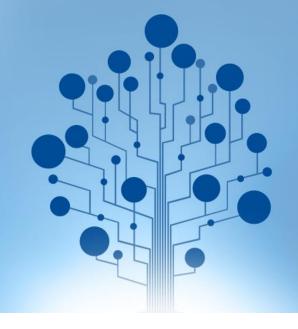
FernUniversität in Hagen



Al in Education, design perspectives and research questions

Keynote MIS4TEL conference, 25.06.2025, Lille Prof. Dr. Marcus Specht, Fernuniversität in Hagen





What is human learning?

Learning is an enduring change in behavior, or in capacity to behave in a given fashion, which results from practice or other forms of experience.



What would happen without the capacity to learn?



| Level | Consequences Without the Ability to Learn | | |
|--|--|--|--|
| Biological Development | - No adaptation to environmental stimuli: reflexes would be innate but could not be refined Brain plasticity would be virtually zero → sensory perception would remain crude, motor skills uncoordinated High mortality: dangers would not be recognized or avoided. | | |
| Child Development | - Language could not be acquired; at most, innate sound patterns No recognition of objects or people beyond reflexive reactions No development of attachment or play → extreme dependence on rigid care routines. | | |
| - Use of tools impossible: knives or fire would be useless because their function wouldn't be understood No memory of cause-and-effect relationships (e.g., tripping → pain), leading to constant repetition of the same mistakes. | | | |
| Social Structures | - Culture, tradition, and morality rely on transmitted knowledge → all would disappear Cooperation would be at most instinct-based (e.g., group protection) Role distribution, division of labor, education: not feasible. | | |
| Society & Culture | - No cumulative knowledge \rightarrow lack of historical consciousness Art, music, religion rely on symbolic learning \rightarrow not possible Values and norms could not be internalized. | | |
| Language & Thinking | - Language is a highly learning-intensive system; without it, hardly any abstract thinking Inner dialogue, planning, and problem-solving would be severely limited. | | |
| Evolutionary Perspective | - Learning ability is a key advantage of complex species Homo sapiens probably would never have prevailed — the inability to learn would have nullified the selective pressure toward flexible intelligence. | | |

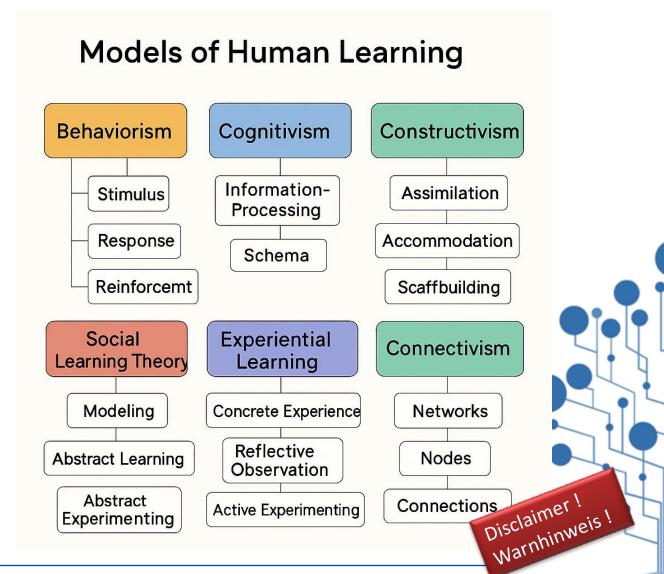
How is learning understood and theorised?





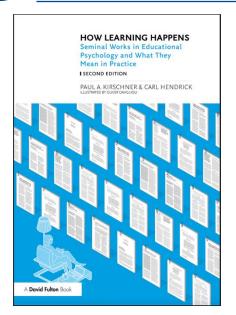
What are explanation of learning and how are the processes modeled?

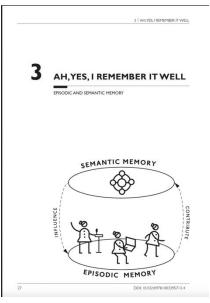
- Learning theories formulate the underlying concepts and can be structured into groups.
- Knowledge, skills, and attitudes develop through external stimuli, feedback loops, reinforcement, models, practice, reflection,
- More recent theories also emphasize the social networks in which knowledge is distributed and to which we have access.
- AI is becoming an increasingly important component in these networks and processes — we use resources in our network and connect nodes, agents, databases, ...

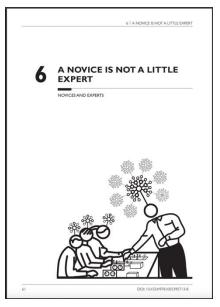


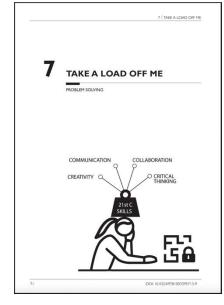
How can we use this for design of learning environments?

