Friedrich-Alexander-Universität
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Disentangling the relationship between spatial abilities and representational competence in chemistry

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Theoretical Framework

1 Representations & representational competence in chemistry

- Representations play a key role in learning chemistry and developing content knowledge for problem-solving processes. (Rau, 2017; Kozma et al., 2000)
- Chemists use representations (e.g., graphs, diagrams and chemical equations) to understand and depict chemical phenomena. (Rau, 2017; Harle & Towns, 2011)
- „Representation dilemma“: students have to learn content they do not understand from representations they may not yet understand, either. (Rau, 2018)

  ⇒ To overcome the „representation dilemma“, students need representational competence. (Rau, 2018)

Representational Competence		
description & interpretation	The ability to describe chemical phenomena with representations and to identify patterns and features of representations.	low-level skills
construction	The ability to construct or choose appropriate representations.	
translation	The ability to translate a given visual representation into another and to change perspectives.	
comparison & critique	The ability to compare multiple representations and explain how one representation says something that cannot be said with another…	high-level skills
epistemology & function	The ability to take the epistemological position that representations correspond to but are distinct from the phenomena that are observed.	
argumentation	The ability to use representations in as evidence to support claims, draw interference, and develop hypothesis on observable chemical phenomena.	

Figure 1: *Overview of the skills of representational competence (adapted from Kozma and Russell, 2007 and Gurung et al., 2022) and their categories (adapted from Nitz, 2012).*

2 Spatial Abilities in Chemistry

- Representations in chemistry are fairly abstract and highly spatial (Rau, 2017), especially in coordination chemistry.

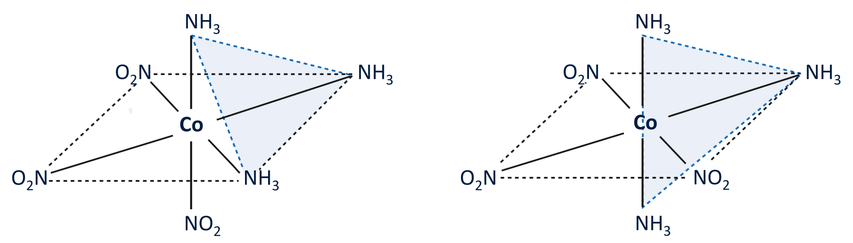

Figure 2: *fac(ial)- and mer(idional) isomer of an octahedral complex as example for an abstract and spatial representation. (Binnewies et al., 2016)*

- Spatial ability is “the ability to generate, retain, and manipulate abstract visual images”. (Lohman, 1979, p. 126)
- In the Cattell-Horn-Carroll (CHC) theory, there are 11 spatial factors which load on spatial ability (*visual processing*). Recently, more spatial factors have been identified. (Schneider & McGrew, 2012)
- In STEM domains, especially mental rotation (2-D: *speeded rotation*, 3-D: *spatial relation*) is a predictor for students’ achievement. (Yoon, 2011; Buckley, Seery & Canty, 2018)
- The interplay between spatial factors (table 1) and representational competence (figure 1) has only been partially investigated.

Research Questions, Designs and Methods

1st Study

Which **reasoning strategies** do students employ while *describing & interpreting*, *translating*, and *constructing* dash-wedge diagrams and ball-and-stick models in the context of coordination chemistry?

Which **difficulties** do students encounter while *describing & interpreting*, *translating*, and *constructing* dash-wedge diagrams and ball-and-stick models in the context of coordination chemistry?

Chemistry education students ($n_{♀}$=17, $n_{♂}$=8; M_{age}=22.04, SD_{age}=1.73) with knowledge about coordination chemistry in summer 2023.

Think-aloud method with representation-based coordination chemistry tasks.

- ▻ Qualitative content analysis. (Mayring & Fenzl, 2022)
- ▻ Deductive analysis with a coding system.

2nd Study

To what extent can the theoretically derived skills *description & interpretation*, *construction* and *translation* be measured by a developed pen and paper instrument?

1st semester students of the preparatory course in winter 2023.

Pilot instrument: representational competence instrument

- ▻ Focus on the low-level skills of representational competence: *description & interpretation*, *construction* and *translation*
- ▻ Single-choice and semi-opened items.
- ▻ Items with non-verbal representations (newly constructed or adapted from Taskin et al. (2015) and Averbeck (2021)).
- ▻ Assignment of the items to the representational skills (figure 1) and checking the assignment through interrater analysis.
- ▻ Content knowledge items with only text-based tasks. (Averbeck, 2021)

spatial factors instrument

- ▻ Eight scales (table 1) for spatial factors. (Ekstrom et al., 1976; Yoon, 2011)

- ▻ Rasch analysis (partial credit model) to analyze the representational competence instrument.
- ▻ Correlation and regression analyses for a first insights into the interplay between representational skills and spatial abilities.

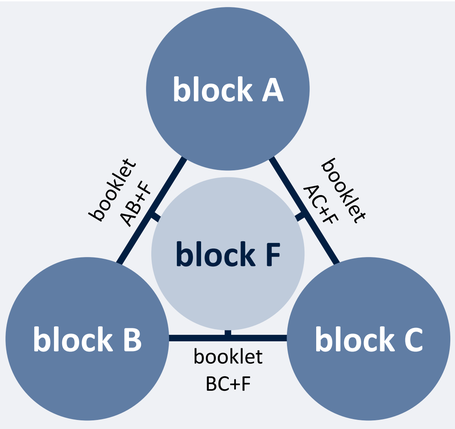

Figure 3: *Incomplete-block-design for the representational competence (blocks A-C) and the text-based tasks (block F).*

Table 1: *Overview of the focused spatial factors and the referring tests.*

Spatial factors (Schneider, & McGrew, 2012)	Test instruments (Ekstrom et al., 1976; Yoon, 2011)
visualization	Paper Folding Test
speeded rotation	Card Rotations Test
closure speed	Gestalt Completion Test
flexibility of closure	Hidden Figure Test
visual memory	Building Memory
spatial scanning	Maze Tracing Speed Test
perceptual speed	Identical Pictures Test
spatial relation	PSVT:R

Preview: interrater analysis of the representational competence

- ▻ Raters’ agreement on the assigned items (Landis & Koch, 1977):
  - ► Low-level skills: substantial ($.601 \leq \kappa_{Fleiss'} \leq .743$)
  - ► High-level skills: fair up to substantial ($.268 \leq \kappa_{Fleiss'} \leq .618$).

⇒ Concretization of the definitions for the skills.
⇒ (high-level) skills cannot be easily assigned.
⇒ Focus on the low-level skills.

3rd Study

How are the skills *description & interpretation*, *construction* and *translation* related to the factors of spatial abilities?

1st semester students of the preparatory course in winter 2024.

Representational competence instrument

- ▻ Revised version of the instrument piloted in the 2nd study.

Spatial factors instrument

- ▻ Eight scales (table 1) for spatial factors. (Ekstrom et al., 1976; Yoon, 2011)

Correlation and regression analyses to investigate the interplay between representational competence and spatial abilities.

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LITERATURE