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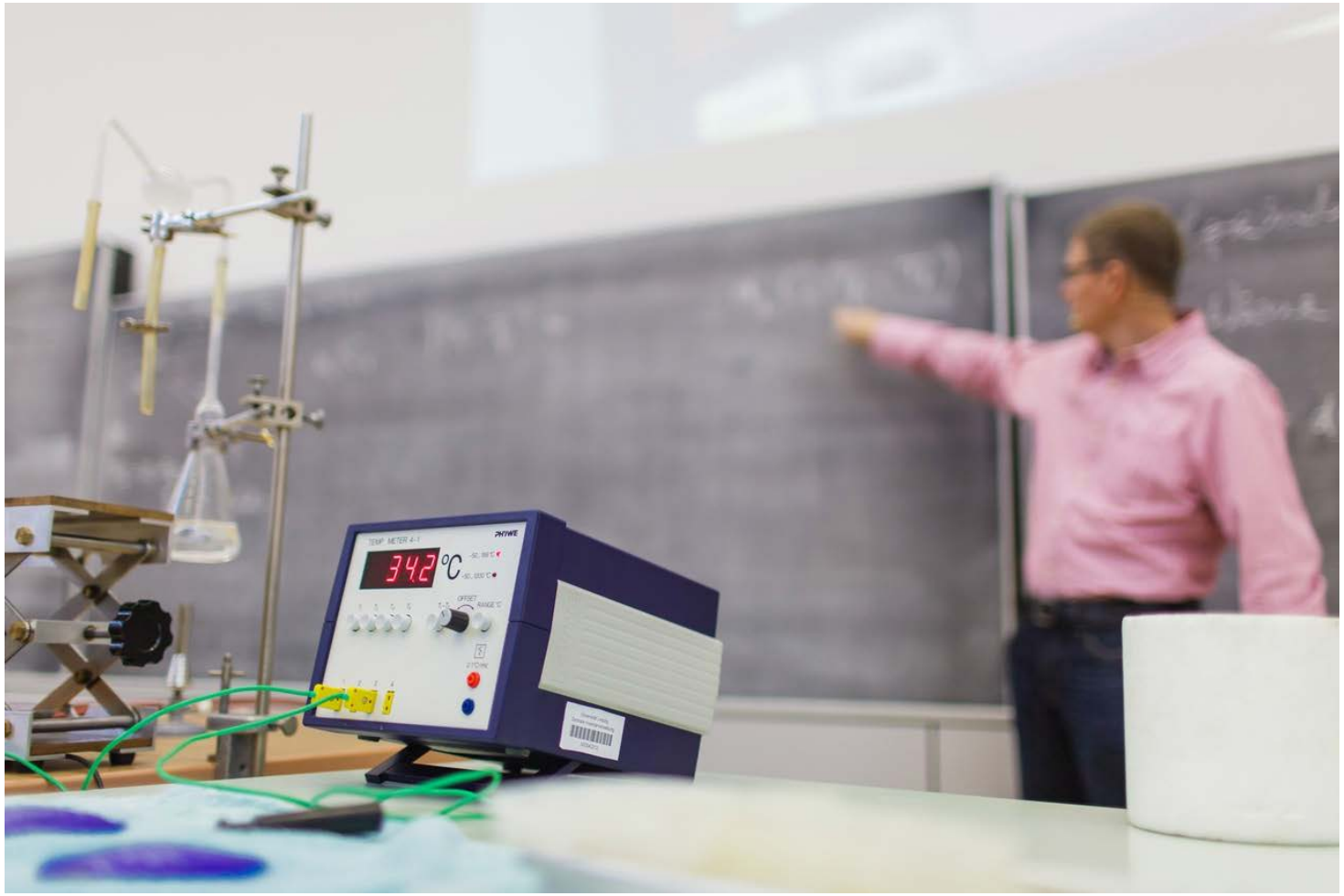
How to Unfold the Potential of Multiple Representations

