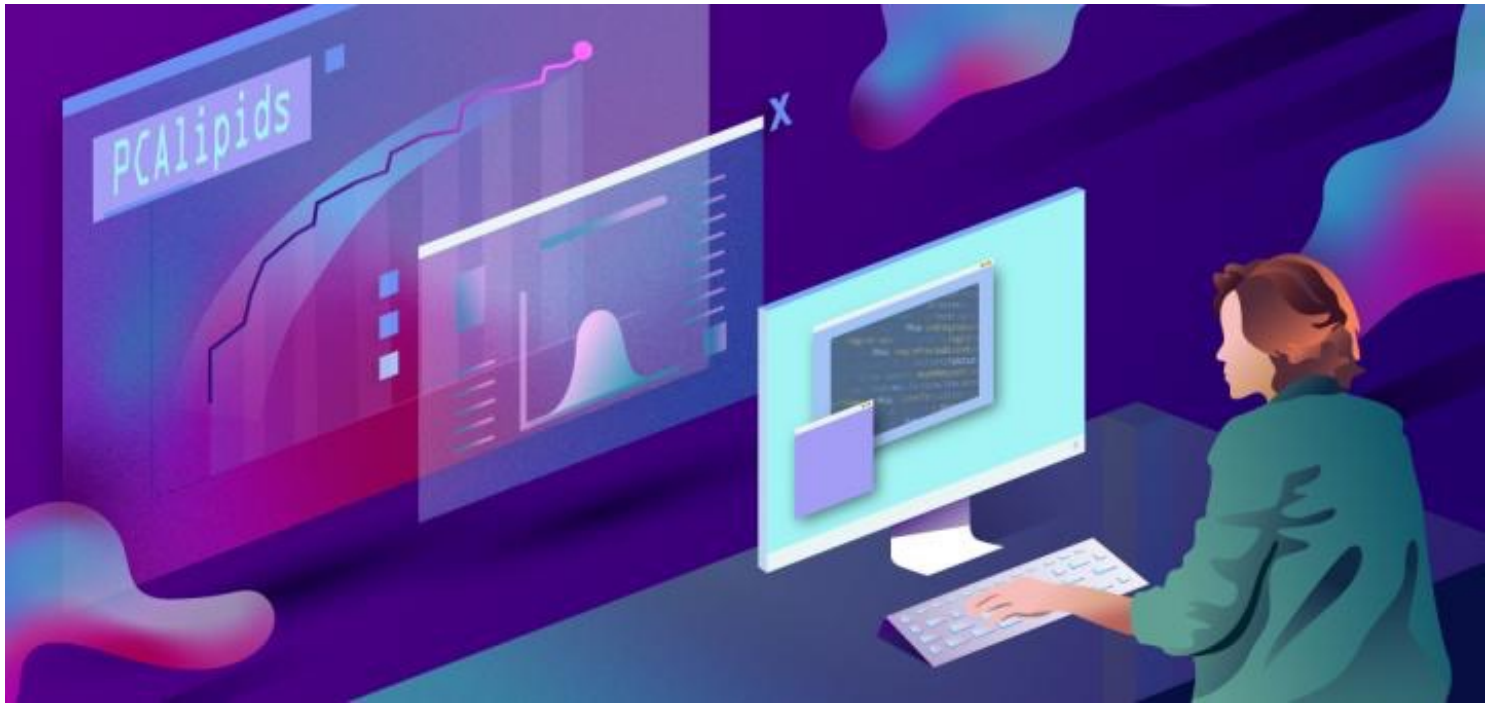
Investigating the Dimensions of the Modeling Competence



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Investigating pre-service science teachers' metaknowledge about the modelling process and its relation to metaknowledge about models

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Modeling competence

The application of knowledge when engaging with and reflecting about models and modeling.

Chr.Th. Nicolaou, C.P. Constantinou / Educational Research Review 13 (2014) 52–73

