

Companion material of the chapter “Experiences in Using the V-Model as a Framework for Applied Doctoral Research”  
from the book “Teaching Empirical Research Methods in Software Engineering”

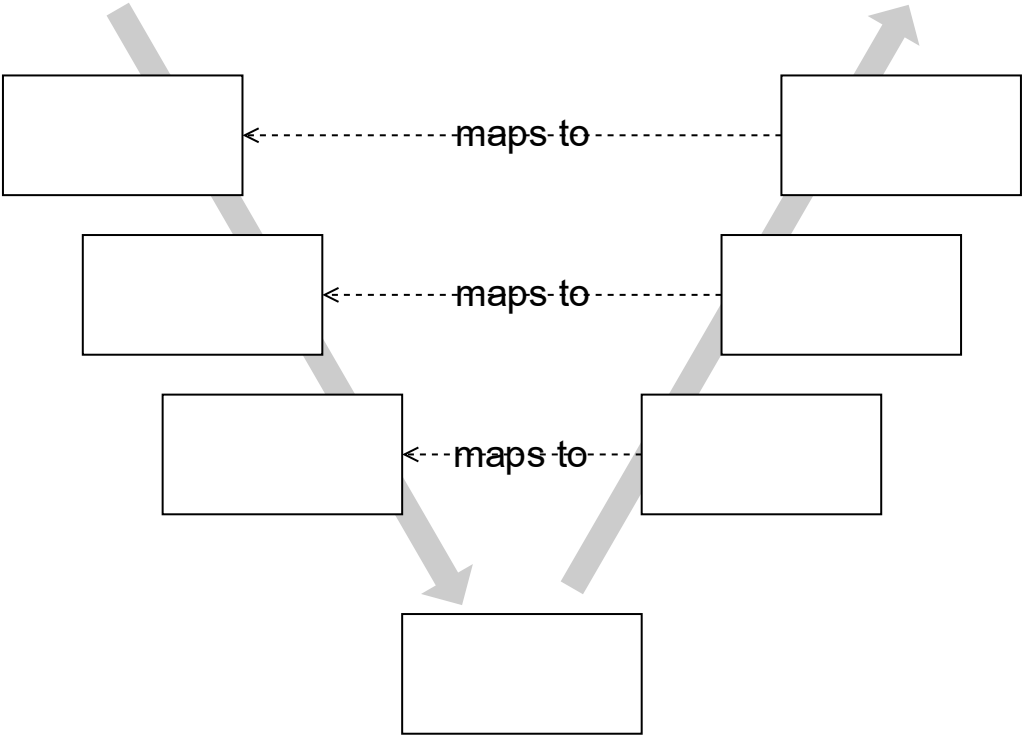
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# The V-Model as a framework for applied research in ESE