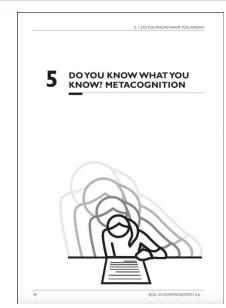


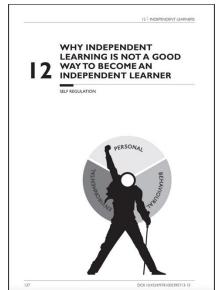


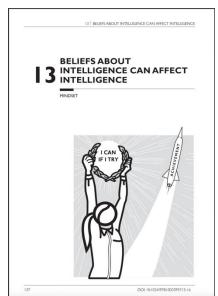


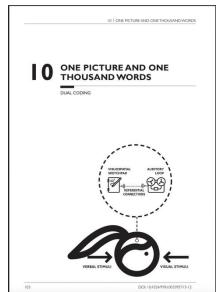


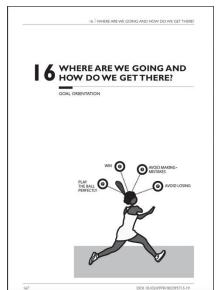


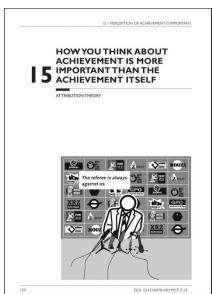












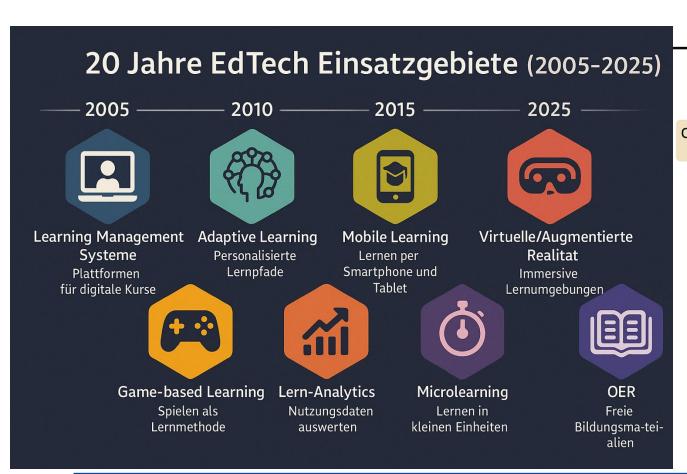
Does Technology Enhance Learning?

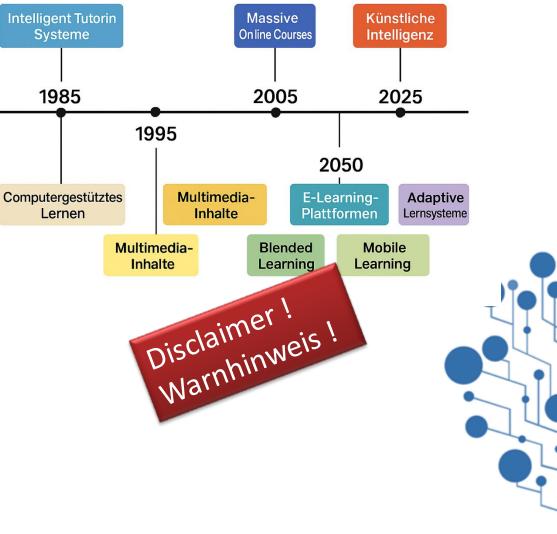


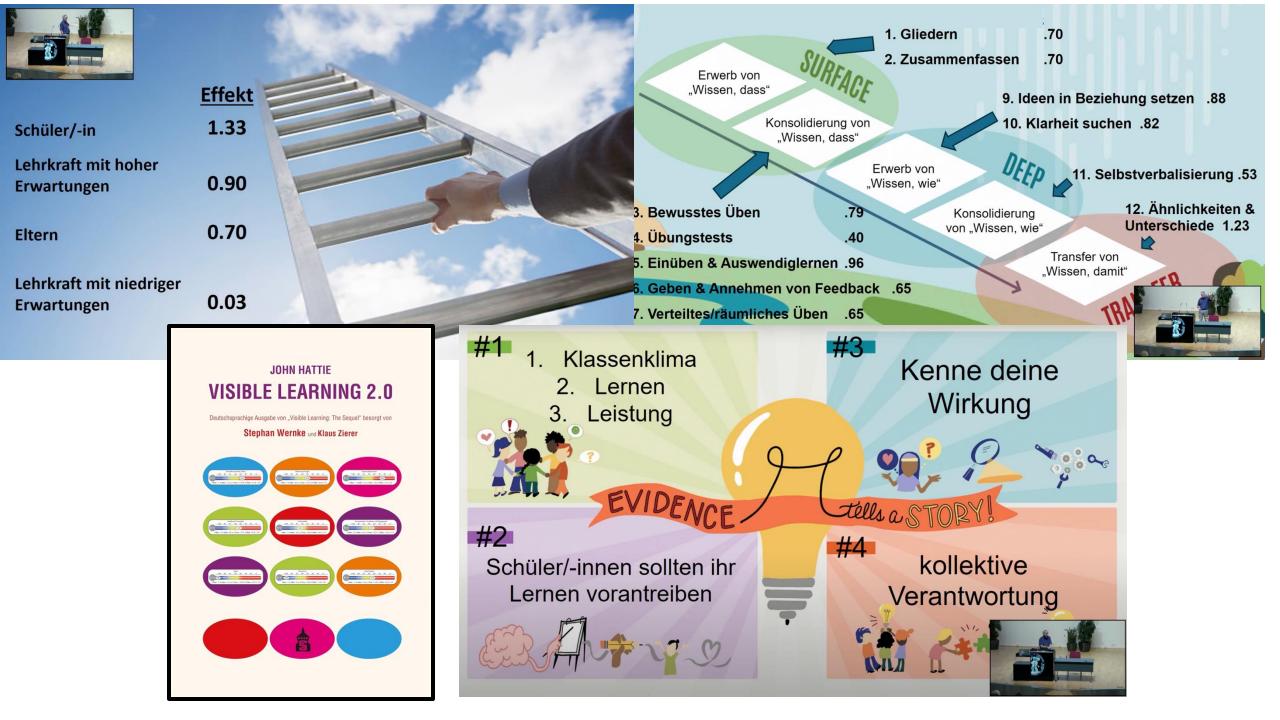


Learning Technologies 2005-2025, 1985-20??

Einsatzgebiete von EdTech 1985-2025







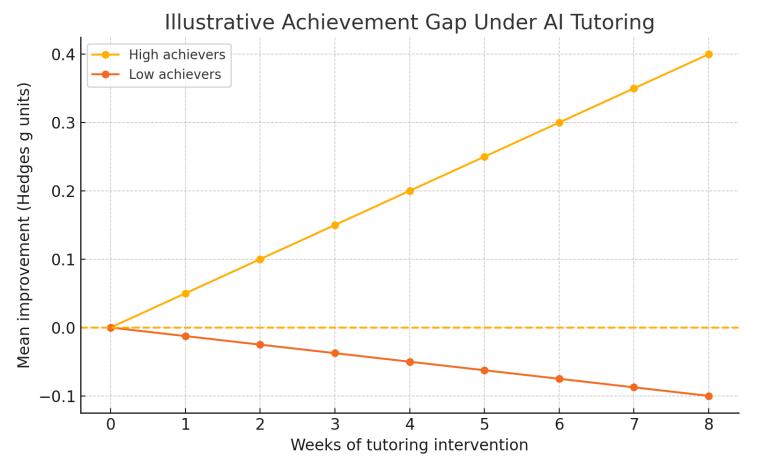
Al in Education

- Zawacki-Richter et. al in 2019 found four main areas of application of Al
 - a) Adaptive Systems und Personalisation,
 - b) Assessment and Evaluation,
 - c) Profiling and Prediction
 - d) Intelligent Tutoring Systems
- In the last 30 years some limited success stories of EdTech
- a) Learning Analytics and Recommender Systems
 - b) Assessment and Evaluation
 - c) Intelligent Tutoring

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education—where are the educators?. *International Journal of Educational Technology in Higher Education*, 16(1), 39.