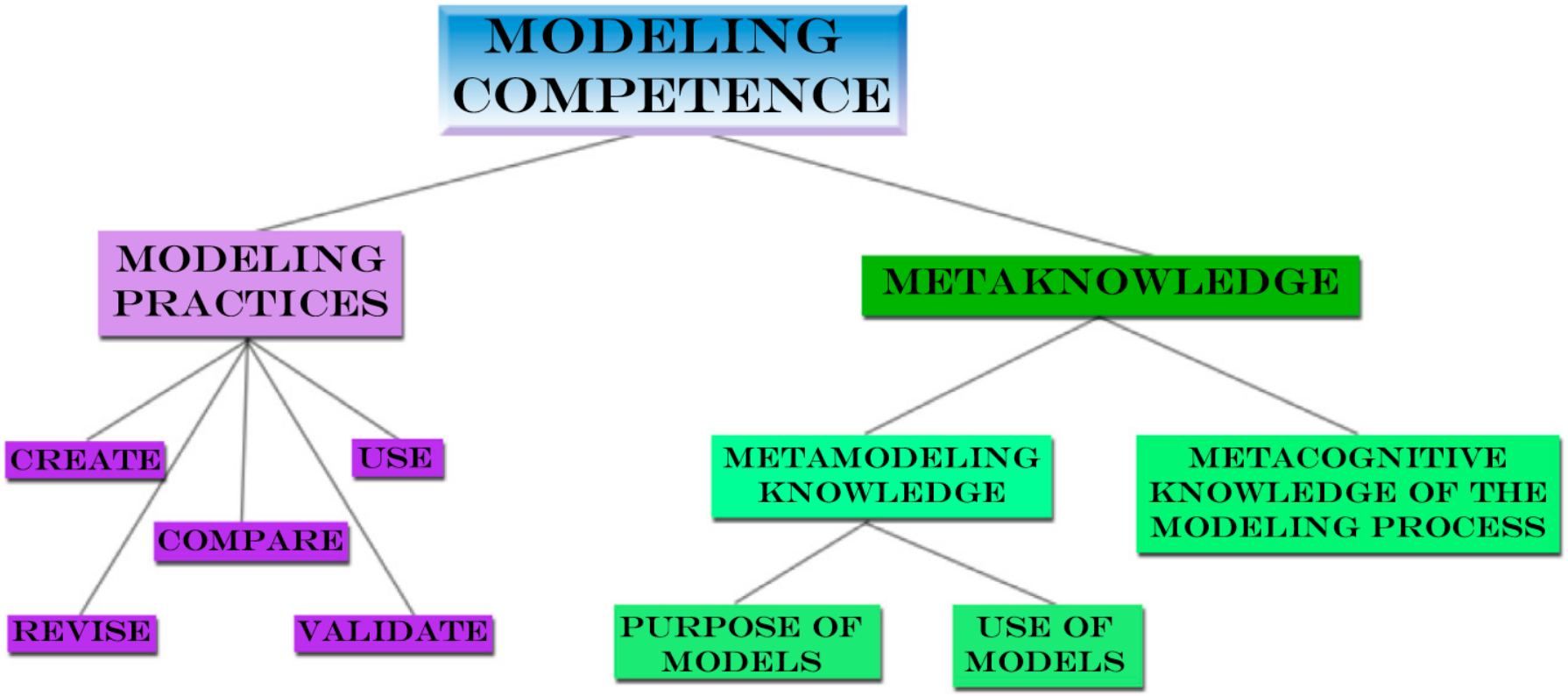

Fig. 1. The modeling competence framework.

Chiu & Lin, 2019
Nicolaou & Constantiou, 2014
Schwarz et al., 2009
Upmeier zu Belzen et al., 2019

Metamodeling knowledge (MMK)

Knowledge about the nature and purpose of models and the modeling process.

Metamodeling knowledge framework

Aspect	Level I	Level II	Level III
Nature of models	Replication of the phenomenon	Idealized representation of the phenomenon	Theoretical reconstruction of the phenomenon
Multiple models	Different model objects	Different foci on the phenomenon	Different hypotheses about the phenomenon
Purpose of models	Describing the phenomenon	Explaining the phenomenon	Predicting something about the phenomenon
Testing models	Testing the model object	Compare the model and the phenomenon	Testing hypotheses about the phenomenon
Changing models	Correcting defects in the model object	Revising due to new insights	Revising due to the falsification of hypotheses about the phenomenon

Schwarz et al., 2009
Upmeier zu Belzen et al., 2019

Metaknowledge about the modeling process (MKP)

Knowledge regarding the components and the iterative nature of the modeling process.

Chiu & Lin, 2019; Justi & van Driel, 2005

Connecting MMK and MKP

MMK and MKP are part of the knowledge about models and modeling and are important for the development of the modeling competence.

Nicolaou & Constantiou, 2014; Nielsen & Nielsen, 2019

Only few studies focus explicitly on students or teachers MKP, mostly using open-ended questions that examine knowledge concerning only certain aspects of the modeling process.

E.g., Lazenby et al., 2019; Sins et al., 2009

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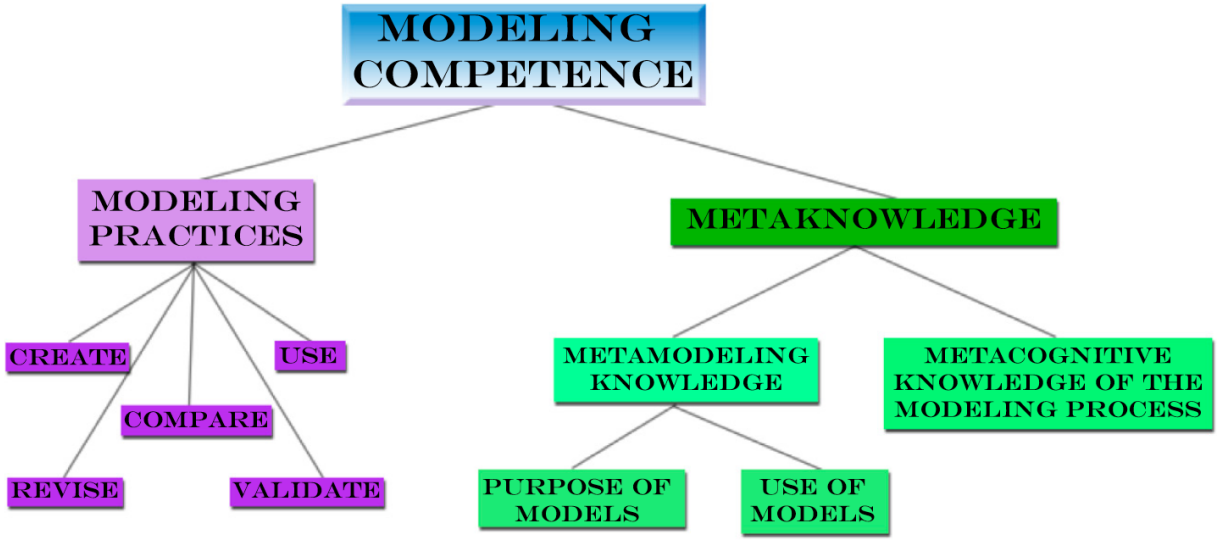


Fig. 1. The modeling competence framework.