Sarah Malone & Roland Brünken

Multiple external representations in STEM education



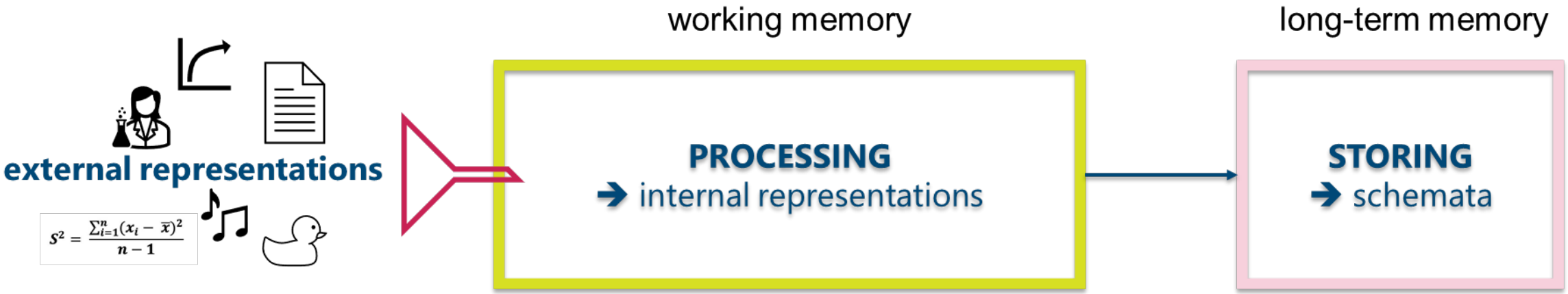
Why?

- „at the core of understanding“ in STEM subjects (e.g., Duval, 1999)
- tools for building sound conceptual knowledge (Stylianou, 2020) that can be used flexibly to solve (real-world) problems (Star & Rittle-Johnson, 2008)
- foster learning and problem solving compared to single representations (e.g., Rau, Aleven & Rummel, 2009; Hu, L., Chen, G., Li, P., & Huang, J.; 2019)

But..

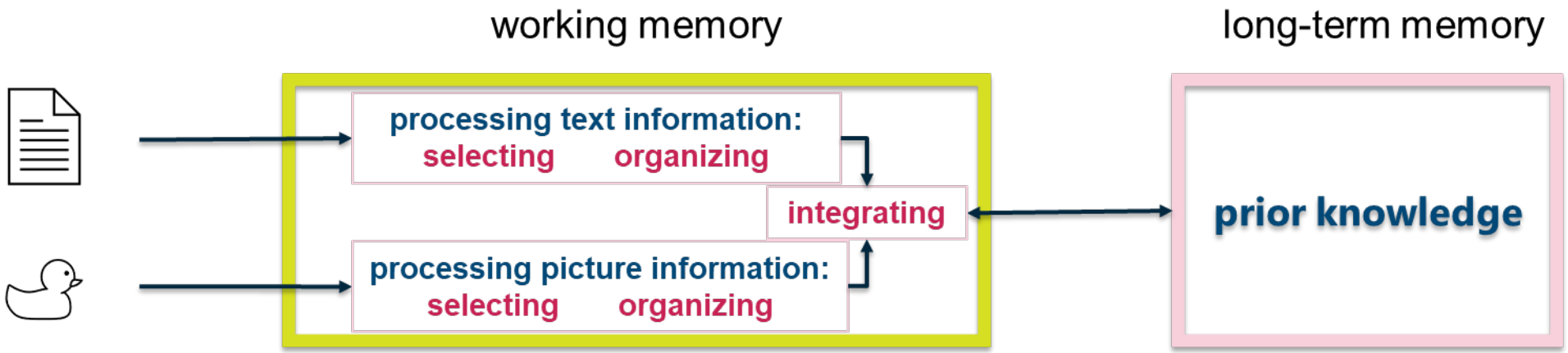
- each type presents specific disciplinary challenges (Fredlund et al., 2014), and relating multiple representations can be difficult for students (e.g., van der Meij & de Jong, 2006)
- presented or assembled inappropriately, they produce extraneous cognitive load and hinder learning (e.g., “redundancy effect”, Sweller, 2005)