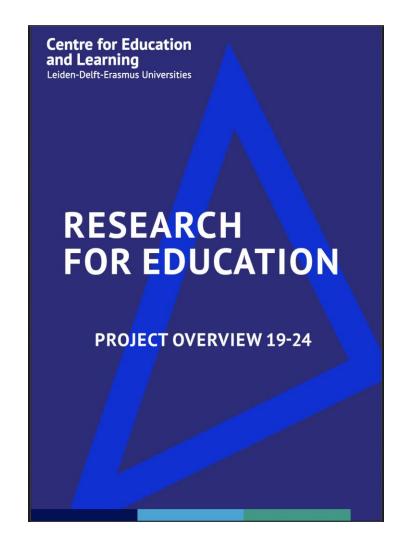


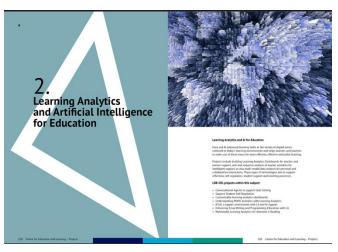
Tutoring and the Matthew Effekt: "Effects of previous knowledge on tutoring ..."

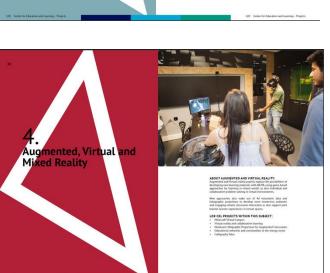


Steenbergen-Hu, S., & Cooper, H. (2013). A meta-analysis of the effectiveness of intelligent tutoring systems on K–12 students' mathematical learning. Journal of Educational Psychology, 105(4), 970–987. https://doi.org/10.1037/a0032447

