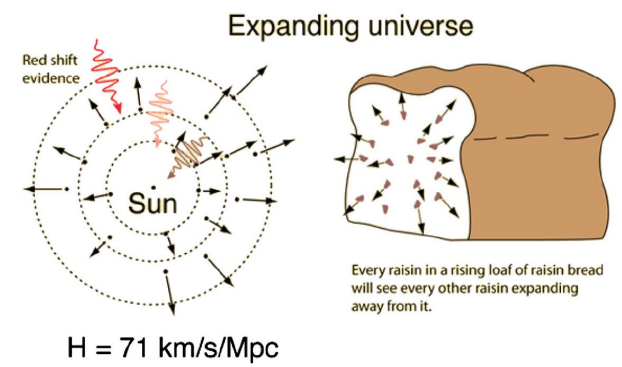
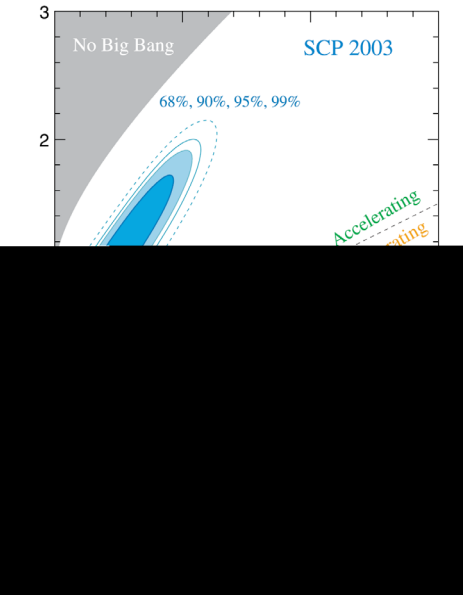




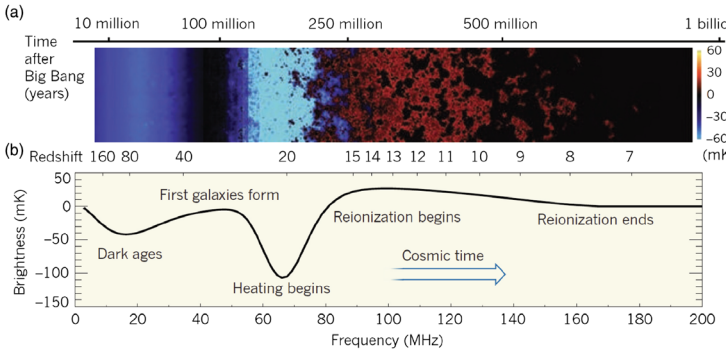


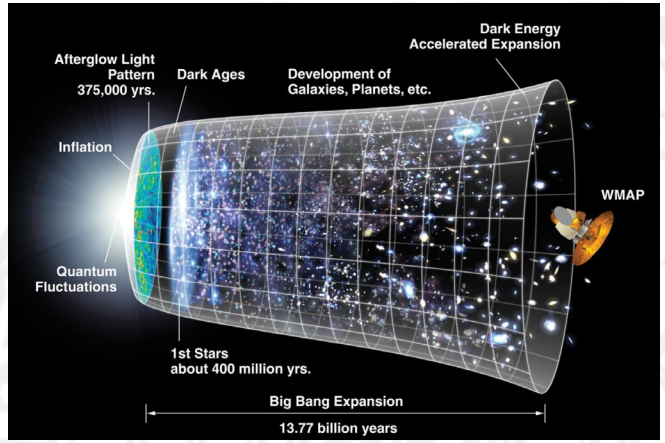


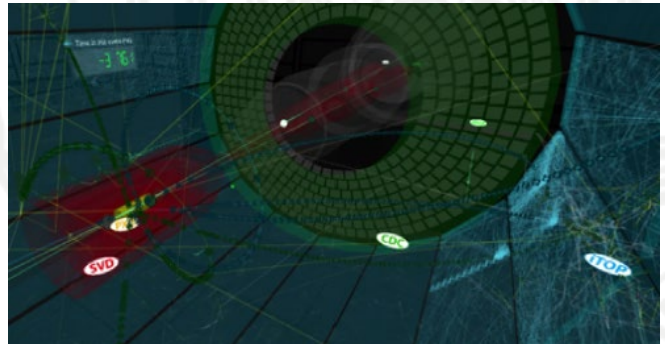
Cosmos visualized: Importance of visualization for communication of ORIGINS research



- Abstract and intangible concepts have already been developed and communicated – but are complex to interpret
- Nevertheless: astrophysics is one of the most interesting context for students
- Very important to make disciplinary concepts visible
- 4 categories of visualizations in Astrophysics: size and scale, spacetime location, composition, and evolution.
- representations created for a higher level are not always suitable at lower levels and unsuitable representations can lead to misconceptions
- teachers have to be aware of various elements of representations to help students.