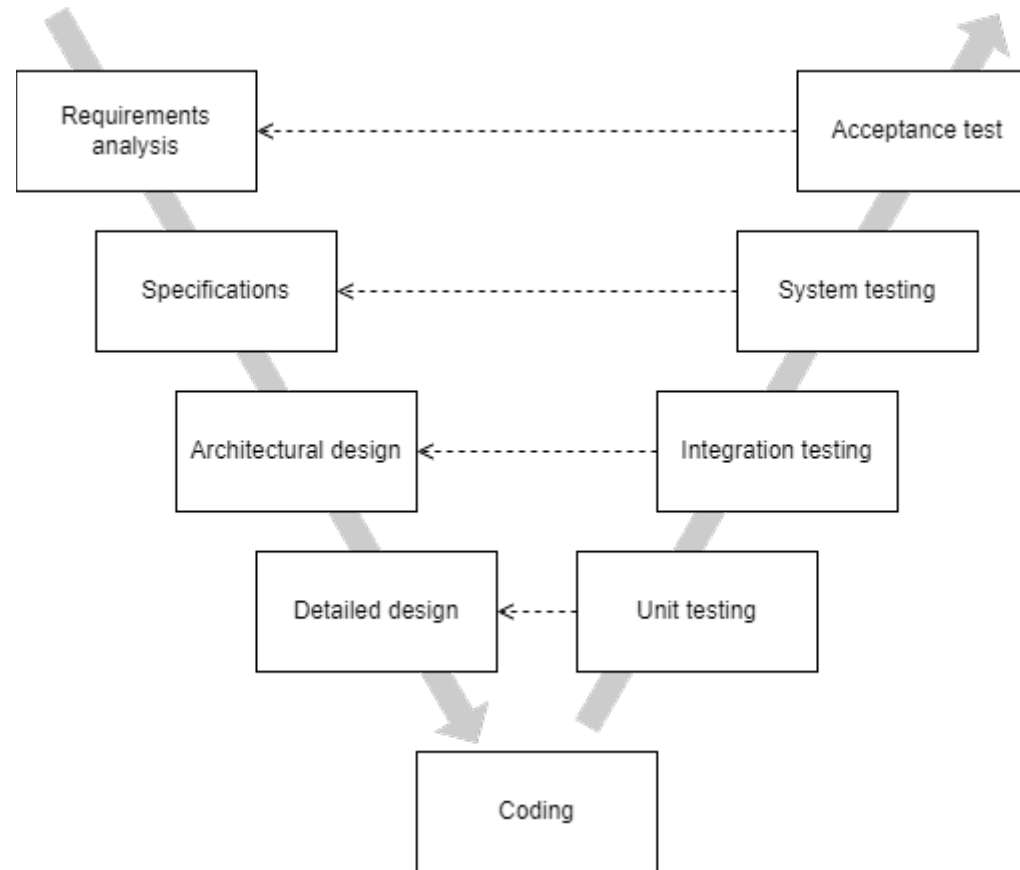
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# The V-Model is a conceptual model that organize elements in a “V-shape”