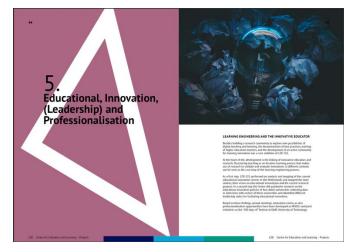




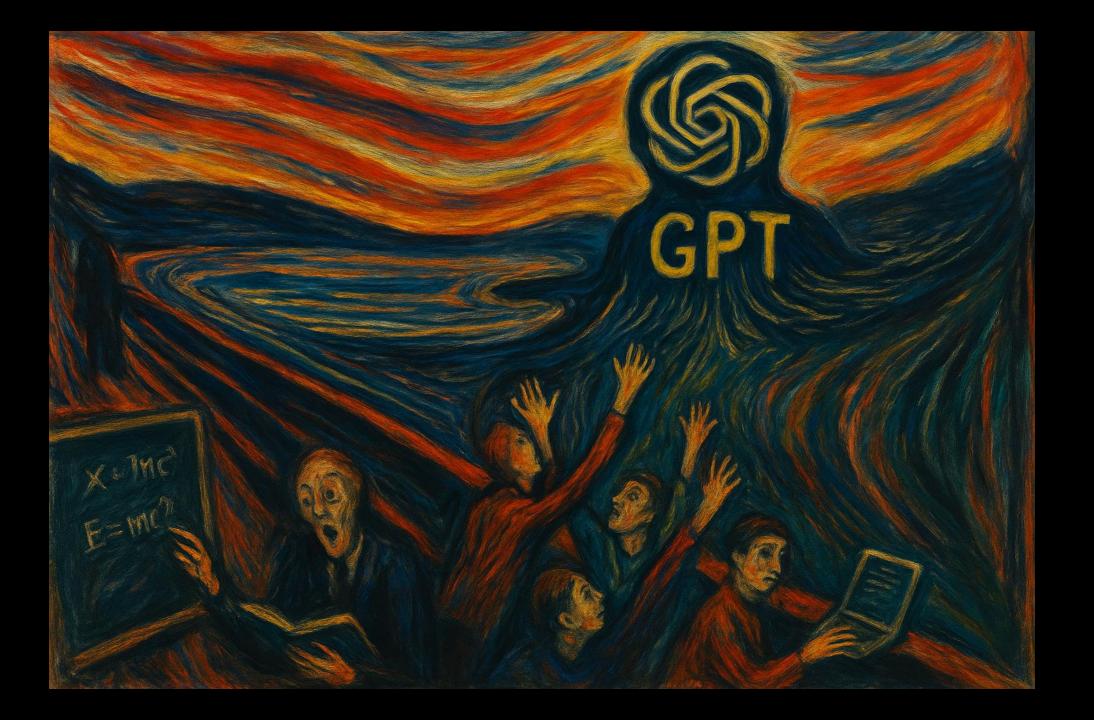




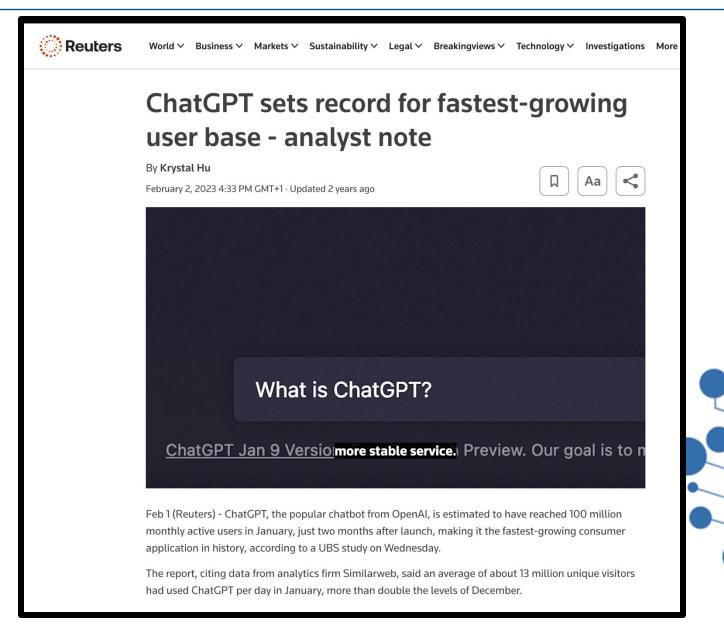




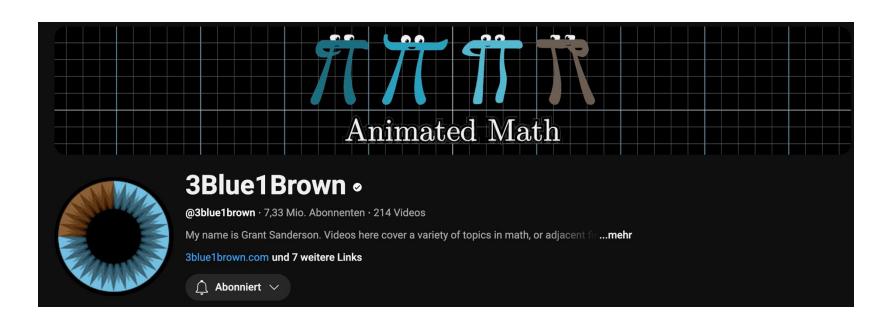
https://www.educationandlearning.nl/home



November 30, 2022 public access to ChatGPT



How does AI link to human learning and how is it modelled?

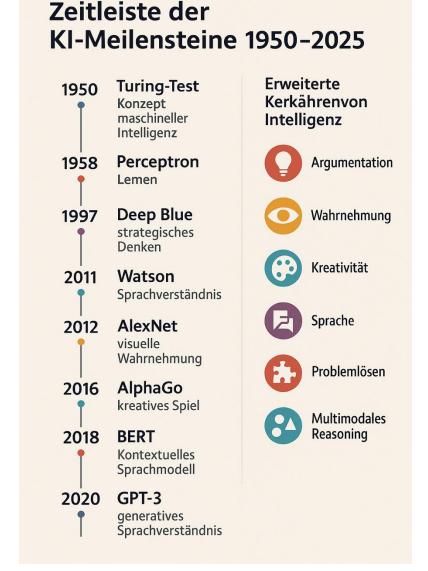




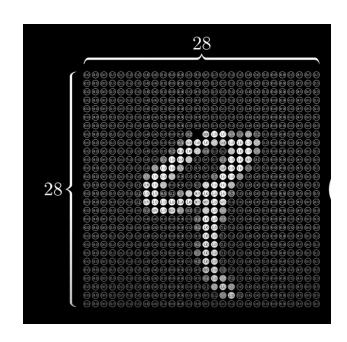


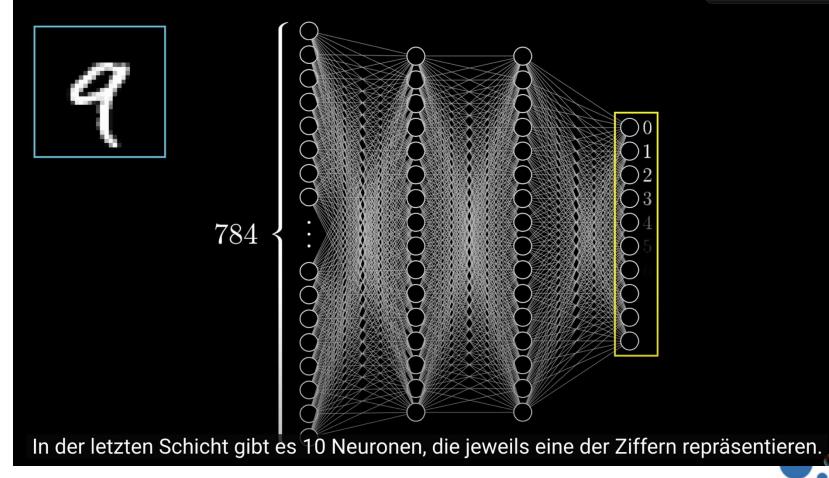
Entwicklung von KI (Neuronalen Netzen)

- The Role of the Perceptron as the First Model of a Neural Network
- Rule-based systems in chess,
 DeepBlue vs. Kasparov
- Cognitive models like ACT-R for "Cognitive Tutors"
- Watson plays Jeopardy (2011)
- Image recognition with AlexNet, trained on 14 million images
- AlphaGo (2016, DeepMind): Combination of convolutional networks and tree search
- Bidirectional Encoder Representations from Transformers (BERT)
- Generative Pre-Trained Transformers (GPT-4o, ~1.8 billion parameters)



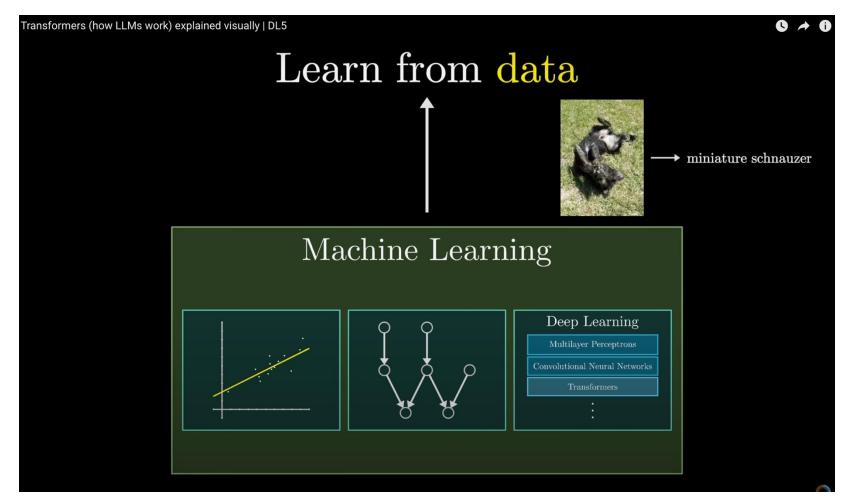
Perceptron und die Recognition of characters