Modeling process framework

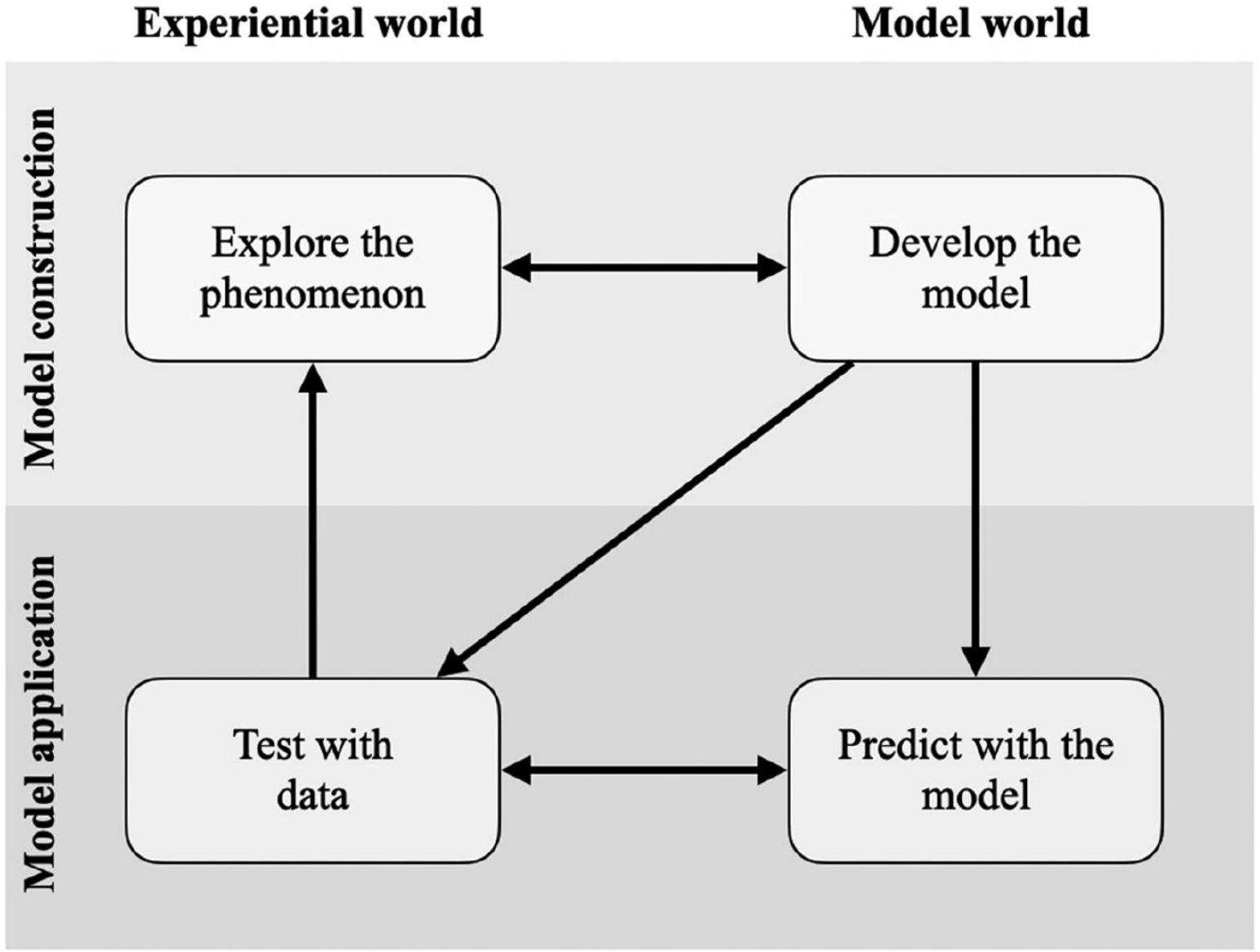


Figure 1. Framework for modelling in scientific inquiry (adapted from Göhner et al., 2022 and Upmeier zu Belzen et al., 2021)

Research questions

- How can preservice science teachers' MKP be evaluated?
- What is preservice science teachers' MKP?
- To what extent is science teachers' MKP connected with other MMK aspects?

Bielik, Engelschalt, et al. (2023)

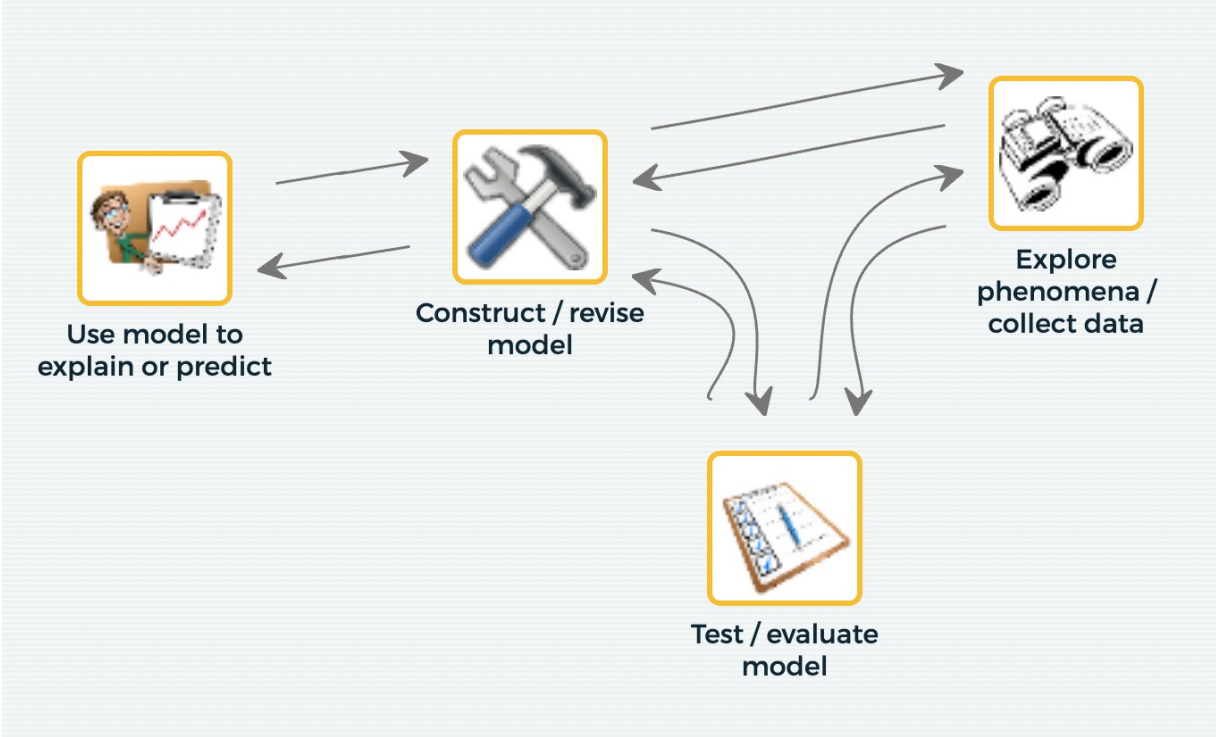
Research tools- MKP diagram task

"Create a diagram representing the modelling process in scientific inquiry"

SAGEMODELER

Moderate to high objectivity and reliability

52 preservice biology teachers



Bielik, Engelschalt, et al. (2023)

