Professorship for Learning Sciences & Higher Education
Theoretical Chemistry – The Reiher Research Group

Access the Molecular World through Haptic Quantum Chemistry

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Introduction

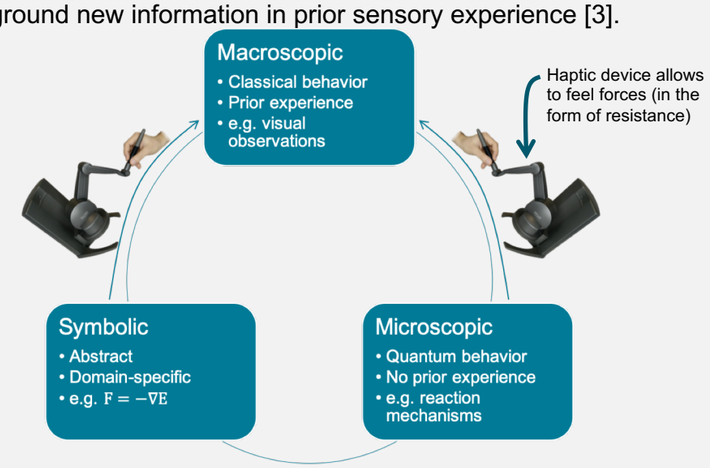
Haptic learning environments (HLE) have been shown to facilitate learning if the haptic features add value & the environment is easy enough to use, research on how is however sparse [1].

The microscopic and abstract nature of chemistry shows many potential applications, of which we focus on the concepts of **potential energy and forces in reactions.** We develop and test a HLE which allows to observe and feel molecular systems that act according to quantum laws.

Theoretical Framework

Chemists understand observations on a **macroscopic, microscopic, and symbolic level**, between which the connections are sometimes hard to make as a novice, especially because the microscopic (molecular) world does not behave classically (but quantum mechanically) [2].

The theoretical framework of **embodied cognition** suggests that experiencing (scientific) concepts through multiple modalities can help ground new information in prior sensory experience [3].



Research Questions

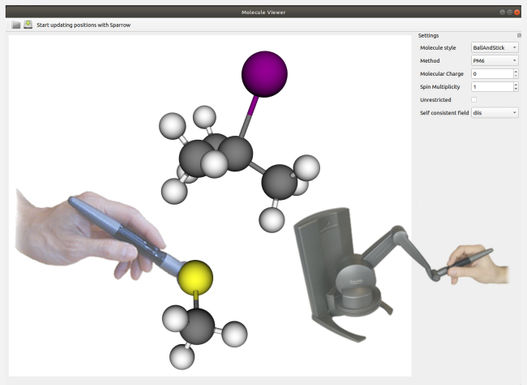
I. How does the introduction of **haptic feedback** in this HLE **prepare for future learning** about chemical forces and reactivity in a lecture relative to the same HLE w/o feedback, or watching a movie of so. interacting with it?
II. What **cognitive mechanisms** facilitate or hinder the learning with this specific learning environment?

Learning Environment

Molecules act quantum mechanically, their movement is calculated based on semi-empirical methods [4-6].

Anytime the user stops manipulating the system, it **relaxes** into the energetically lowest structure.

Drag and drop atoms across screen, trigger reactions and **feel** forces that act on the atom.



Summary

Done → Content validation & **pilot** studies (of HLE & posttest)

Fall, 2021 → Further optimization of HLE & posttest according to results of **user study**.

Spring, 2022 → **PFL study** with the goal of answering the research questions of how haptic feedback facilitates learning of selected (quantum) chemical concepts.

Hypotheses

I. The higher the level of embodiment (HLE w haptic feedback > HLE w/o feedback > movie) , the better the preparation for learning about energy and forces in a chemistry context.
II. Using the HLE increases affect, state curiosity, and knowledge gap awareness more compared to watching a movie about it.

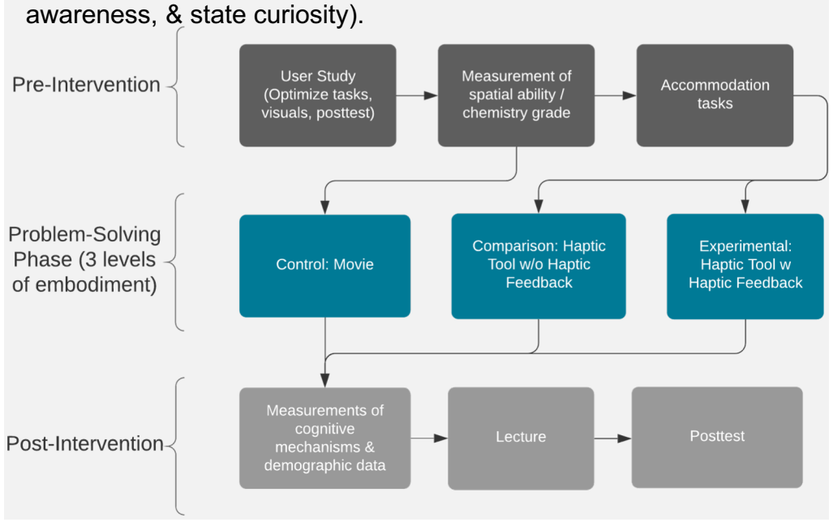
Methods

Participants: 1st year university students**,** aiming for N = 25 for the user study, N = 3∗40 for the PFL study.

Design: Preparation for future learning (PFL) study design with preliminary user study.

Independent Variable: Level of embodiment.

Dependent Variables: Learning outcome (posttest developed in-house), cognitive mechanisms (embodiment, affect, knowledge gap awareness, & state curiosity).



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