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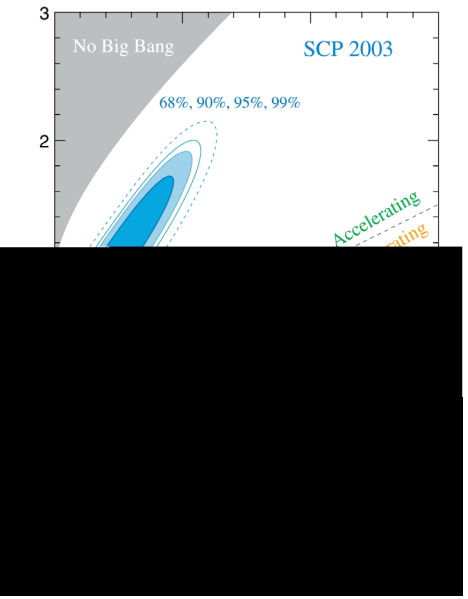

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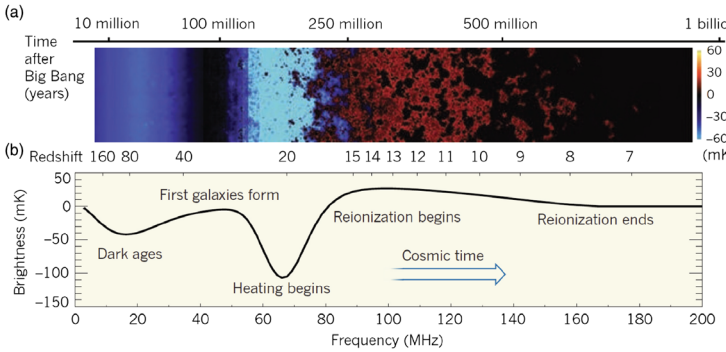

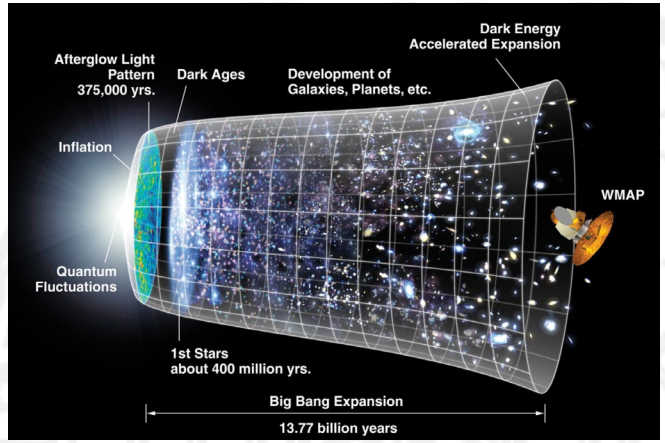

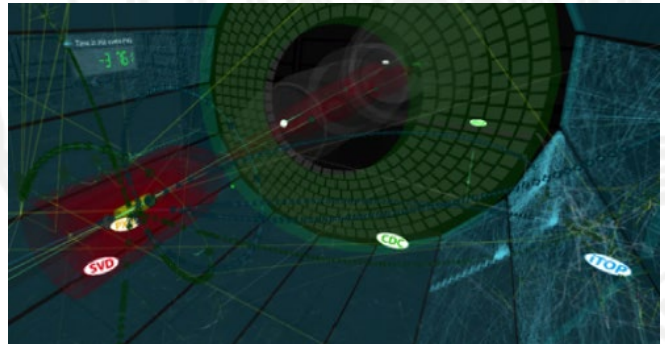

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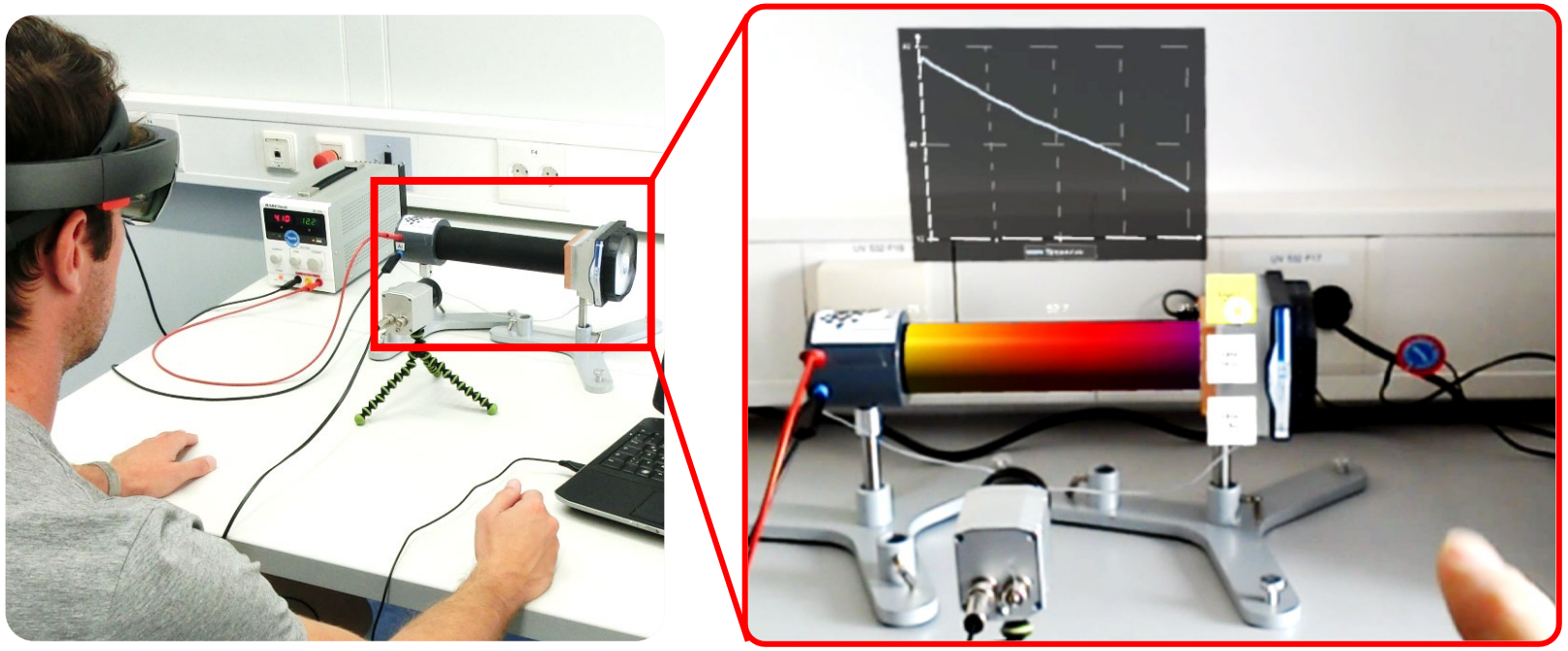
Making the invisible visible

