Getting the big picture: The role of visual model comprehension for cognitive load and performance in chemistry and engineering studies

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Domains such as chemistry or engineering are often called “visual sciences” (e.g., Wu & Shah, 2004) because of the abundance of different visualizations that can be found in respective textbooks. However, although visualizations are supposed to foster learning (Mayer, 2014), the high university drop-out rates especially for these domains (OECD, 2011) make it necessary to have a look at the actual learning benefits of visualizations and at individual differences between learners regarding their abilities to process visualizations. In this regard, our project focuses on investigating how visual model comprehension in chemistry and engineering is able to predict performance and study success and which factors, in turn, have an impact on visual model comprehension. For instance, we assume that the higher the visual model comprehension of a student, the less cognitive load she or he will experience during learning or problem solving, which should result in higher performance accordingly. In a first step, a visual model comprehension test was developed which comprises 33 items on three scales: chemistry-related visual model comprehension, engineering-related visual model comprehension and general visual model comprehension. Mental effort and perceived difficulty were assessed for each of the test subscales as well as once after all items had been answered.

For the main study, we accompanied 424 students (238 chemists, 186 engineers) over the course of their first study semester. Visual model comprehension, cognitive load, domain-specific performance and other variables such as learning strategies, spatial and cognitive abilities or study motivation were assessed both at the beginning and at the end of the semester. Results show that at the beginning of the semester, chemistry as well as engineering students with higher visual model comprehension indicated less perceived difficulty ($r=-.202$; $p=.001$ and $r=-.281$; $p<.001$) and had higher achievements in domain-specific knowledge tests (all $p<.001$). Furthermore, perceived difficulty significantly predicted achievement in chemistry ($r=-.194$; $p=.002$) as well as engineering ($r=-.275$; $p<.001$). The results for mental effort at the beginning of the semester are similar, but mostly miss statistical significance slightly.

At the end of the semester, a similar and even clearer pattern emerges. Higher visual model comprehension is again attached to perceived difficulty for both chemists ($r=-.351$; $p<.001$) and engineers ($r=-.329$; $p<.001$), and the same applies to mental effort ($r=-.181$; $p=.006$ and $r=-.173$; $p=.019$). Furthermore, visual model comprehension, mental effort and perceived difficulty all significantly predict domain-specific performance in chemistry (all $p<.02$) and engineering (all $p<.002$). Finally, further preliminary analyses show that higher visual model comprehension, less perceived difficulty and less mental effort also go along with more sophisticated self-regulatory abilities, higher spatial and higher cognitive abilities. We will go into more details with these findings to shed more light on the question of possible mediation and moderation effects. To sum up, and in line with our expectations, visual model comprehension appears to be an important prerequisite for successful chemistry as well as engineering study achievement as students with this ability experience less cognitive load and show higher performance. These results will be presented and discussed at the ICLTC 2017.