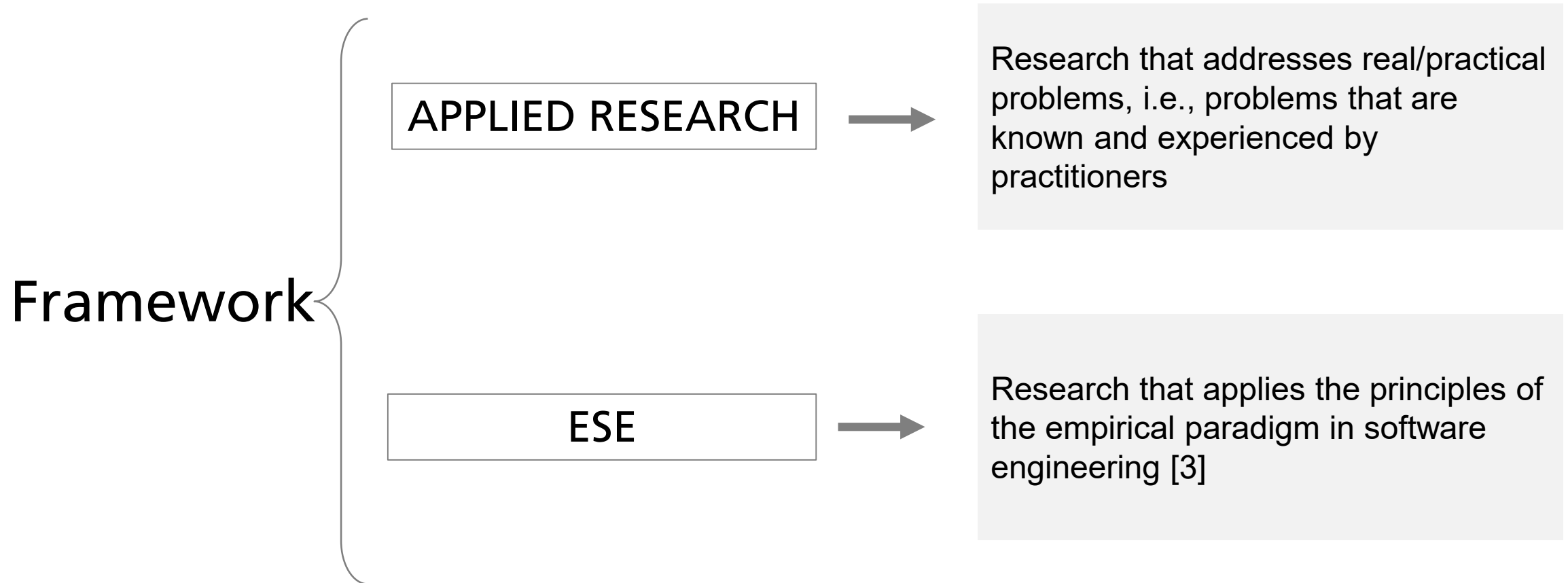


# Historically, the V-Model was introduced as a “process model” [1]

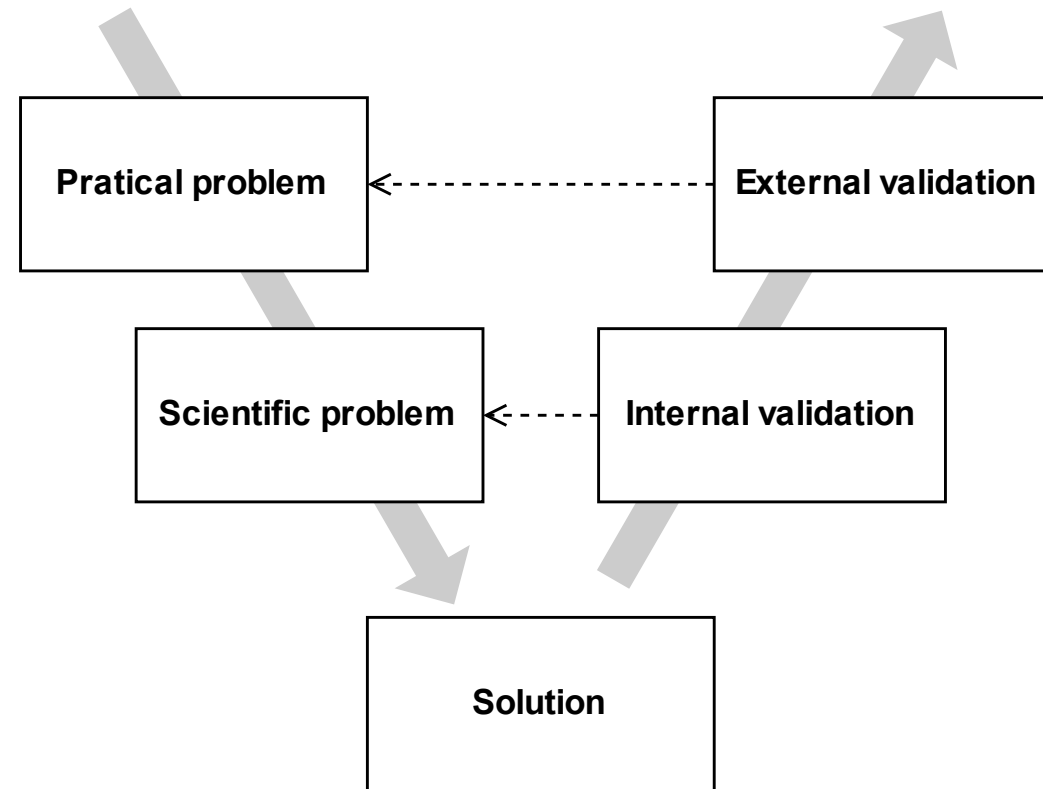


A variant of the original V-Model being used to frame a traditional software development lifecycle. Source: adapted from [2].