Using cutting-edge-technology to virtually augment our real world

Head mounted-AR environments: R&D

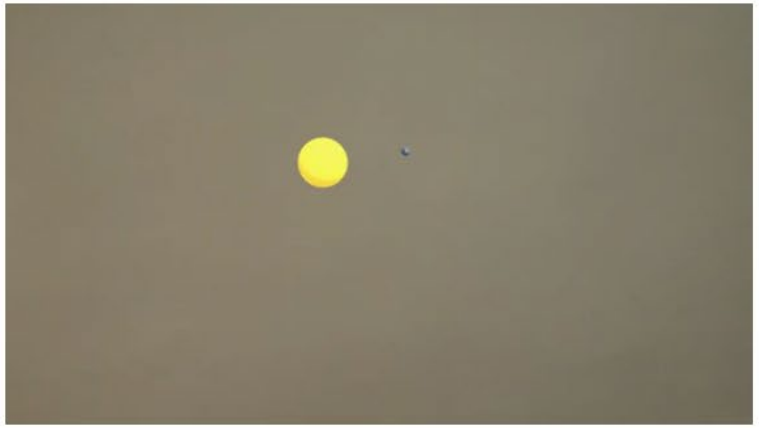
Heat conduction in metals



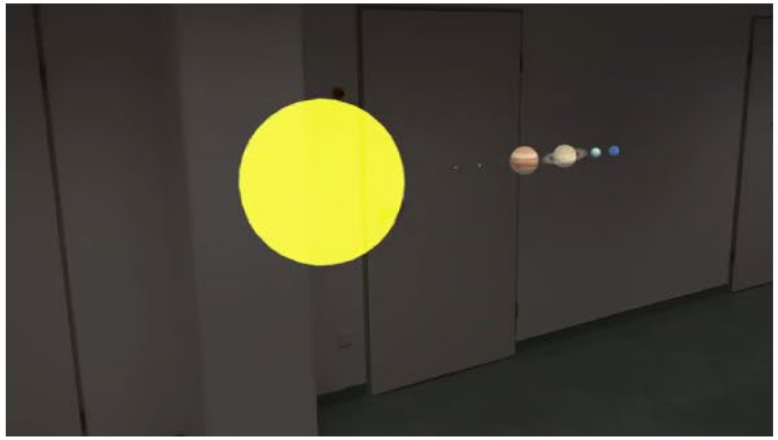
Typical experiment on heat conduction in metals in the university physics lab course at TUK

Strzys, M. P., Kapp, S., Thees, M., Klein, P., Lukowicz, P., Knierim, P., Schmidt, A. & Kuhn, J. (2018). Physics holo.lab learning experience: Using Smartglasses for Augmented Reality labwork to foster the concepts of heat conduction. *Eur. J Phys. 39* (3), 035703.

Head mounted-AR environments: R&D



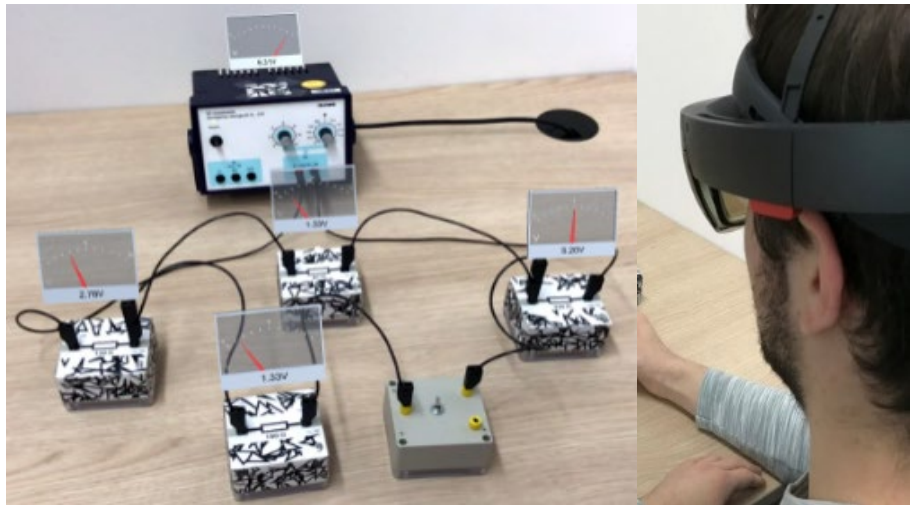
Discovery of exoplanets using the Doppler effect