Information processing



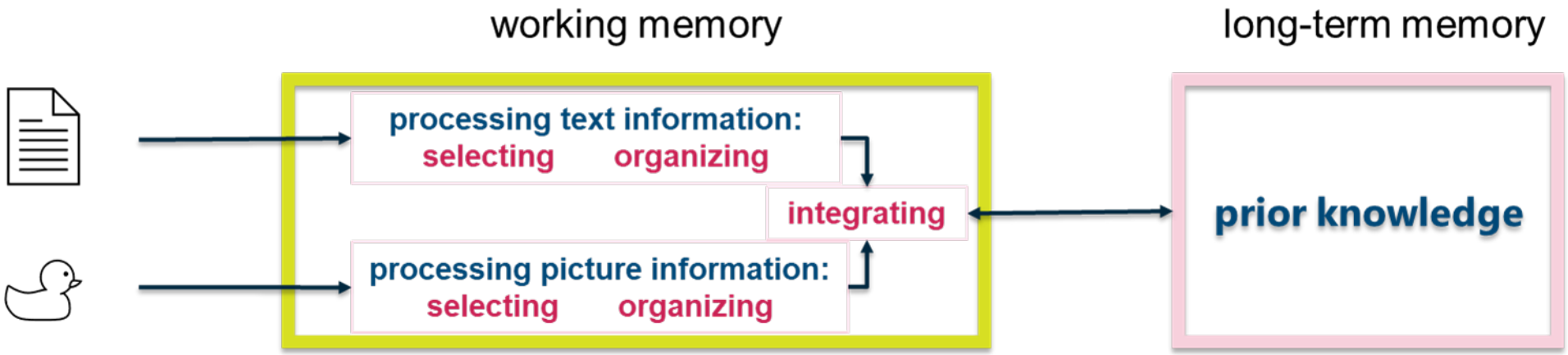
Atkinson & Shifrin, 1968; Mayer, 2001

Information processing



Mayer, 2001; Paivio, 1986; Schnotz & Bannert, 2003