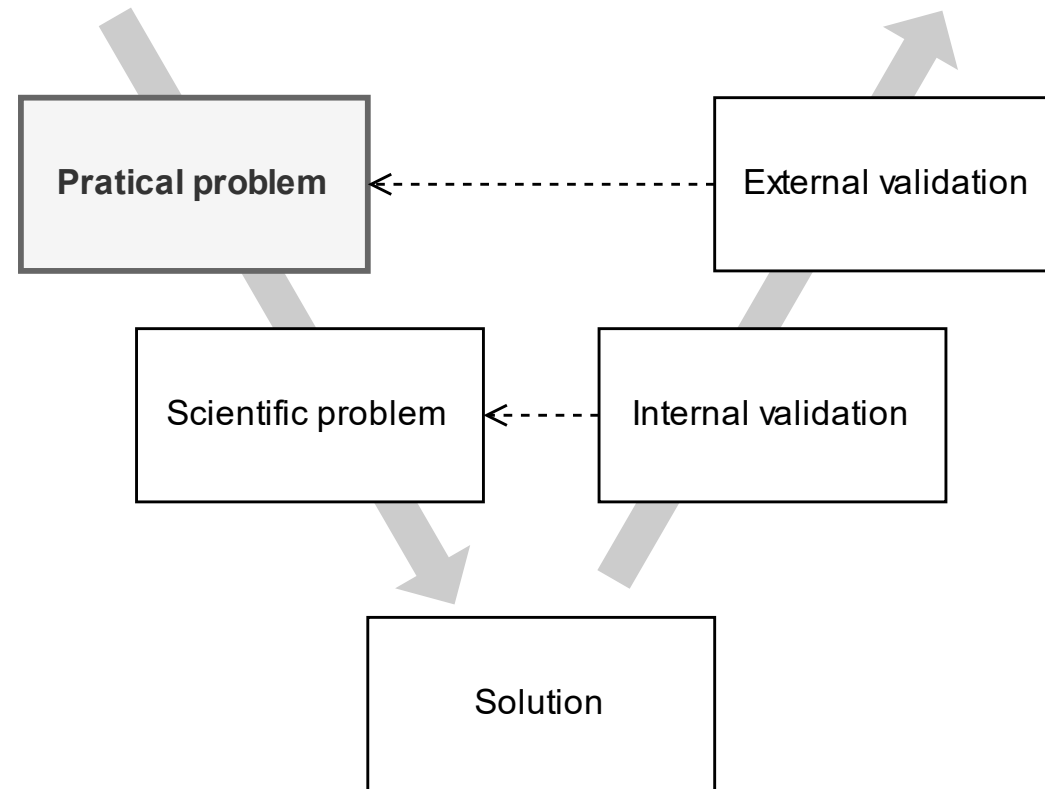
# The *empirical* V-Model is a framework for applied research in ESE



# Most of the time, the empirical V-Model is pictured with five stages



# The first stage is “practical problem”



Also known as “industry problem”/“state of the practice”

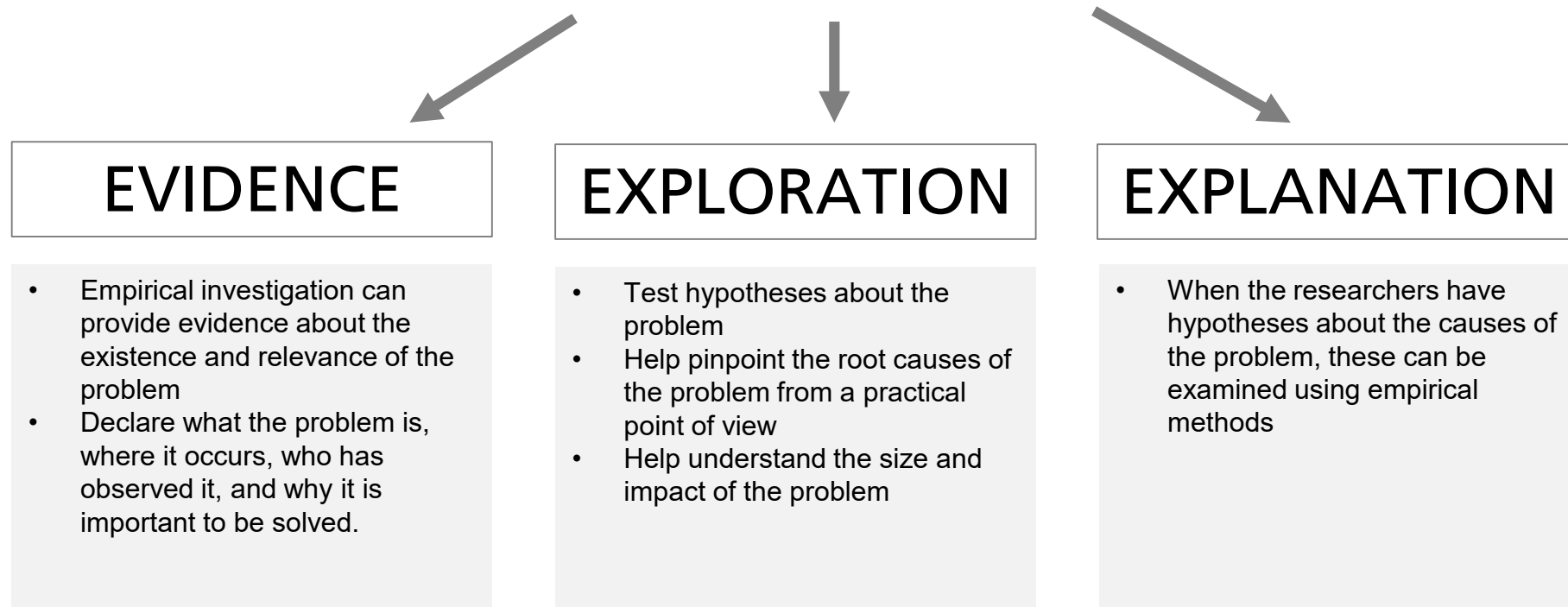
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# What is the practical problem faced by practitioners?