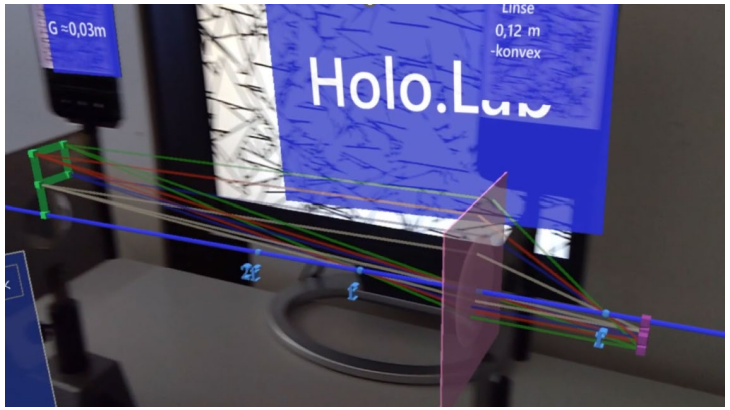


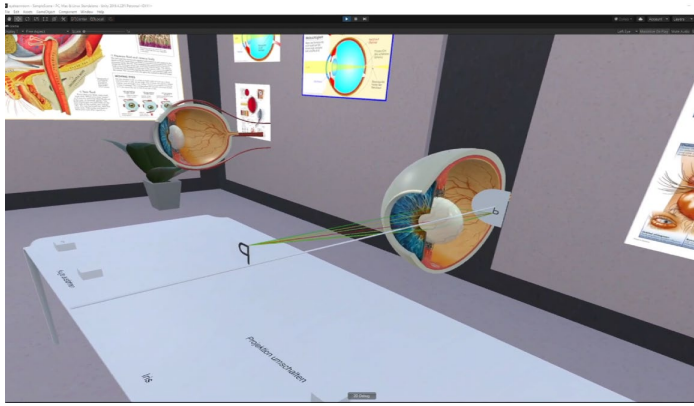
Size comparison of the planets in our solar system

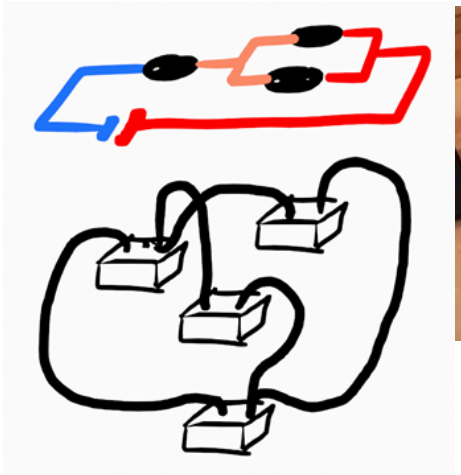
Planetary orbits depending on the reference system