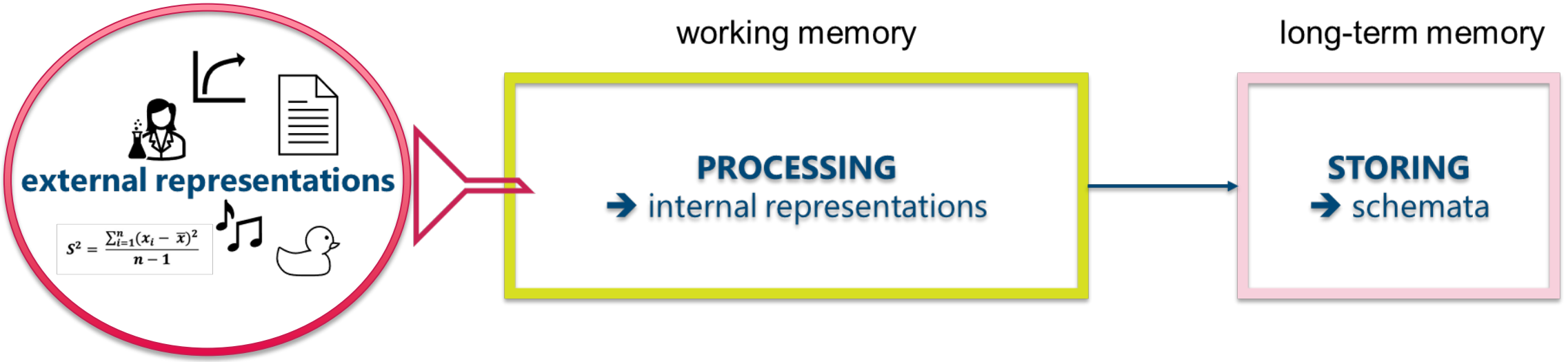
Information processing



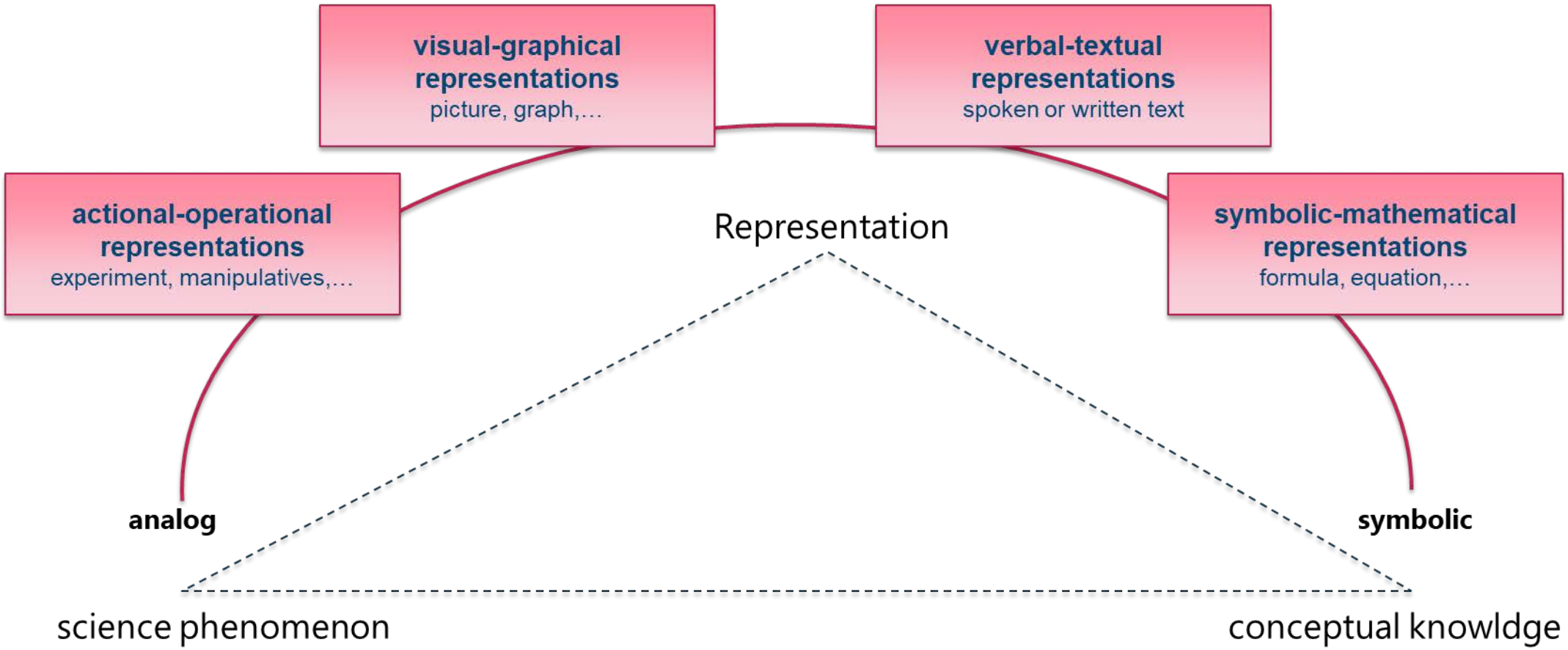
DUAL CODING!
MULTIMEDIA EFFECT!