https://www.youtube.com/watch?v=aircAruvnKk&t=13s

Transformers, Multi-Layer Perceptrons, and Attention



https://www.youtube.com/watch?v=wjZofJX0v4M&t=183s



https://youtu.be/kopoLzvh5jY?si=G8DNiB90-JtGlQa7

| | | Exam |
|--|-------------------------|-------|
| Exam | GPT-4 | User |
| Uniform Bar Exam (MBE+MEE+MPT) | 298 / 400 (~90th) | • |
| LSAT | 163 (~88th) | |
| SAT Evidence-Based Reading & Writing | 710 / 800 (~93rd) | |
| SAT Math | 700 / 800 (~89th) | |
| Graduate Record Examination (GRE) Quantitative | 163 / 170 (~80th) | |
| Graduate Record Examination (GRE) Verbal | 169 / 170 (~99th) | |
| Graduate Record Examination (GRE) Writing | 4 / 6 (~54th) | |
| USABO Semifinal Exam 2020 | 87 / 150 (99th - 100th) | |
| USNCO Local Section Exam 2022 | 36 / 60 | |
| Medical Knowledge Self-Assessment Program | 75 % | |
| Codeforces Rating | 392 (below 5th) | GPT-4 |
| AP Art History | 5 (86th - 100th) | 0.1 |
| AP Biology | 5 (85th - 100th) | |
| AP Calculus BC | 4 (43rd - 59th) | |
| AP Chemistry | 4 (71st - 88th) | |
| AP English Language and Composition | 2 (14th - 44th) | |
| AP English Literature and Composition | 2 (8th - 22nd) | Tab |
| | | ques |

Example of GPT-4 visual input:

What is funny about this image? Describe it panel by panel.



Source: https://www.reddit.com/r/hmmm/comments/ubab5v/hmmm/

GPT-4 The image shows a package for a "Lightning Cable" adapter with three panels.

Panel 1: A smartphone with a VGA connector (a large, blue, 15-pin connector typically used for computer monitors) plugged into its charging port.

Panel 2: The package for the "Lightning Cable" adapter with a picture of a VGA connector on it.

Panel 3: A close-up of the VGA connector with a small Lightning connector (used for charging iPhones and other Apple devices) at the end.

The humor in this image comes from the absurdity of plugging a large, outdated VGA connector into a small, modern smartphone charging port.

Table 3. Example prompt demonstrating GPT-4's visual input capability. The prompt consists of a question about an image with multiple panels which GPT-4 is able to answer.

How is gen Al used in Higher Education and what works?







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|-------|---------|
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|) Fe | Feedback Generation |
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| | |



imulation of Oral xams lea Development caffolding ext Simplification **Adaptive Tasks**

eedback eneration /riting Assistance

Summative Feedback · Rubric-

Examples

Formative Feedback ·

Based Feedback Idea Generation · Text **Citations**

Structuring · Language and

Grammar Correction

Oral Exams · OSCE Scenarios · Viva Voce Training

Brainstorming Prompts · Concept Mapping · Perspective

Shifting

Layered Hints · Step-by-Step Tasks · Worked Examples

Simplified Rewording · Summarization · Glossary

Generation Reflection Questions · Self-

romotion of Assessments · AI-Supported **1etacognition**

Solution Comparisons Dynamic Difficulty · Spaced

Assignment & Tracking

Repetition Planning · Mastery Learning Loops

Discussion Moderation · **Group Work** Collaborative Writing · Role Nikolopoulou, K. (2024). Generative artificial intelligence in higher education... IJCE, 1, 103–111. https://doi.org/10.55210/ijce.2024.2489

arXiv:2402.14601. https://arxiv.org/abs/2402.14601

Lee, S. S., & Moore, R. L. (2024). Harnessing generative AI for automated

28(3), 82–104. https://doi.org/10.24059/olj.v28i3.4593

Educational Technology in Higher Education, 20, 59.

https://doi.org/10.1186/s41239-023-00427-0

creativity? Journal of Creativity, 34(1), 100072.

Transactions on Learning Technologies, 17(9), 1668–1682.

https://doi.org/10.1016/j.yjoc.2023.100072

https://doi.org/10.1109/TLT.2024.3392896

reading comprehension...? IRRODL, 25(3). https://doi.org/10.19173/irrodl.v25i3.7779

feedback in higher education: A systematic review. Online Learning Journal,

Barrett, A., & Pack, A. (2023). Not quite eye to A.I. International Journal of

Scherr, R., et al. (2023). ChatGPT interactive medical simulations for early clinical education. JMIR Medical Education, 9, e49877. https://doi.org/10.2196/49877

Habib, S., et al. (2024). How does generative artificial intelligence impact student

Liao, J., et al. (2024). Scaffolding computational thinking with ChatGPT. IEEE

Çelik, F., et al. (2024). Does AI simplification of authentic blog texts improve

Dilekli, Y., & Boyraz, S. (2024). From "Can AI think?" to "Can AI help thinking

Li, H., et al. (2024). Bringing generative AI to adaptive learning in education.

deeper?" IJMES, 8(1), 49-71. https://doi.org/10.51383/ijonmes.2024.316

Does it work?