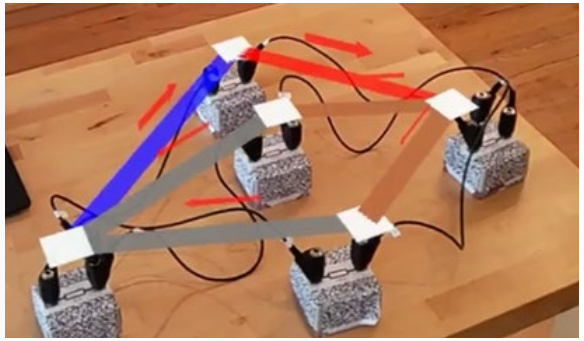
Head mounted-AR environments: R&D

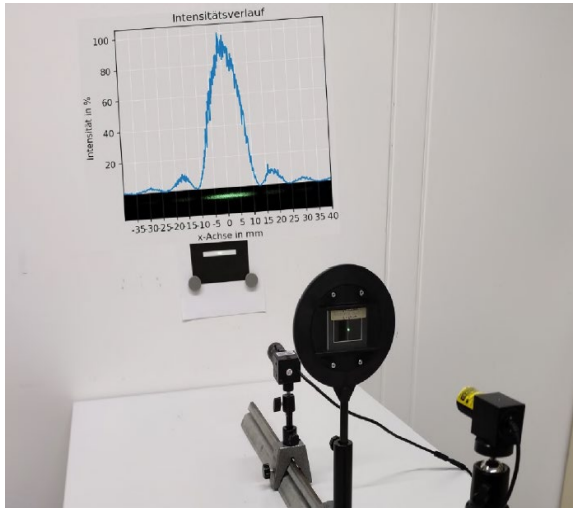




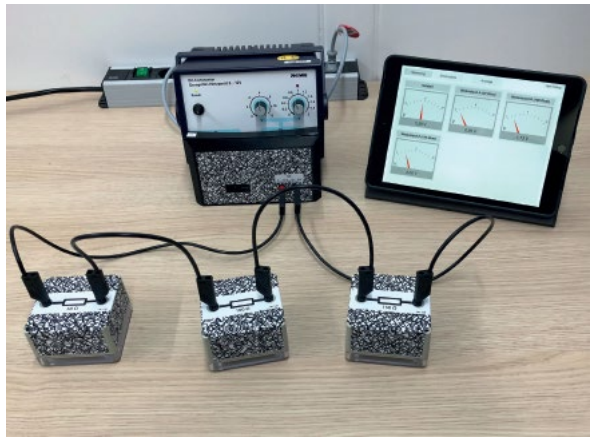




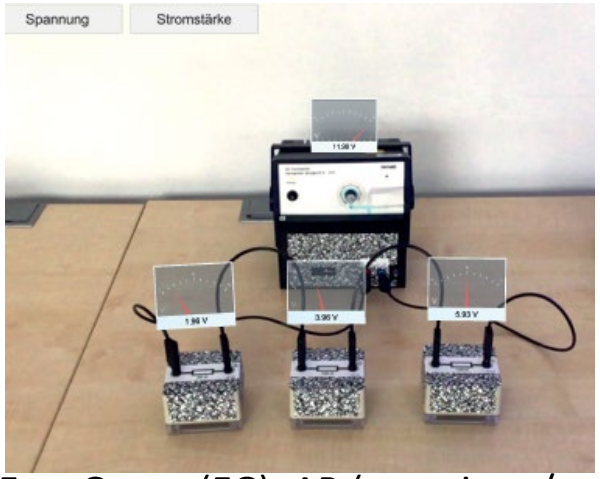




Inquiry-based learning studies: Learning with AR vs. non-AR environment



Control Group (CG): non-AR (tablet-2D; split source format)



Exp. Group (EG): AR (superimp./ see-through; integrated format)

Materials and methods:

- 5 (experimental and quasi-experimental) trials in thermodynamics and electrics with experimental and control groups in pre-post test design
- More than 250 university students (all fields)
- Cognitive (cognitive load, conceptual understanding) and affective (interest/motivation, curiosity, usability) measures
- AR (EG; superimposed/see-trough) vs. non-AR (CG; tablet-2D)

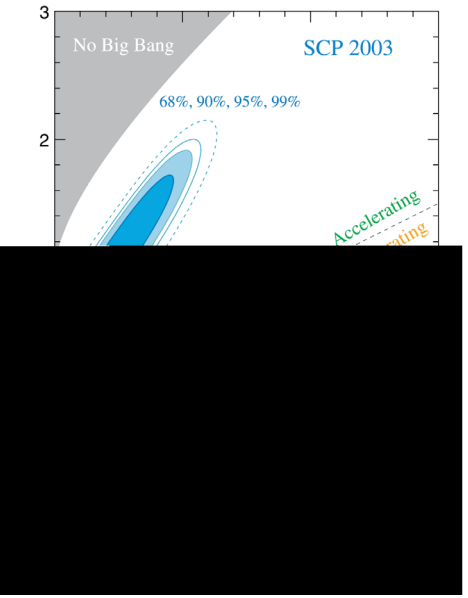
Results:

- Increase of conceptual understanding higher in EG than in CG (only superimp. AR)
- Learning-irrelevant (extraneous) cognitive load in EG lower than in CG (electric: only superimp. AR; thermodynamics: see-through AR)

Coming soon: replication study with primary students

- Additional measures of students learning process with eye-tracking

Cosmos visualized: Importance of visualization for communication of ORIGINS research



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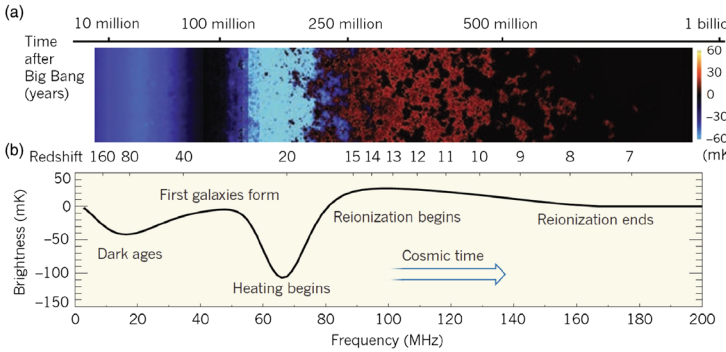