Mayer, 2001; Paivio, 1986; Schnotz & Bannert, 2003

Information processing

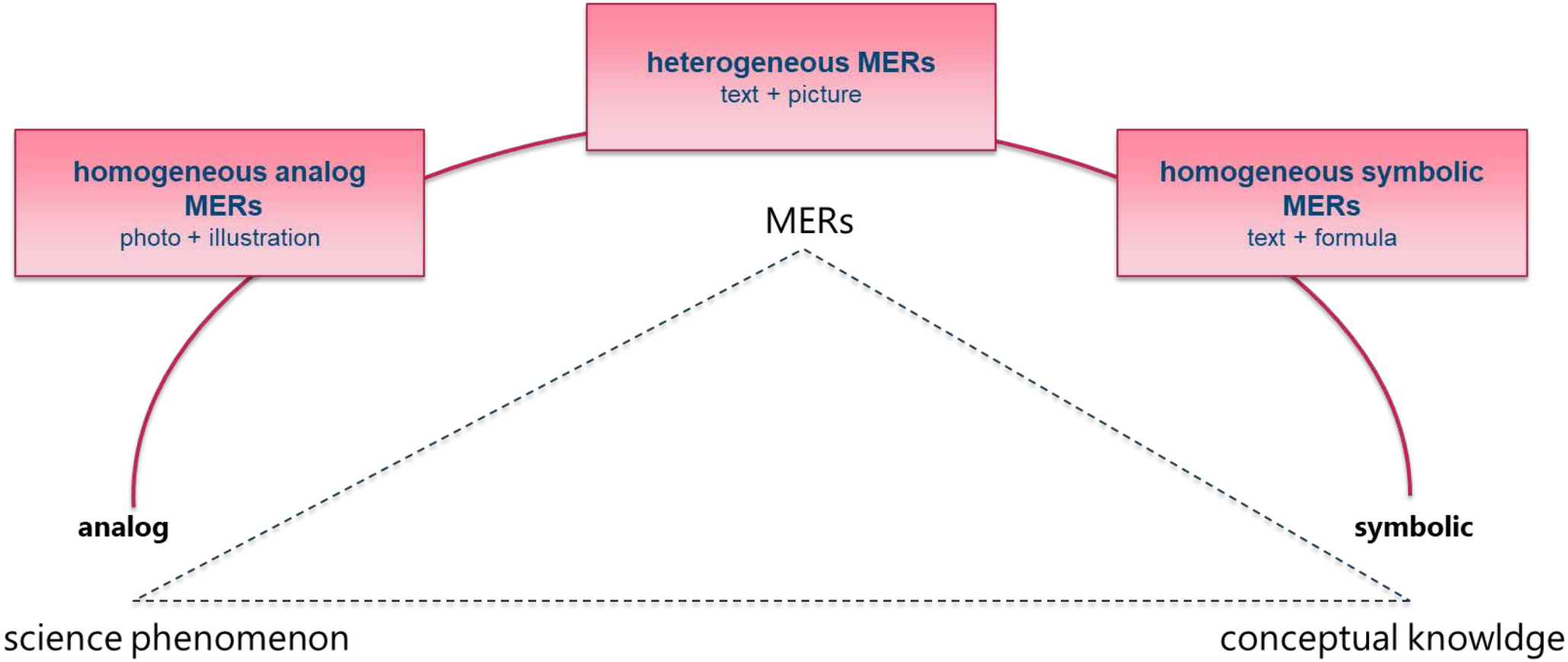


More types of representations



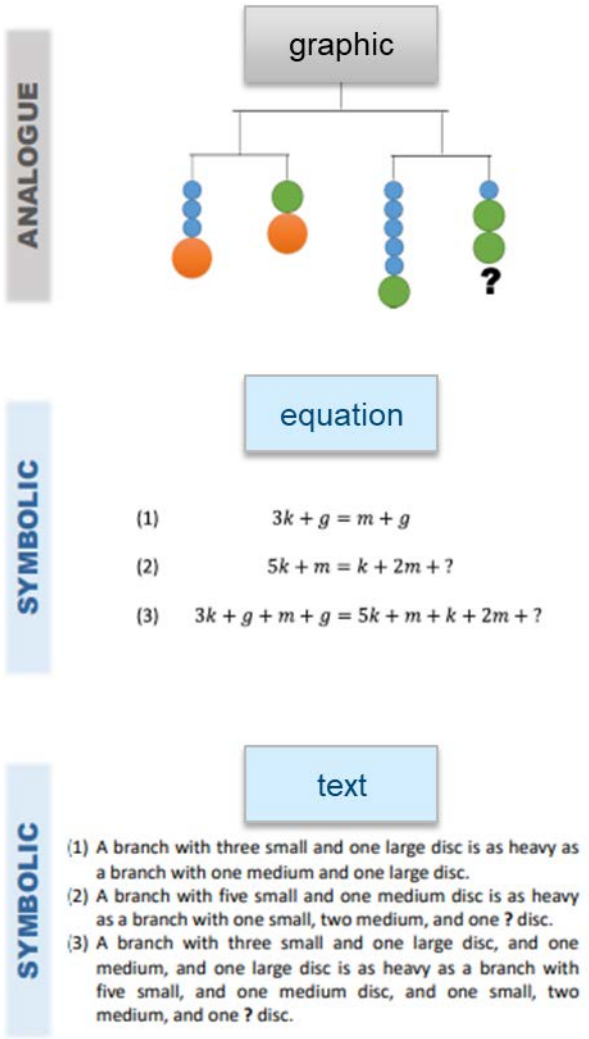
e.g., Wu & Puntambekar, 2012

More types of *multiple* representations



Malone et al. 2020; Ott et al., 2018

First insights



Performance

- Homogeneous symbolic/heterogeneous MERs > single representations
- homogeneous symbolic MERs = heterogeneous MERs

