BOUNDARY OBJECTS IN INTERDISCIPLINARY RESEARCH ON MULTIMODAL ALGEBRA LEARNING

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We present a set of boundary objects we indentified in an ongoing interdisciplinary research and development project, where mathematics didacticians collaborate with human-computer interaction experts to develop digitally enhanced versions of manipulatives for algebra learning.

Keywords: interdisciplinary research, multimodality, tangible interaction, technology design

Developing truly novel technologies for learning requires interdisciplinary teams that consist of experts from different domains, e.g., didactitians and computer scientists. This is also the case in the research project MAL: Mathematics educators and human-computer interaction (HCI) researchers jointly develop interactive and digitally enhanced versions of manipulatives for algebra learning.

BOUNDARY OBJECTS AT THE ELECTRONIC FRONTIER

While both mathematics education and HCI can be seen as interdisciplinary in themselves, conferences, journals, professorships, etc. have been established for each, thus exemplifying disciplinarity "(a) [as] a phenomenon of the social world marked by increasing specialization and differentiation of (material and discursive) practices and (b) [as] a form of discourse making the specialization thematic" (Williams et al., 2016, p. 4). For interdisciplinary research, common objects are a condition: "they coordinate the activities involved even though the practices surrounding these objects differ. These objects are known as *boundary objects*" (p. 11). Here, we share experiences about boundary objects we encountered in our particular collaboration.

Design cycles. The widespread implementation of design research gives didacticians common ground with engineering and design disciplines, where the term originated. However, what is investigated in such research can vary. Computer scientists and HCI researchers, in order to build systems, have to focus on details (colour schemes, sizes, single modes of feedback) and sometimes consider these isolated from each other. In contrast, the design of mathematics tasks is more dominated by basic assumptions that both guide the design and are subject to testing in each cycle.

Users. HCI research focuses heavily on usability and user experience. Doing so, the user is defined the person who deals with the technology, *either* a (group of) student(s) *or* the teacher or possibly another person with a defined role. From a didactical perspective, however, the users of new learning environments are (a) not limited to teachers and learners as individuals and may encompass larger institutions (up to the society as a whole) and (b) are often seen as interconnected.

Embodiment and Modalities. In both disciplines theories on *embodied cognition* have been taken up. In this context, the involved *modalities* are central. The term, however, can be used differently. In HCI, modalities are usually either defined by the sensory channels (e.g. Obrist et al., 2016) or by the input and output modes (Oviatt, 2012) used for interaction with a system. In mathematics education, modalities are used as an analytic term whose definition is often dependent on the mathematical context: A picture of a situation may be seen as a different modality than a graph in a coordinate system, although both would be "graphical output" in HCI terminology. **Gesture** is one particular modality that has received much attention in both fields. Again, both disciplines refer to the same background theory (e.g., McNeill, 1992). But in practice, the HCI discourse is dominated by the gestures possible to track with current technology, while mathematics educators are more open towards all the gestures that may occur in the classroom (de Freitas and Sinclair, 2017).

Feedback. In HCI, feedback refers to communication from the system to the user as a direct result of a user's action (Shneiderman, 1987). While there is awareness that feedback is not an end in itself, this definition may lead to oversimplified interactions. Research from mathematics education can be helpful here, e.g. by identifying different levels of feedback (Hattie & Timperley, 2007) or by working out adequate feedback in specific learning situations referring to concepts like scaffolding (e.g., Sharma & Hannafin, 2007).

OUTLOOK

Although often a pragmatic approach will suffice to fulfil the goals of a particular collaboration, the identification and deeper reflection of boundary objects can help to understand each other and the roles of both sides. If interdisciplinary working groups manage to understand their partners' fields, the transfer of discourses and practices from one field to the other is facilitated. Mathematics educators could help HCI researchers broaden their view on users and feedback, for example. HCI researchers could challenge their mathematics education partners to identify gaps in existing technology, and then proceed together to improve it. Furthermore, what each side learns when working with the other may also help shaping the self-understanding of the two juvenile disciplines, and possibly prevent their boundaries from becoming incrusted.

ACKNOWLEDGEMENTS

The MAL (*Multimodal Algebra Learning*) project is funded by the German Federal Ministry of Education and Research in the grant programme "Erfahrbares Lernen" (experiencable learning).

REFERENCES

de Freitas, E. & Sinclair, N. (2017). *Mathematical gestures: multitouch technology and the indexical trace*. Paper presented at CERME10. Retrieved from https://keynote.conference-services.net/resources/444/5118/pdf/CERME10_0525.pdf

Hattie, J. & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112.

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. Chicago, IL: University of Chicago Press.

Obrist, M., Velasco, C., Vi, C., Ranasinghe, N., Israr, A., Cheok, A., … (2016). Sensing the future of HCI: Touch, taste, and smell user interfaces. *interactions, 23*(5), 40–49.

Oviatt, S. Multimodal interfaces. (2012) In J. A. Jacko (Ed.), *The human-computer interaction handbook: Fundamentals, evolving technologies and emerging applications* (3rd ed.) (pp. 405–429). Boca Raton, FL: CRC Press.

Sharma, P. & Hannafin, M. J. (2007). Scaffolding in technology-enhanced learning environments. *Interactive Learning Environments, 15*(1), 27–46.

Shneiderman, B. (1997). *Designing the user interface: Strategies for effective human-computer interaction* (3rd ed.). Boston, MA: Addison-Wesley Longman.

Williams, J., Roth, W.-M., Swanson, D., Doig, B., Groves, S., Omuvwie, M., … (2016). *Interdisciplinary mathematics education. A state of the art*. Cham: Springer.