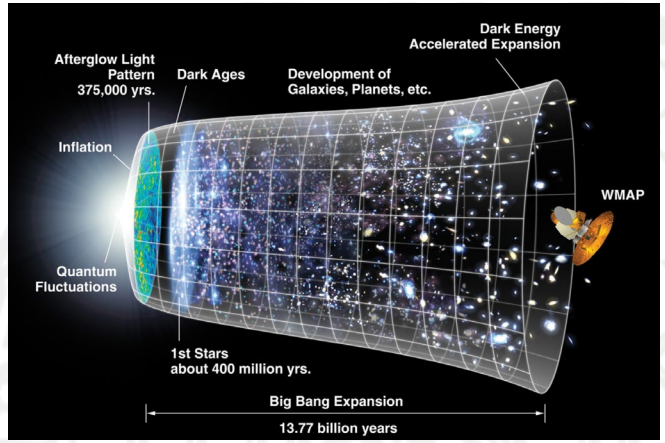

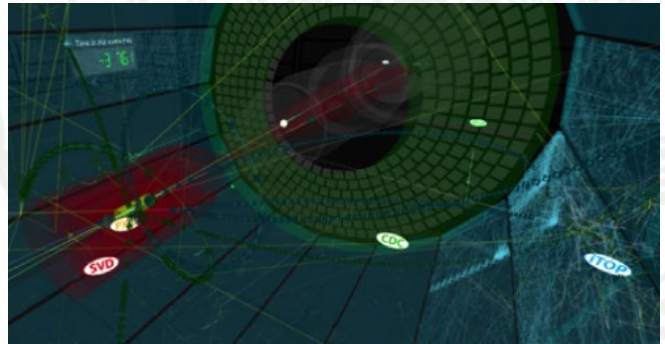

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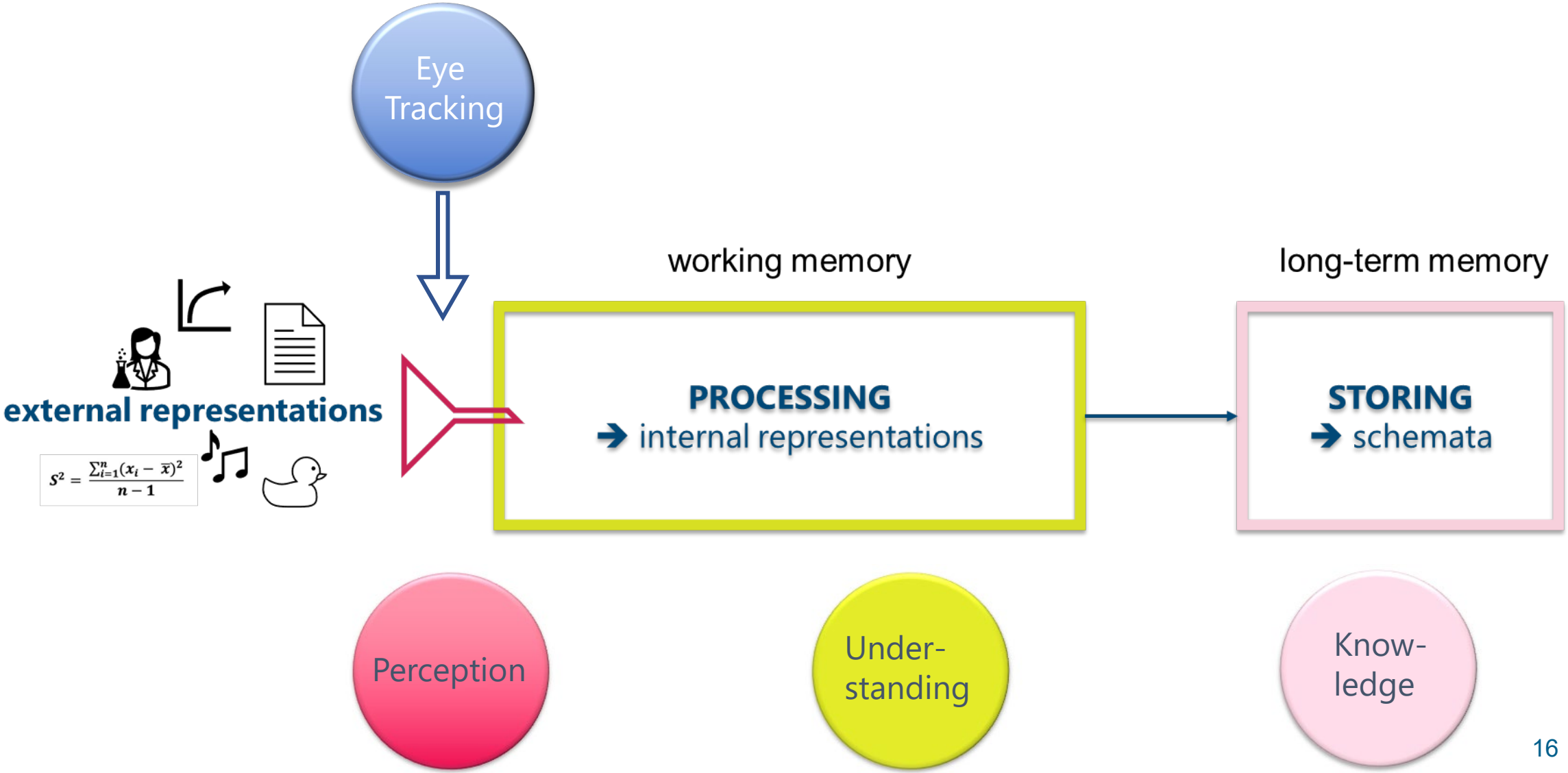
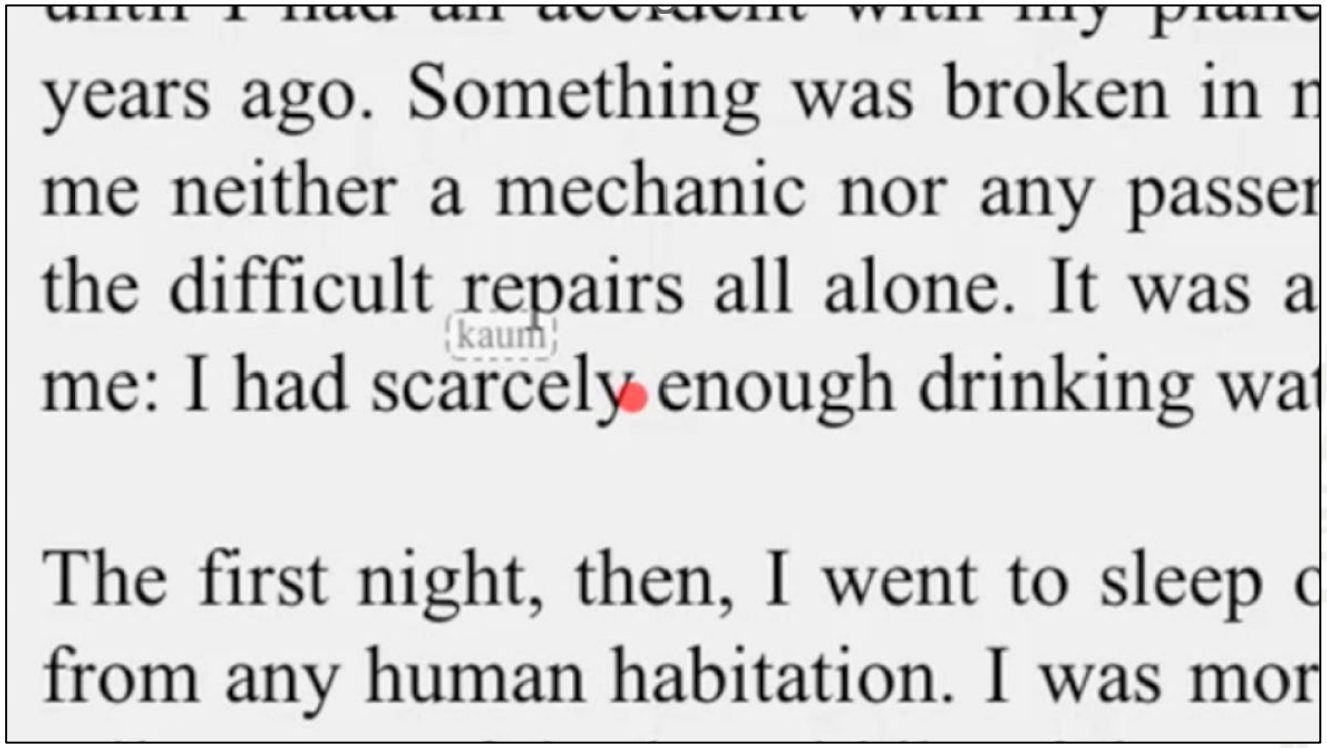
Provide the right one for everyone