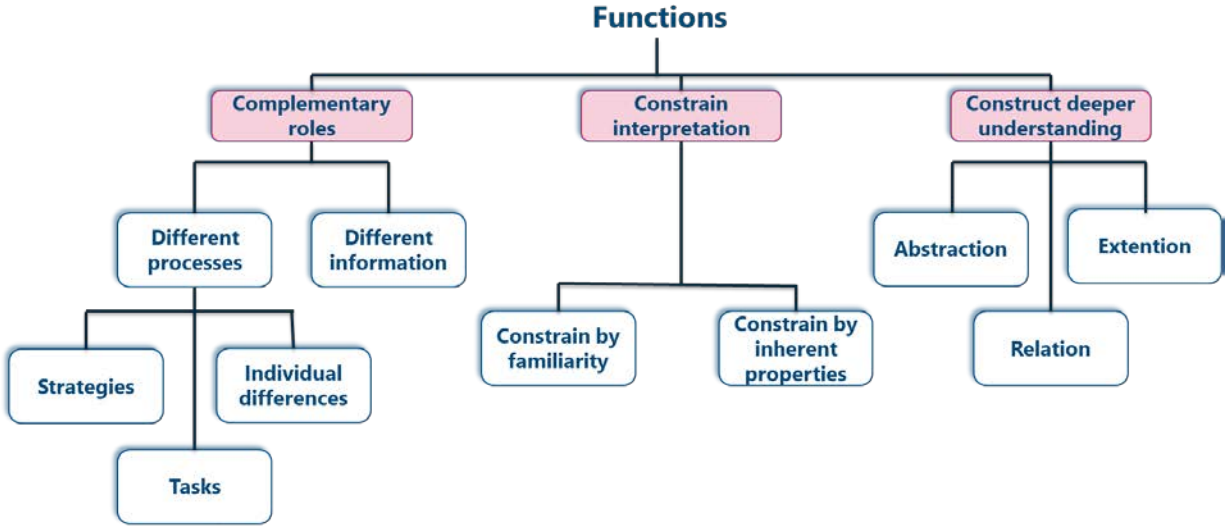
Processing

- more cross-representational gaze switches with heterogeneous MERs
- more cross-representational integration with heterogeneous MERs according to verbal reports

Malone et al., 2020; Ott et al., 2018

DeFT-Framework

- **De**sign aspects (types of representations, modality, sequencing,…)
- **F**unctions



- **T**asks (understand, interpret, select, construct,…) ➔ use their representational competence