MKP Diagram task analysis

Component score

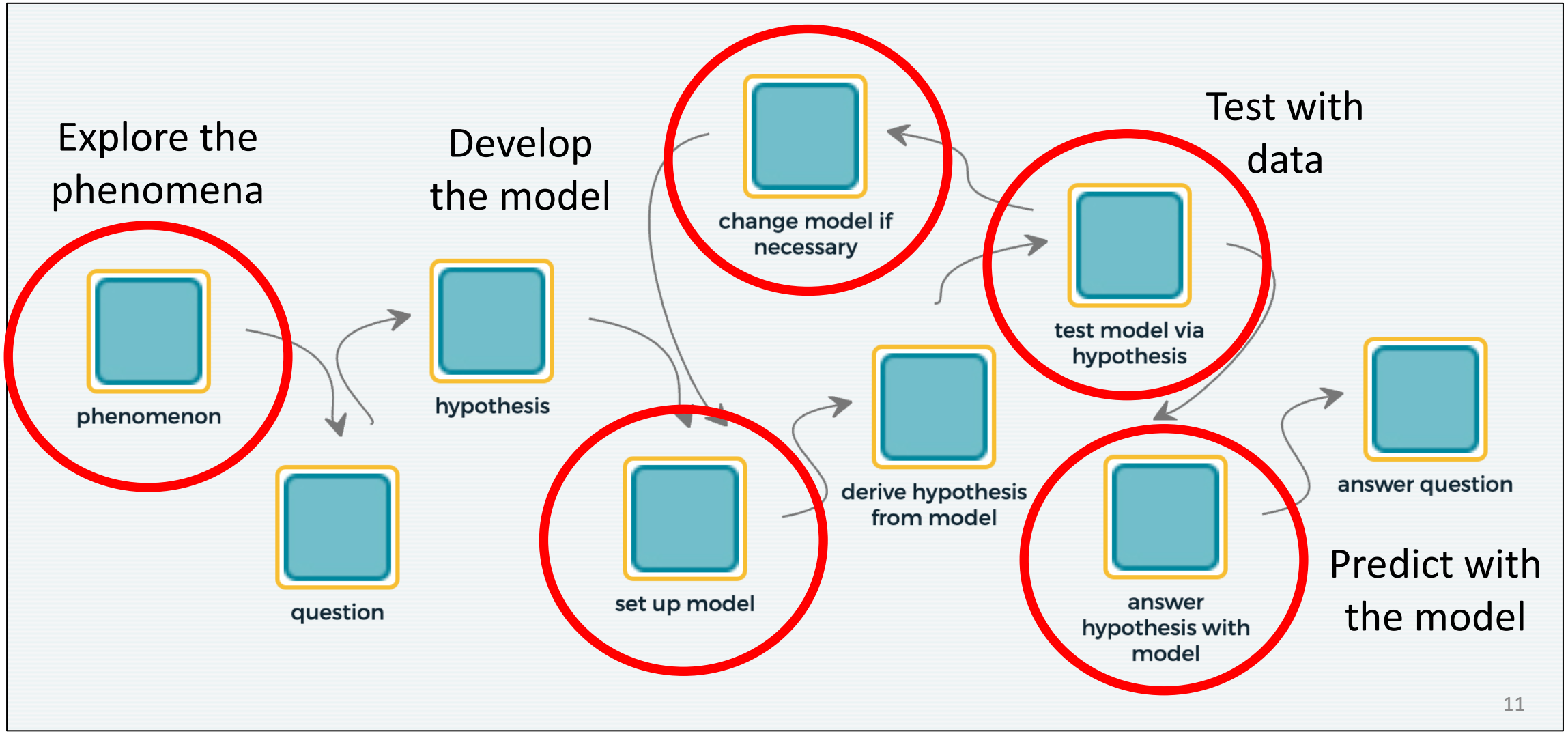
Bielik, Engelschalt, et al. (2023)

Table 1. Descriptions of the components and referring sub-elements used for coding.

Components	Sub-elements (with theoretical reference)	Exceptions
Explore the phenomenon	• Perceiving the phenomenon (Göhner et al., 2022) • Collecting data, e.g. by observation (Gilbert & Justi, 2016; Greve & Wentura, 1997)	Not counted if another representation (a picture or another model) is chosen as the starting point for the modelling process.
Develop the model	• Identifying relevant variables in the investigated system and characterising relationships between them (Schwarz et al., 2009) • Activating theories, analogies, and experiences developing a model (Göhner et al., 2022; Oh, 2019; Schwarz et al., 2009) • Evaluating or revising model due to logical inconsistencies or inconsistency with data from exploration (Göhner et al., 2022; Passmore et al., 2014; Schwarz et al., 2009) • Generating explanations or assumptions for a phenomenon in model construction (Göhner et al., 2022; Oh, 2019)	Not counted if diagrams do not include any references to models and modelling, e.g. describing a generic process of scientific inquiry.
Predict with the model	• Predicting possible outcomes by deriving hypotheses from the model (Gouvea & Passmore, 2017; Upmeier zu Belzen et al., 2021) • Manipulating a (simulation) model to explain the future behaviour of the phenomenon (Giere et al., 2006; Krell & Krüger, 2016)	Not counted if terms such as *hypotheses/ assumptions/claims (or synonyms)* are mentioned only before a model is constructed AND if the model is then not tested in the diagrams. This case only counts for *developing the model.*
Test with data	• Conducting scientific inquiry to test the model of its derived hypotheses (Gilbert & Justi, 2016; Göhner et al., 2022; Schwarz et al., 2009) • Testing with datas with data (Giere et al., 2006; Gilbert & Justi, 2016)	Testing with data's logical consistency (e. g., by 'comparing it to theories' or 'asking experts') is not scored here but as part of *developing the model.*