AI-based personalized science outreach communication

Eye Tracking: Monitoring Perception

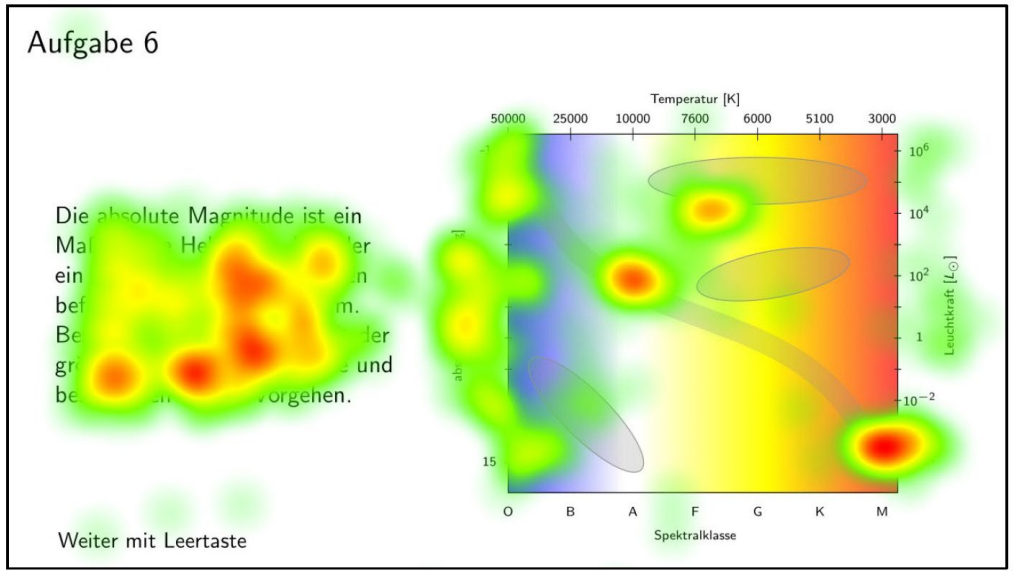


When the text knows what is being read....

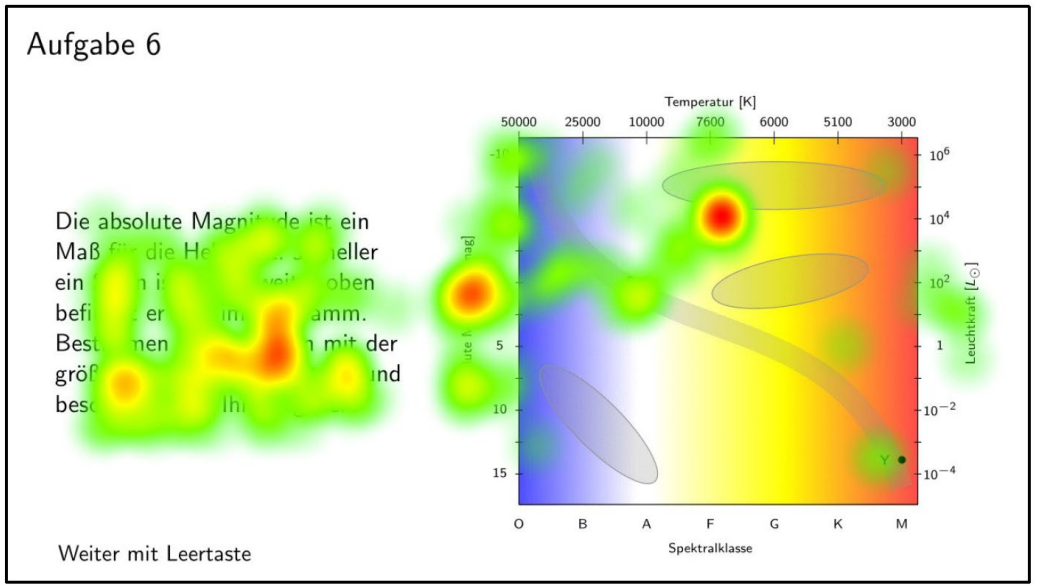


Different visual strategies solving HRD related problems

high performers



low performers



- Visual attention (visual dwell time; called “heat maps”) of high performers (left) compared to low performers (right)…
- ….during solving a physical problem/task: three stars are given, and the problem requires comparing their magnitude values to identify the brightest one (bottom right).
- Visual strategies of high and low performers (correct and uncorrect solvers) differ siginficantly.
- Train AI-algorithms to support visitors/learners gaze by providing hints if incorrect gaze patterns would be detected