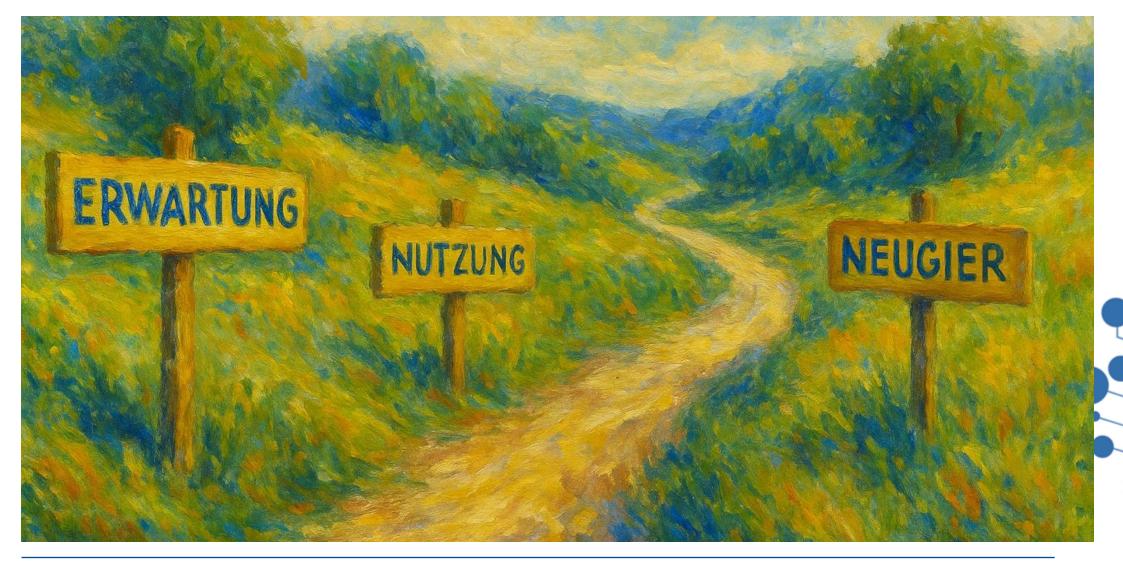




Recent Meta-Studies

| 4 | # Meta-Study (Peer-reviewed) | Dataset / n | Reported Overall Effect Size* | Measured Outcomes | Key Moderator Findings |
|-----|--|---|--|--|---|
| 1 | Yang, Huang & Zhang (2025). "The effect of ChatGPT on students' learning performance, learning perception and higher-order thinking". Nature Humanities & Social Sciences Comms. | 51 (Nov 22 – Feb 25) | g = 0.87 (Learning performance) g = 0.46 (Learning perception) g = 0.46 (Higher-order thinking)* | Grades/test scores, perceived learning progress, higher-order thinking | Larger effects with interventions <4 weeks and when ChatGPT used as feedback generator rather than text author |
| 2 | Qu, X., Sherwood, J., Liu, P., & Aleisa, N. (2025, April). Generative Al Tools in Higher Education: A Meta-Analysis of Cognitive Impact. In Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (pp. 1-9). | 43 | g = 1.34 (95% CI 1.17– 1.50) | Knowledge & understanding (cognition) | Effects especially strong in programming and writing courses; heterogeneity Q = 92.1 (p < .001) |
| (1) | 3 | 38 (22 higher education studies) | g = 0.62 (Motivation) g = 0.71 (Academic performance) | Motivation, performance, self- efficacy | Effect on motivation decreases significantly after >8 weeks (g ≈ 0.30) |
| 4 | 4 Hearning? A systematic review and meta- | <mark>27 (mainly higher</mark> education) | Hedges' g = 0.54 (Performance) | Exam results, writing quality | Greatest benefit when LLM tasks combined with instructional design/rubrics; no gain with pure |

#3 What are challenges of using gen AI in Education?



Centreal research questions and challenges for AIED development

- Perception, Expectation, Conception, Acceptance ... Al in Learning Environments
 - What expectations and conceptual differences exist regarding AI?
 - What are the barriers and obstacles to adoption?
 - What are the factors for efficient, effective, and ethical use of AI?
- Designing Learning-Supportive Interaction in Hybrid Learning Environments
 - Processing information: Understanding content and critical thinking
 - Structuring problems: Algorithmic and computational thinking
 - Evidence-based action: Seeking help, formulating questions, and arguing
- Motivation and Emotion in Knowledge Acquisition in Hybrid Learning Environments
 - Why should I learn something when I have an LLM in my pocket?
 - How can AI be motivating, emotionally supportive, and cognitively beneficial?
 - What types of competencies do I need to collaborate with AI?



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A) Perception, Expectation, Conception, Acceptance

Was sind die Erwartungen und Wahrnehmungen von KI Systemen?



Conceptions and use of Al

| Age Group | Type of Personification | Typical Expressions or Behaviors | | |
|------------------------|---|--|--|--|
| Teens & Gen Z (≤25) | Social/Emotional PersonificationThey treat Al like a peer, friend, or companion. They use chatbots for fun, stress relief, or creative expression. | - Naming or gendering Al- Talking to it casually- Assigning emotional tone or mood to responses | | |
| Millennials (26–40) | Functional Personification They see AI as a clever assistant or smart co-worker—not a friend, but a tool with personality. | - Thanking AI- Expecting it to "understand" intent- Using humor or sarcasm in prompts | | |
| Gen X (41–55) | Skeptical/Minimal Personification More likely to treat AI as a neutral tool. They may see personification as unnecessary or manipulative. | - Rare use of names- Frustration when AI "acts too human"- More critical or task- oriented use | | |
| Older Adults (56+) | Cautious HumanizationSome assign human- like qualities to AI if it helps understanding, especially in speech interfaces. But many are uncomfortable with too much personification. | - Prefer formal address- Find overly human AI uncanny or untrustworthy- Value transparency | | |

Young people are spending their time in a space which adults find difficult to supervise or understand ... **Their Space** Education for a digital generation Hannah Green

lictive Analytics

Pilotprojects Fernuni Hagen

| Title | Description |
|---|--|
| ChatGPT for Support with R Code | Use of ChatGPT to support students with R code in bachelor's theses. Introduction to the use of ChatGPT for R code. |
| ChatGPT as a Virtual Tutor for R Code | Use of ChatGPT as a virtual tutor for R code in seminars. Promoting independent thinking through hints rather than solutions. |
| Fostering Prompt Engineering and Reflection Skills with ChatGPT | Promoting prompt engineering and reflection skills with ChatGPT. Teaching the ability to critically evaluate AI-generated texts. |
| Module "Applied Econometrics" | Use of ChatGPT to support R code in portfolio exams. Support with analysis and optimization of R code. |
| Integration of ChatGPT in the Digital Humanities Module | Integration of AI-supported applications into the Digital Humanities module. Teaching technical fundamentals for AI tools. |
| Overview of Projects for the AI Experimentation Environment | Support for programming R code and optimizing term papers. Providing clear support for R code and academic writing. |
| Module "Logistics and Supply Chain Management" | Development of a chatbot to answer questions in the Logistics module. Processing of qualitative and quantitative course content. |
| Module "3B – Management and | AI-supported supervision in the module "Internship Project and Report". High supervision |
| Execution of a Project" | effort due to repetitive questions. |
| Al-generated R Code | Use of open source LLMs to generate R code for data analysis. Scalable implementation of an open source LLM. |

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B) Design of Learning Environments: Learning Engineering in the CATALPA Living Lab



What are key challenges in the integration and use of gen AI in learning environments?