MKP Diagram task analysis

Component score



MKP Diagram task analysis

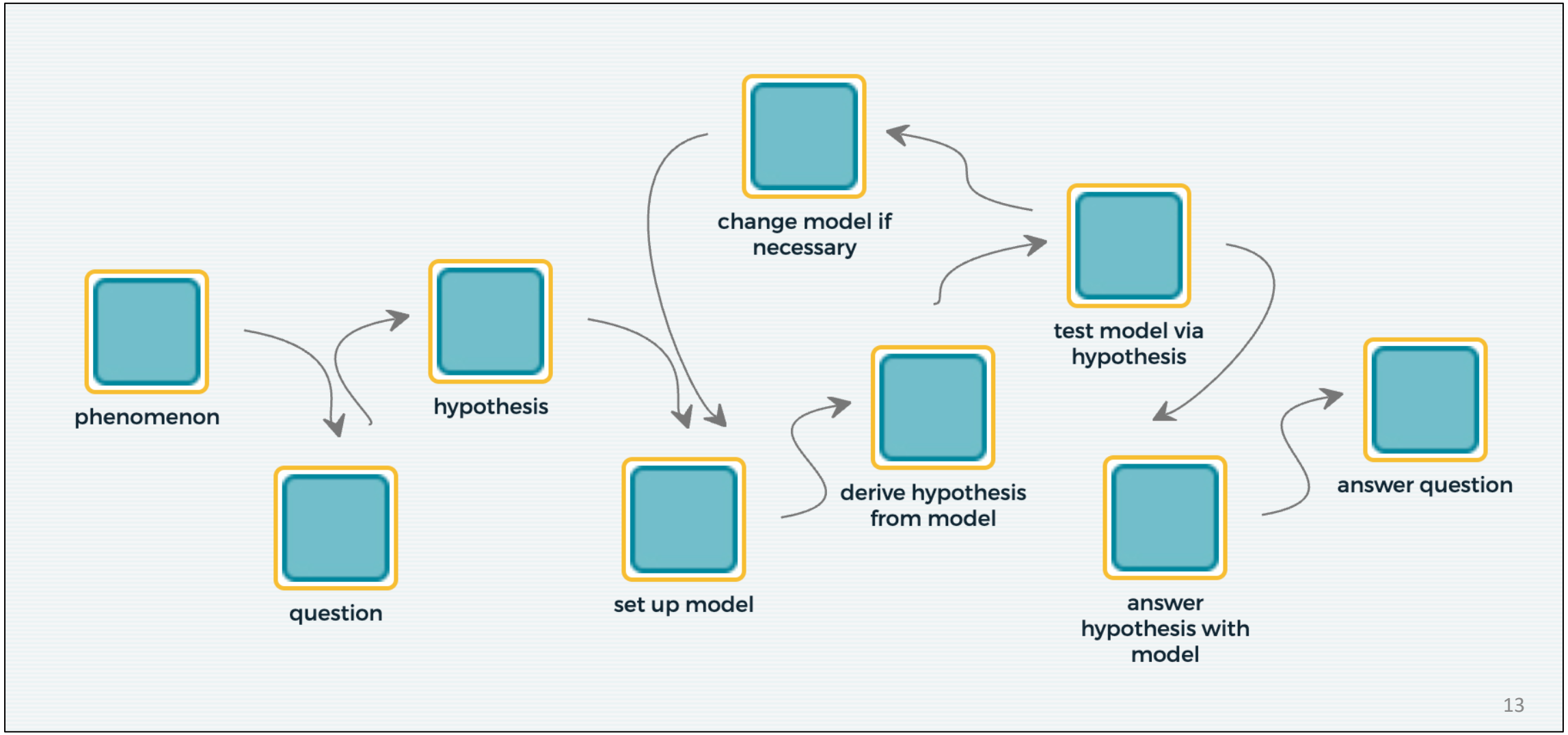
Structure score

Structure score	Description
1	Diagram displays no model revision beyond the initial model development.
2	Diagram displays only one cycle of model revision without additional data collection to test the model.
3	Diagram displays model testing, revision, and data collection as a cyclic process.

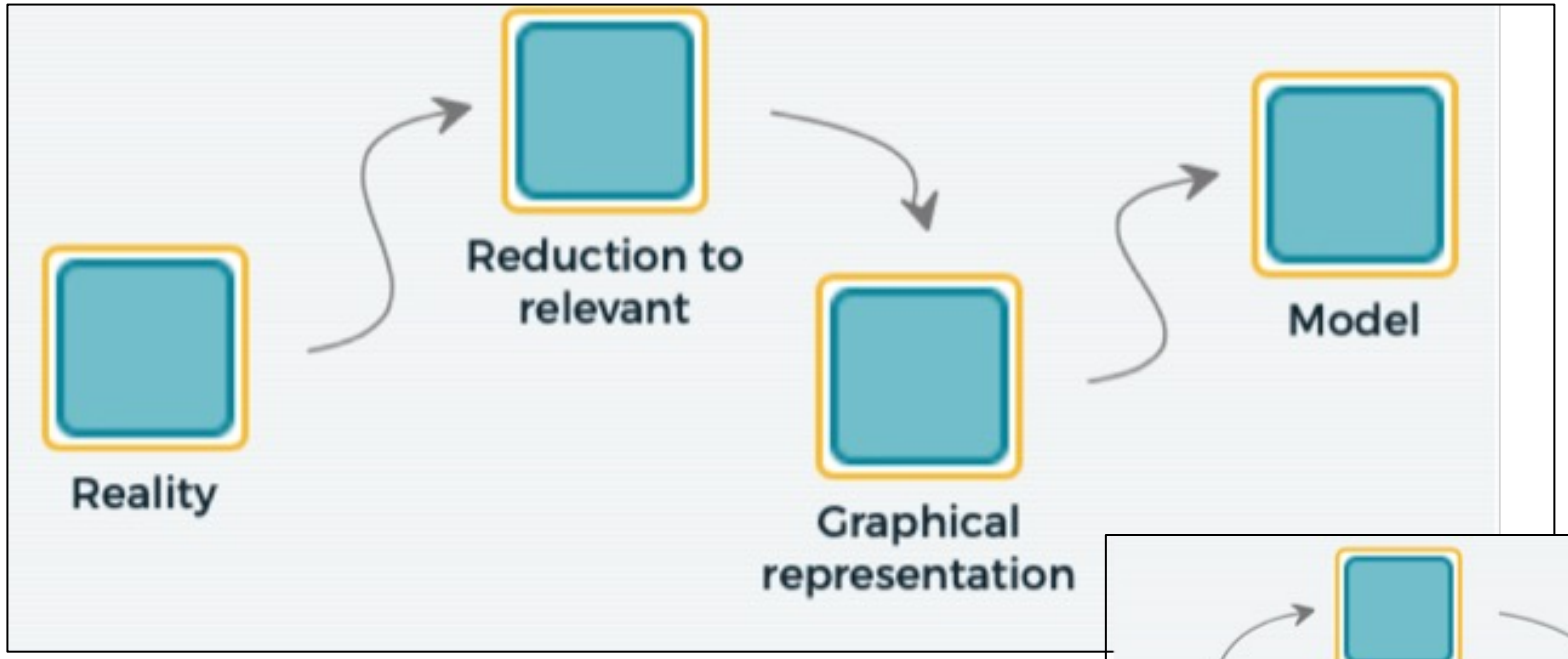
Bielik, Engelschalt, et al. (2023)