Langendorf, R., Schneider, S. & Klein, P. (2022). Extracting information from the Hertzsprung-Russell diagram: An eye-tracking study. *Phys. Rev. Phys. Educ. Res. 18*, 020121

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Local and global

Implementation of ORIGINS PER

ORIGINS (Physics) Education: local and global

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- World of ORIGNS exhibition in the new Physics Forum at the English Garden
- Intelligent Demonstrators with cutting-edge technologies related to ORIGINS sub-projects and research units
- Learning modules for students at the ORIGINS SchoolLab – related to school curriculum
- Teacher Training program
- Combining learning at home with local learning modules using ORIGINS mobile app

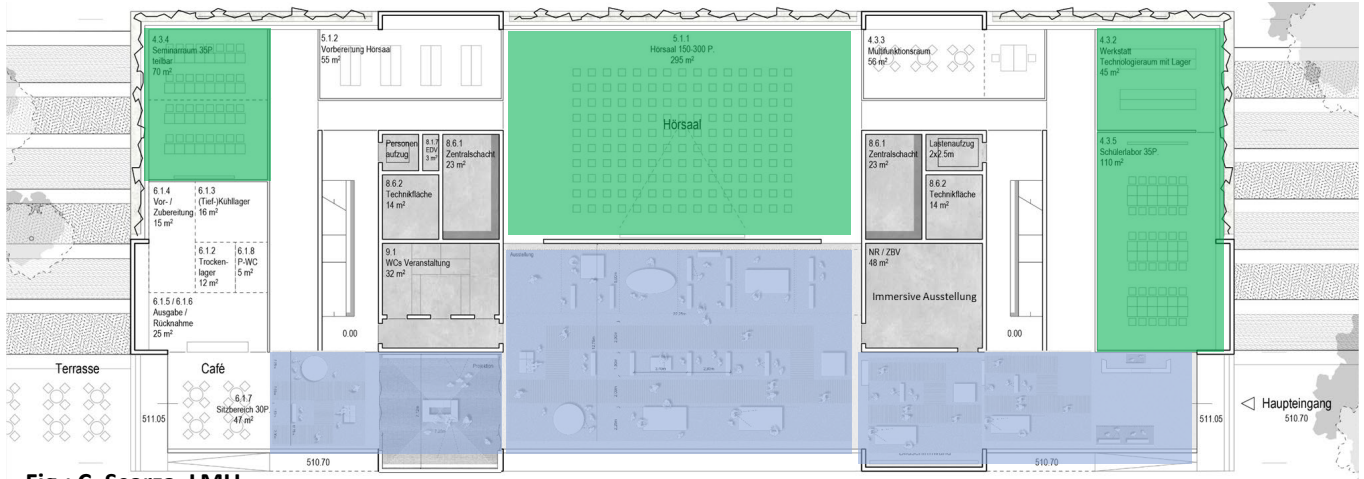
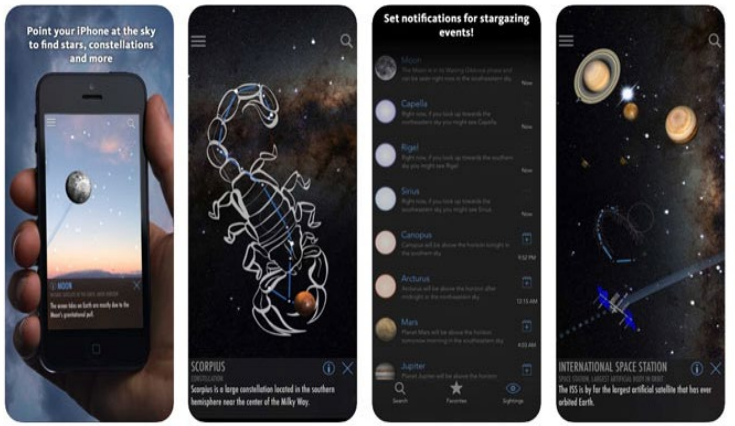
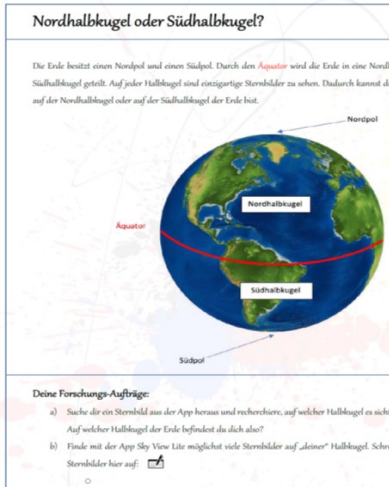


Fig.: C. Scorza, LMU





Thanks for your attention
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