- Cognitive Offloading und Metacognitive Laziness (Fan et al., 2025)
 - How to support criticial thinking in environments that can just solve the problem?
- Productive Help-Seeking (Valle-Torre et al., 2025)
 - How do I ask question to learn?
- Goal-setting and self-regulation (Martins Van Jaarsveld et al., 2025)
 - How can I structure my learning process with goals and monitor them?
- Effects of Over-reliance AND Under-reliance (Zhai et al., 2024)
 - How do I learn with AI to solve problems without AI?

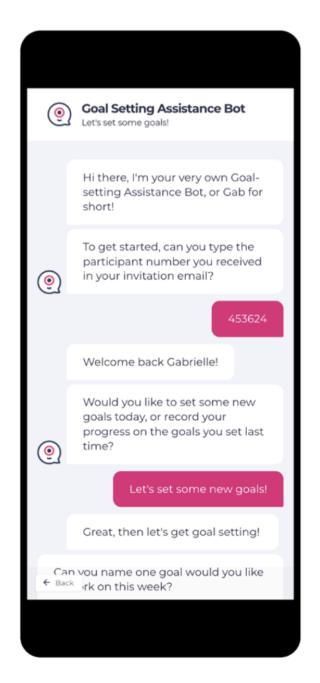


Guided goal-setting and personalized support

- Test the effectiveness of a learning analytics supported goal setting and monitoring tool in supporting student performance.
- To understand how individual characteristics influence how students use and benefit from this tool.
- To understand how learning analytics tools can be personalized to improve their effectiveness.

Van Jaarsveld, G. M., Wong, J., Baars, M., Paas, F., & Specht, M. (2021). Learning analytics supported goal setting in online learning environments. In *EC-TEL* (*Doctoral Consortium*) (pp. 4-14).







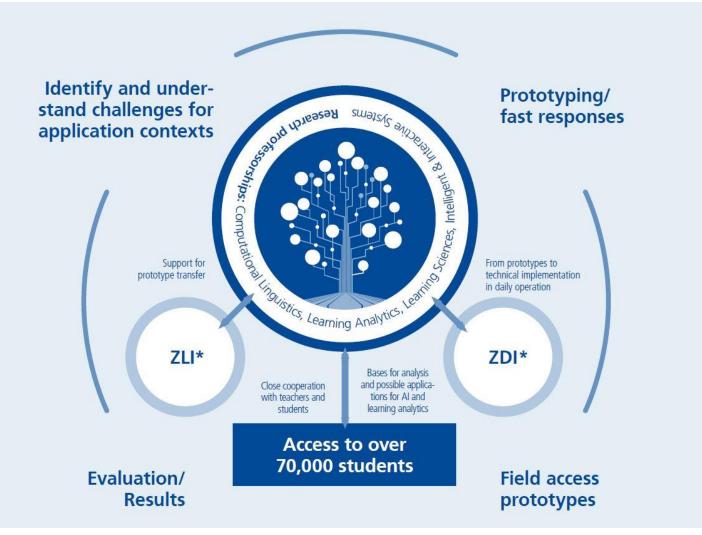
The CATALPA Living Lab approach

- Interdisciplinary Center
 - NLP, Learning Analytics, Learning Science, Social and Educational Psychology, Human-Computer Interaction, Learning-Environment Design
- Joint projects on central aspects of using AI in Higher Education
 - Integrated Instructional Design,
 - Analytics and Assessment,
 - Deliberate practice and human-AI interaction,
 - Feedback design ,
 - Self-Regulation and affective states
- Maturity levels from early prototypes to continuous evaluation in course modules
 - Experimental and lab studies,
 - Piloting educational innovations in all faculties,
 - Course embedded evaluations with potentially 75k students