MKP Diagram task analysis

Structure score

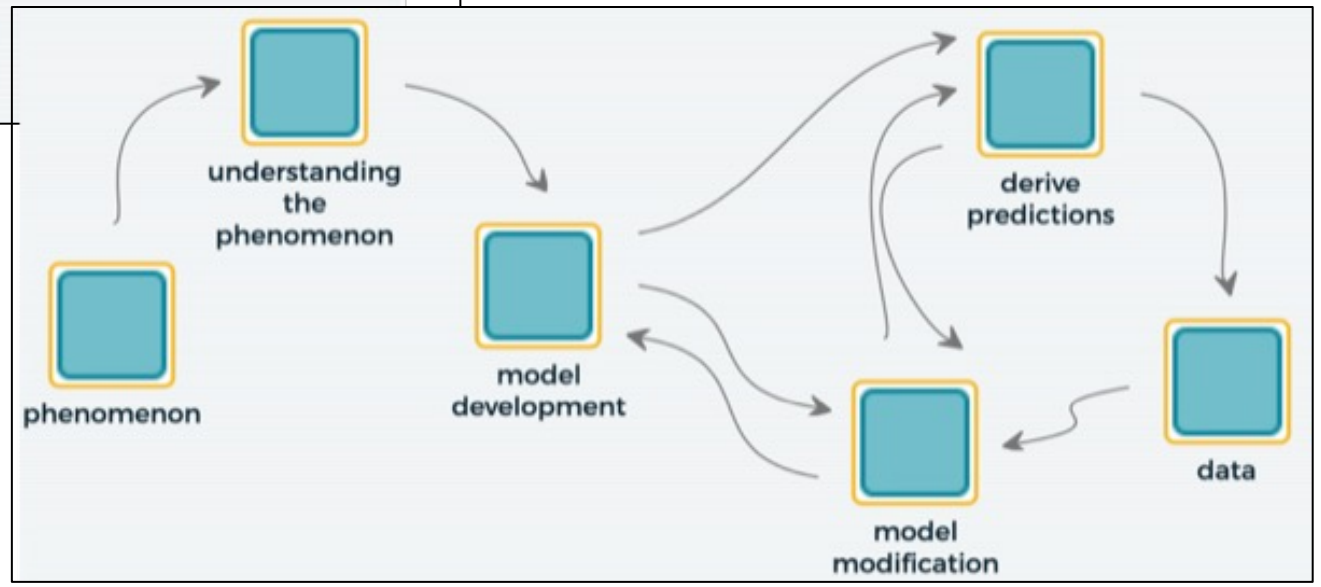


Results



Component score 1
Structure score 1

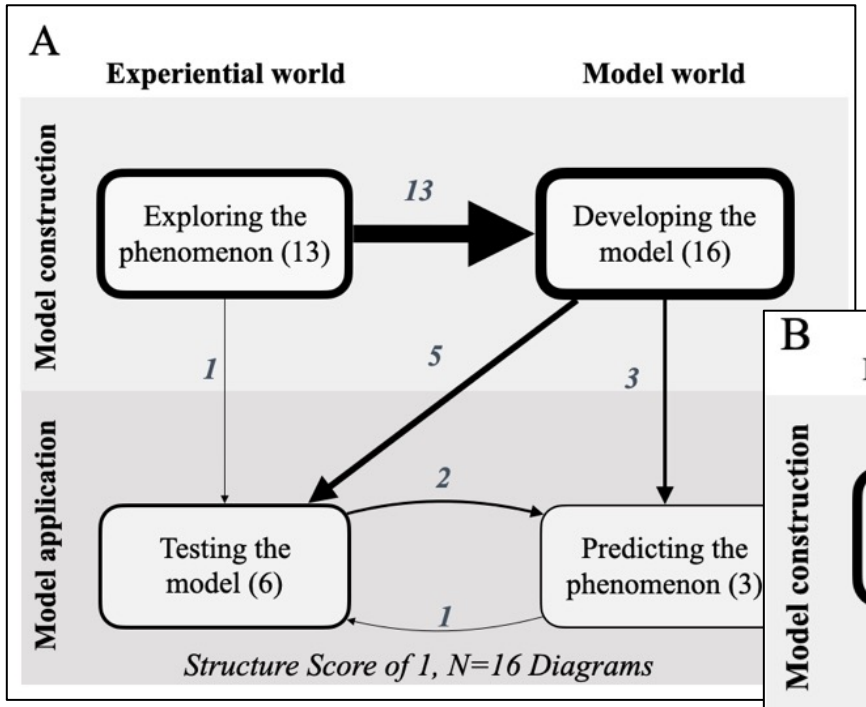
Component score 3
Structure score 3

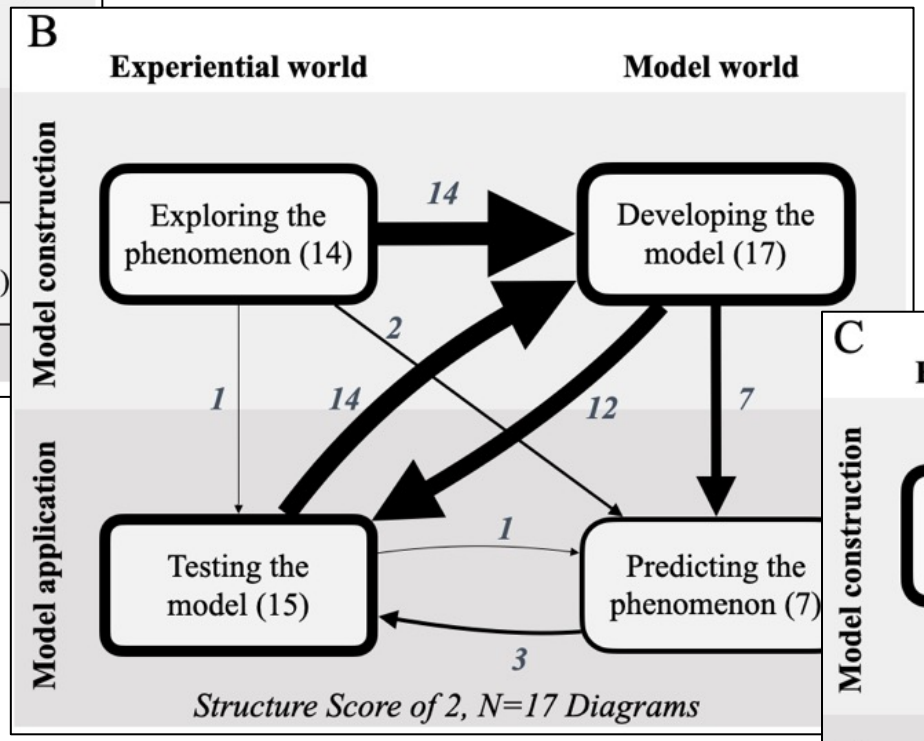


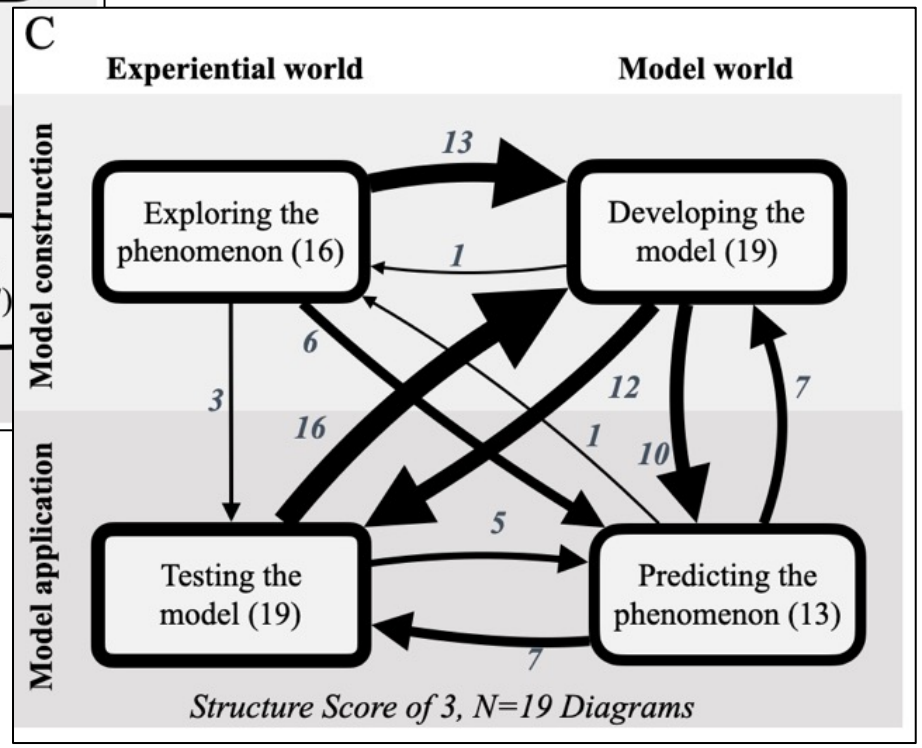
Bielik, Engelschalt, et al. (2023)

Results

Analysis of grouped MKP structure scores







Bielik, Engelschalt, et al. (2023)

Results

Moderate correlation was found between MKP structure score and MMK aspect of testing models (r=.33, p<.05) and between MKP component score and MMK aspect of Purpose of models (r=.30, p< 0.5).