Ainsworth, 1999; 2006

DeFT-Framework

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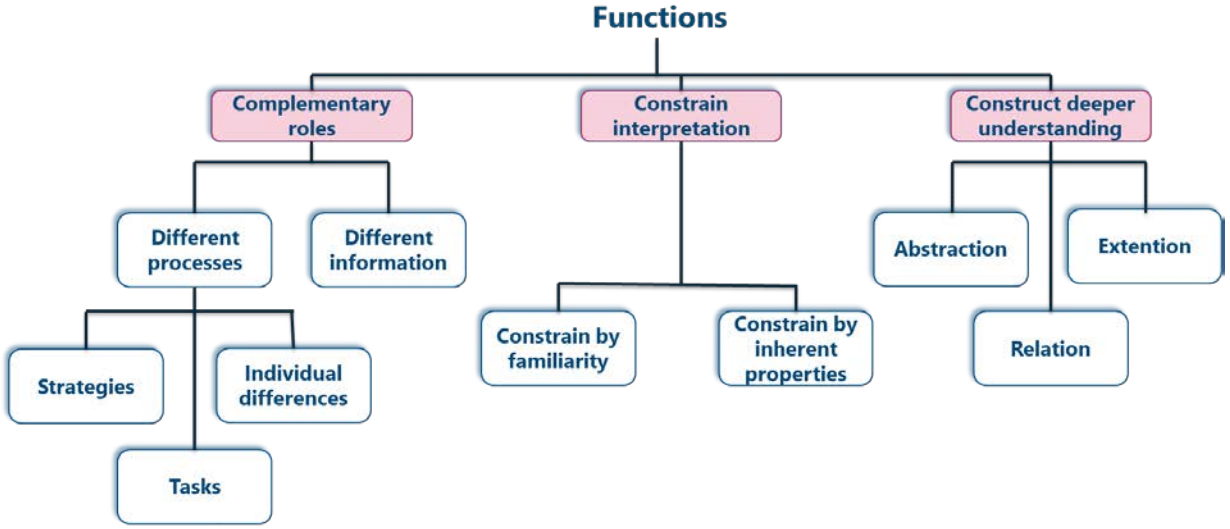

- **T**asks (understand, interpret, select, construct,…) ➔ use their representational competence
- **OUTCOMES? PRINCIPLES?**

Ainsworth, 1999; 2006

Cognitive Load in learning with multiple representations

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cognitive load type	refers to...	reduced learning if...	examples	instructional measures
Intrisic Cognitive Load	task difficulty	element interactivity too high	• complex representations • many representations to be integrated	• segmenting materials • sequencing representations
	prior knowledge	prior knowlegde too low	• representational competencies too low: *representation dilemma*	• pre-train representational competence
Extraneous Cognitive Load	design of materials	unnecessary (incidental) processing activities	• related representations in spatial distance • seductive details	• merging multiple representations via AR • identify and remove unnecessary/distracting representations
Germane Cognitive Load	resources devoted to: • essential processing • schema acquisition • automation	learners do not engage in active processing	• no support for cross-representational integration • selection of representations does not appear to be challenging ==> need for desirable difficulties	• prompting representational activities • pre-train self-regulated learning • adaptive/adaptable learning programs

Altmeyer et al. 2020; Malone et al. 2021; Mayer, 2009; Rau, 2017; Sundararajan & Adesope, 2020; Sweller et al., 1998

Conclusions

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theory

- extend theoretical models towards representational systems beyond text + picture

future research

- systematically investigate different kinds of representational systems
- use non-intrusive methods (e.g., eye tracking, smart pens) as process measures

practice

- consider all factors that may influence learning with multiple representations
- adapt systems to different levels of representational competence

References

Ainsworth, S. (1999). The functions of multiple representations. *Computers & Education, 33*(2), 131-152. doi: https://doi.org/10.1016/S0360-1315(99)00029-9

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16*(3), 183-198. doi: https://doi.org/10.1016/j.learninstruc.2006.03.001

Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., & Brünken, R. (2020). The use of augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses—Theoretical background and empirical results. *British Journal of Educational Technology, 51*, 611-628. doi: 10.1111/bjet.12900

Atkinson, R. C., & Shiffrin, R. M. (1969). Storage and retrieval processes in short-term memory. *Psychological Review*, 76, 179-193.