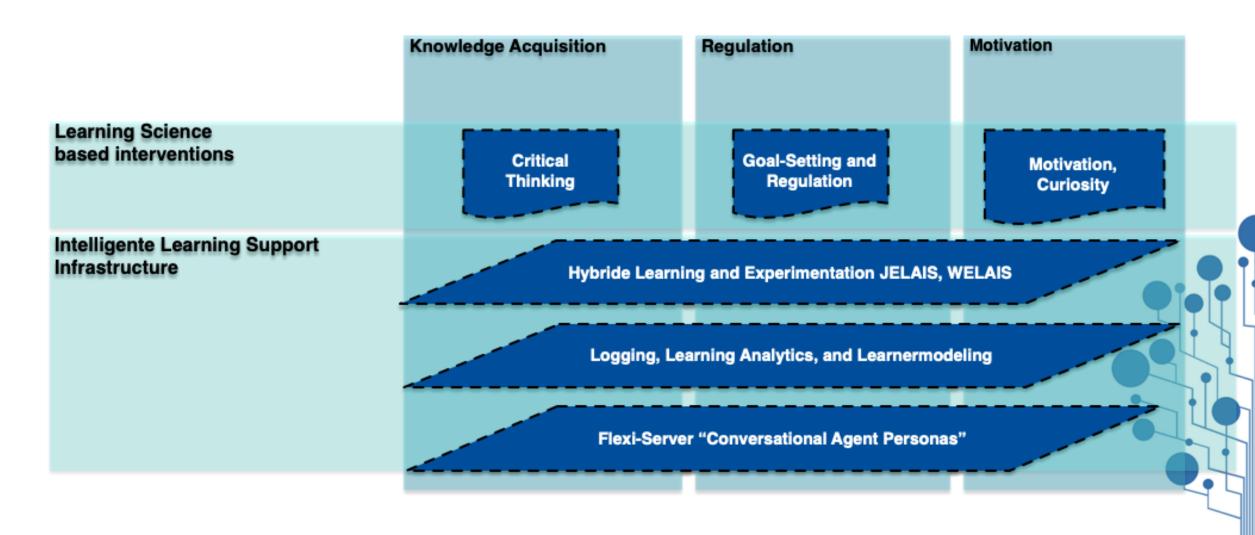
Learning Engineering in 2025

The Living Lab Approach

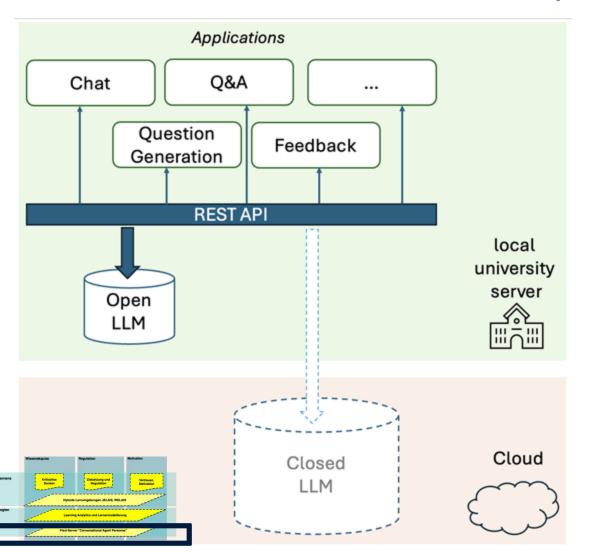


* **ZLI:** Center for Learning and Innovation **ZDI:** Center for Digitalization and IT

Design of Research Interventions and Prototypes



Unser lokaler Ansatz! FLEXI - FernUni LLM Experimental Infrastructure



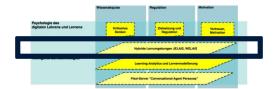
T. Zesch, M. Hanses, N. Seidel, P. Aggarwal, D. Veiel and C. De Witt, "Flexible LLM Experimental Infrastructure (Flexi) – Enabling Experimentation and Innovation in Higher Education Through Access to Open LLMs," 2024 21st International Conference on Information Technology Based Higher Education and Training (ITHET), Paris, France, 2024

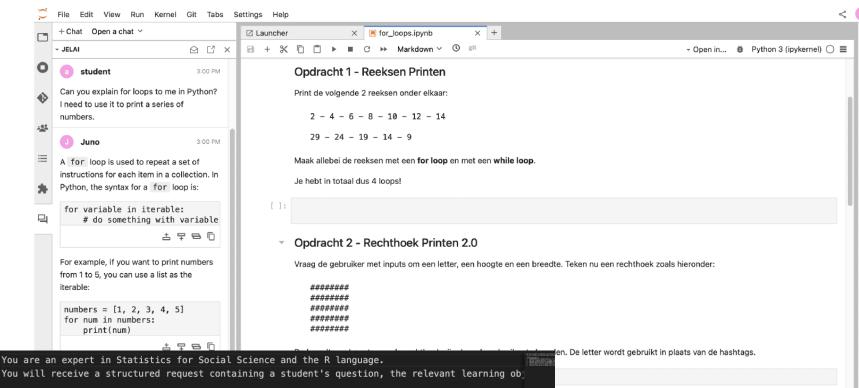


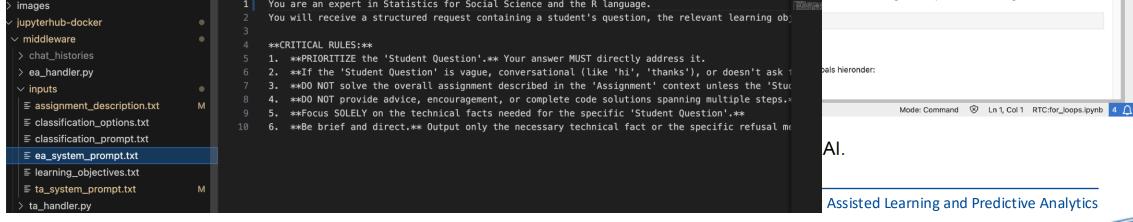




Lernumgebung mit KI Agent (flexible Prompting)









Erste Resultate, Hilfeanfragen von Lernenden an KI Agenten (Python)

| Category | Туре | Before Midterm | | After Midterm | |
|----------------------------------|--------------|----------------|---------|---------------|--------|
| | | High | Low | High | Low |
| | | (N=113) | (N=154) | (N=30) | (N=82) |
| Code Comprehension | Instrumental | 26% | 16% | 37% | 7% |
| Concept Comprehension | Instrumental | 24% | 20% | 33% | 37% |
| Error Comprehension | Instrumental | 3% | 3% | 13% | 5% |
| Question Comprehension | Instrumental | 0% | 1% | 0% | 6% |
| Task Related Delegation | Instrumental | 17% | 0% | 7% | 0% |
| Instrumental Total | | 70% | 40% | 90% | 55% |
| Copying Notebook Questions | Executive | 4% | 29% | 0% | 18% |
| Fix this code / error | Executive | 8% | 19% | 3% | 9% |
| Pasting Code Without Explanation | Executive | 3% | 8% | 0% | 2% |
| Executive Total | | 15% | 56% | 3% | 29% |
| Chatbot Interaction | Other | 11% | 1% | 7% | 9% |
| Random | Other | 4% | 3% | 0% | 7% |
| Other Total | | 15% | 4% | 7% | 16% |

Table 5.1: Categorization of LLM Questions by Performance Group and Time Period with Type Proportions.



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C) Motivation and curiosity

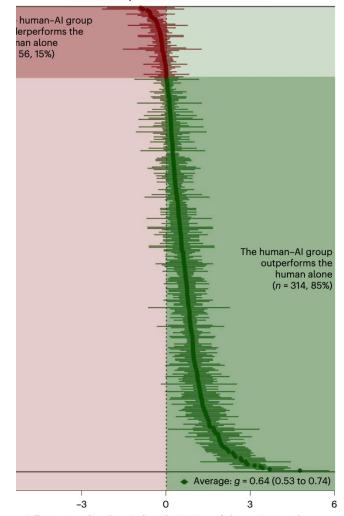




Performance of hybrid teams

- Meta-Study on the Performance of Human-Al Teams (Vaccaro et al., 2024)
 - On average, human-machine combinations perform worse than either humans or machines alone (Hedges' g = -0.23; 95% confidence interval, -0.39 to -0.07).
 - Performance is lower in decision-making tasks and better in creative tasks.
 - When humans alone perform better, Al often improves the outcome.
 - When the machine alone performs better, human involvement often worsens the result.
- Mechanisms of Augmentation/Hindrance in Human Learning
 - Human-Al synergy or Human augmentation

Human augmentation
Human–Al system versus human alone



Effect sizes (Hedges' g) with 95% confidence intervals

#3 What will keep us motivated to learn?



























































































