Table 4. Correlations between MKP diagram task (*component score and structure score*) and aspects of the MKM questionnaire (*nature of models*, *alternative models*, *purpose of models*, *testing models*, and *changing models*).

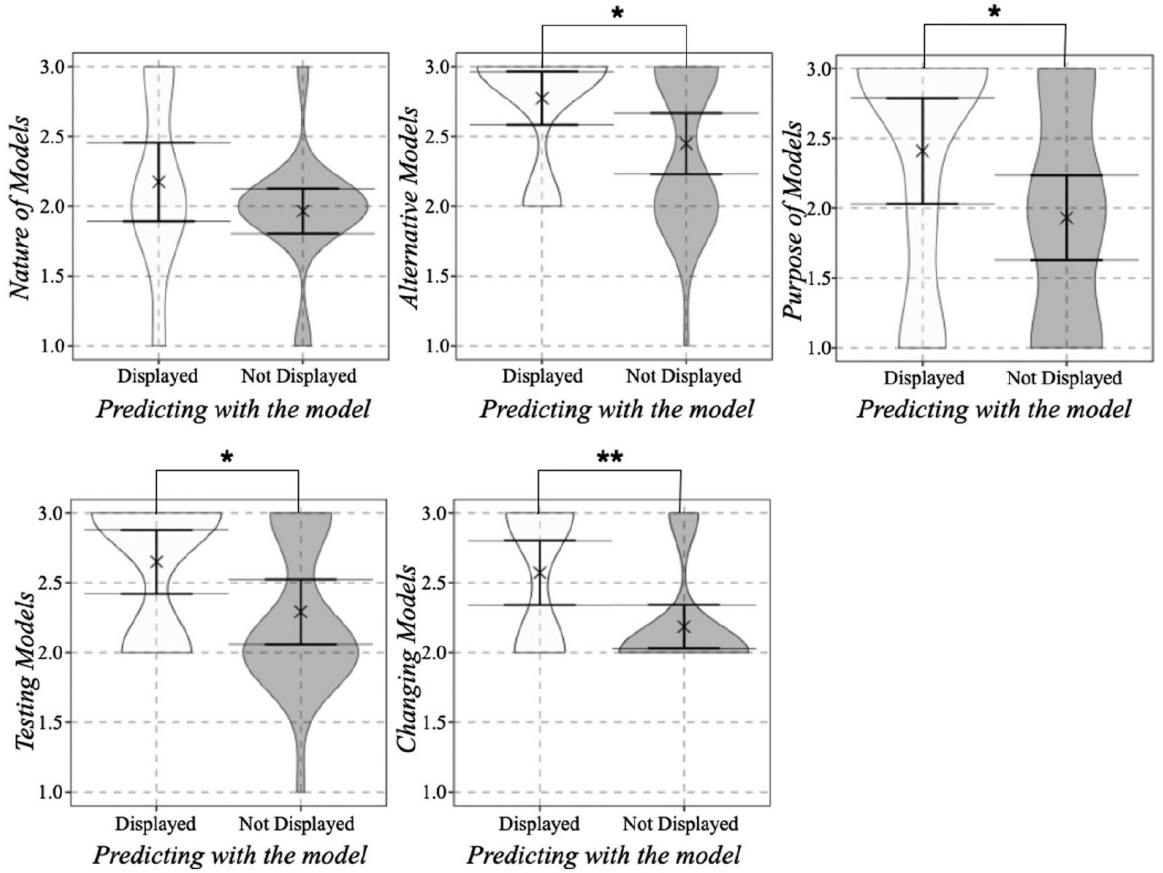
	Nature of Models	Alternative Models	Purpose of Models	Testing Models	Changing Models
Component Score	.18	.18	.30*	.28	.26
Structure Score	2.6	.27	.16	.33*	.03

*Significance level $p < .05$.