Duval, R. (2006). A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics, 61*(1), 103-131. doi: 10.1007/s10649-006-0400-z

Fredlund, T., Linder, C., Airey, J., & Linder, A. (2014). Unpacking physics representations: Towards an appreciation of disciplinary affordance. Physical Review Special Topics - Physics Education Research, 10(2), 020129. doi: 10.1103/PhysRevSTPER.10.020129

Hu, L., Chen, G., Li, P., & Huang, J. (2019). Multimedia Effect in Problem Solving: a Meta-analysis. *Educational Psychology Review*. doi: 10.1007/s10648-019-09490-4

Malone, S., Edelsbrunner, P., Lichtenberger, A., Küchemann, S., Kuhn, J., Vaterlaus, A., . . . Brünken, R. (2021). *The relation of representational competence and conceptual knowledge about electromagnetism*. Paper presented at the EARLI, virtual.

Malone, S., Altmeyer, K., Vogel, M., & Brünken, R. (2020). Homogeneous and heterogeneous multiple representations in equation-solving problems: An eye-tracking study. *Journal of Computer Assisted Learning, 36*(6), 781-798. doi: https://doi.org/10.1111/jcal.12426

Mayer, R. E. (2001). Multimedia Learning. Cambridge, UK: Cambridge University Press.

Mayer, R. (2009). Spatial Contiguity Principle. In *Multimedia Learning* (pp. 135-152). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511811678.010

Ott, N., Brünken, R., Vogel, M., & Malone, S. (2018). Multiple symbolic representations: The combination of formula and text supports problem solving in the mathematical field of propositional logic. *Learning and Instruction, 58*(C), 88-105. https://doi.org/10.1016/j.learninstruc.2018.04.010

Paivio, A. (1986*). Mental Representations: A Dual Coding Approach.* New York: Oxford University Press.

References

Rau, M.A. (2017).Conditions for the Effectiveness of Multiple Visual Representations in Enhancing STEM Learning. *Educ Psychol Rev* 29, 717–761. https://doi.org/10.1007/s10648-016-9365-3

Rau, M., Aleven, V., & Rummel, N. (2009). Intelligent Tutoring Systems with Multiple Representations and Self-Explanation Prompts Support Learning of Fractions. *Proceedings of the 14th International Conference on Artificial Intelligence in Education, AIED,* Brighton, UK.

Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representation. *Learning and Instruction, 13*(2), 141-156. doi: https://doi.org/10.1016/S0959-4752(02)00017-8

Star, J. R., & Rittle-Johnson, B. (2008). Flexibility in problem solving: The case of equation solving. *Learning and Instruction, 18*(6), 565-579. doi: https://doi.org/10.1016/j.learninstruc.2007.09.018

Stylianou, D. A. (2020). Problem solving in mathematics with multiple representations. In P. Van Meter, A. List, D. Lombardi & P. Kendeou (Eds.), *Handbook of learning with multiple representations and perspectives*. New York: Routledge.

Sundararajan, N., Adesope, O. (2020). Keep it Coherent: A Meta-Analysis of the Seductive Details Effect. *Educ Psychol Rev* 32, 707–734. https://doi.org/10.1007/s10648-020-09522-4

Sweller, J. (2005). The Redundancy Principle in Multimedia Learning. In R. Mayer (Ed.), The Cambridge Handbook of Multimedia Learning (pp. 159-167).

Sweller, J., van Merrienboer, J.J.G. & Paas, F.G.W.C. (1998). Cognitive Architecture and Instructional Design. Educational Psychology Review 10, 251–296. https://doi.org/10.1023/A:1022193728205

van der Meij, J., & de Jong, T. (2006). Supporting students' learning with multiple representations in a dynamic simulation-based learning environment. Learning and Instruction, 16(3), 199-212. https://doi.org/10.1016/j.learninstruc.2006.03.007

Wu, H.-K., & Puntambekar, S. (2012). Pedagogical Affordances of Multiple External Representations in Scientific Processes. *Journal of Science Education and Technology, 21*(6), 754-767. doi: 10.1007/s10956-011-9363-7

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