Bielik, Engelschalt, et al. (2023)

Results

Significant difference was found between groups that included or didn't include the MKP component of 'Predict with model' to most MMK aspects.



Bielik, Engelschalt, et al. (2023)

Figure 4. Scoring of the aspects of open-ended questionnaire depending on whether the component predict with the model was displayed in the diagram or not (N = 52 diagrams, 23 displayed predicting with the model). Significant differences between groups in cases where mean value of one group ($\times$) is outside 95% confidence interval of the other group (Loftus, 1993). Indication of significance level: *p< .05, **p< .01.

Discussion

The limited moderate correlation between MKP and MMK supports the idea that MKP is a separate construct from MMK, suggesting that MKP and MMK should be separately addressed and evaluated.

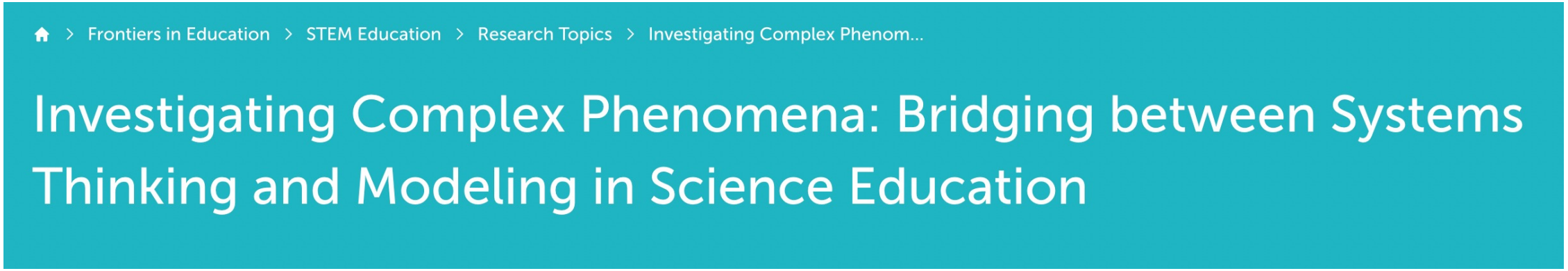
However, some MKP components and MMK aspects may serve as bridging concepts (Predict with model, Testing models, and Purpose of models).

More studies are required to further test these relationships and to explore how to support teachers and students in the development of their metaknowledge about models and modeling.

Bielik, Engelschalt, et al. (2023)

What's next?

- Investigating the relationships between the dimensions of the modeling competence. (DFG grant received: PIs Bielik, Nordmeier, & Krell, 2022)
- Exploring the connection between modeling and systems thinking. (ISF proposal submitted: PIs Ben Zvi Assaraf & Bielik, 2023)
- Developing PD units about climate change from modeling and systems thinking perspectives. (Erasmus+ proposal submitted, PIs Bielik et al., 2023)



Complexity Thinking

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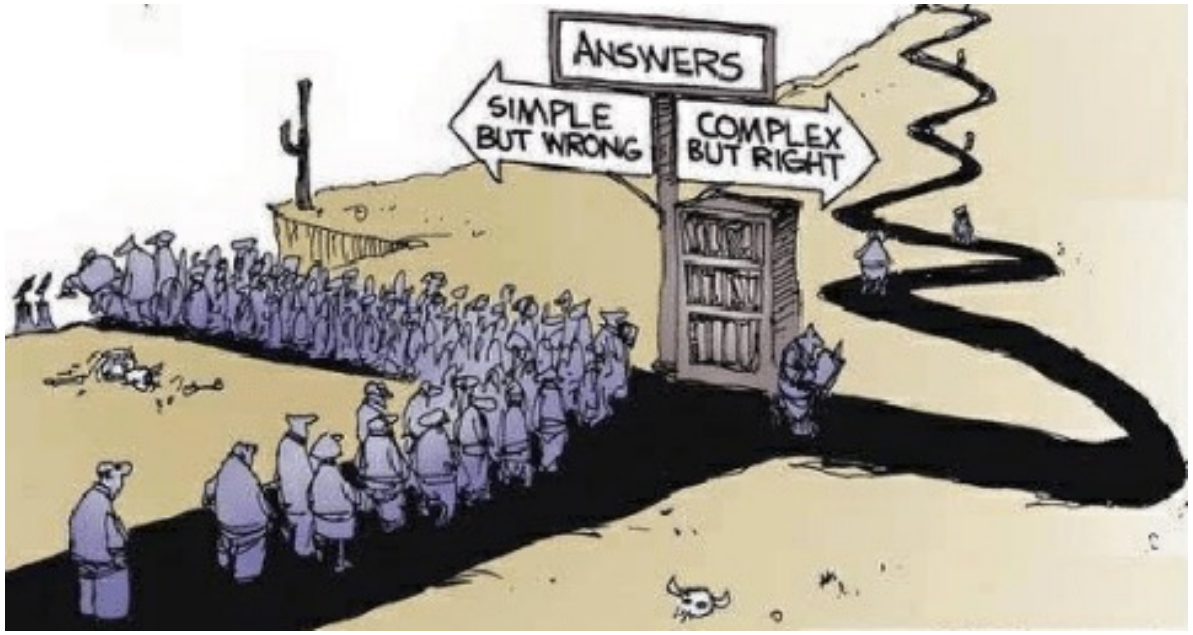
Prof. Orit Ben Zvi Assaraf, Ram Tamir (*Ben Gurion University of the Negev*)



Thank you

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