Guiding question to “practical problem”

# The investigation of the practical problem may serve different purposes

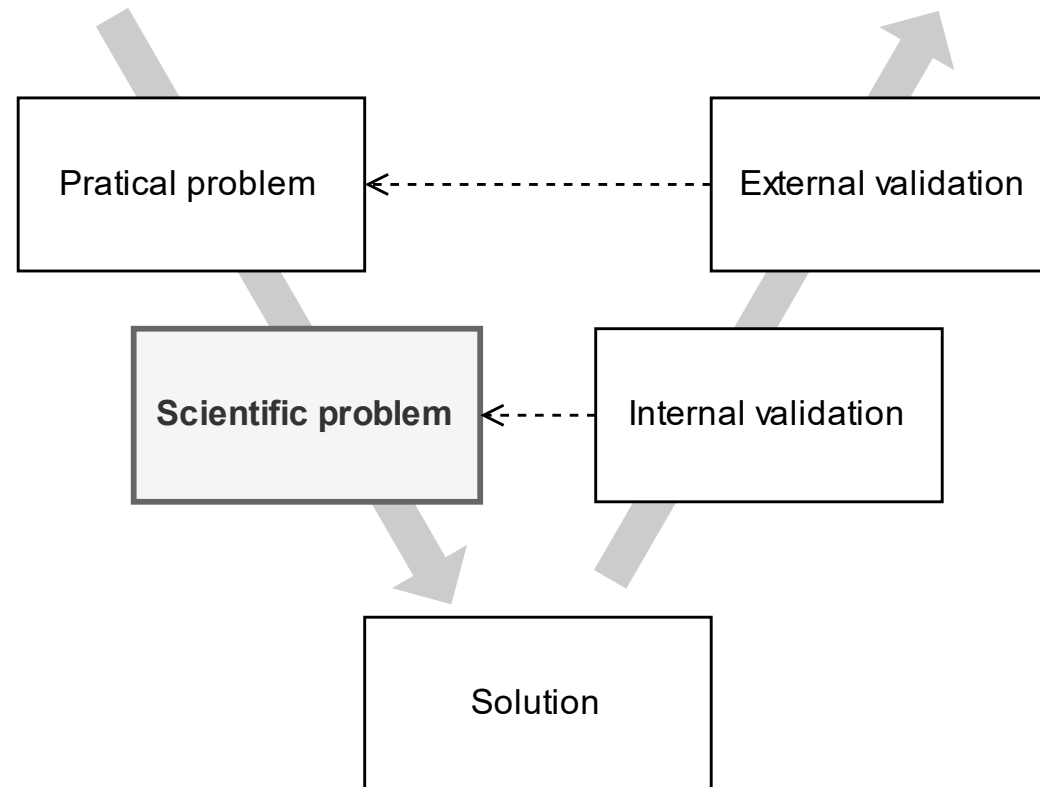
## Practical problem investigation



Typical empirical strategies for investigating practical problems: surveys with practitioners, case studies



## The second stage is “scientific problem”



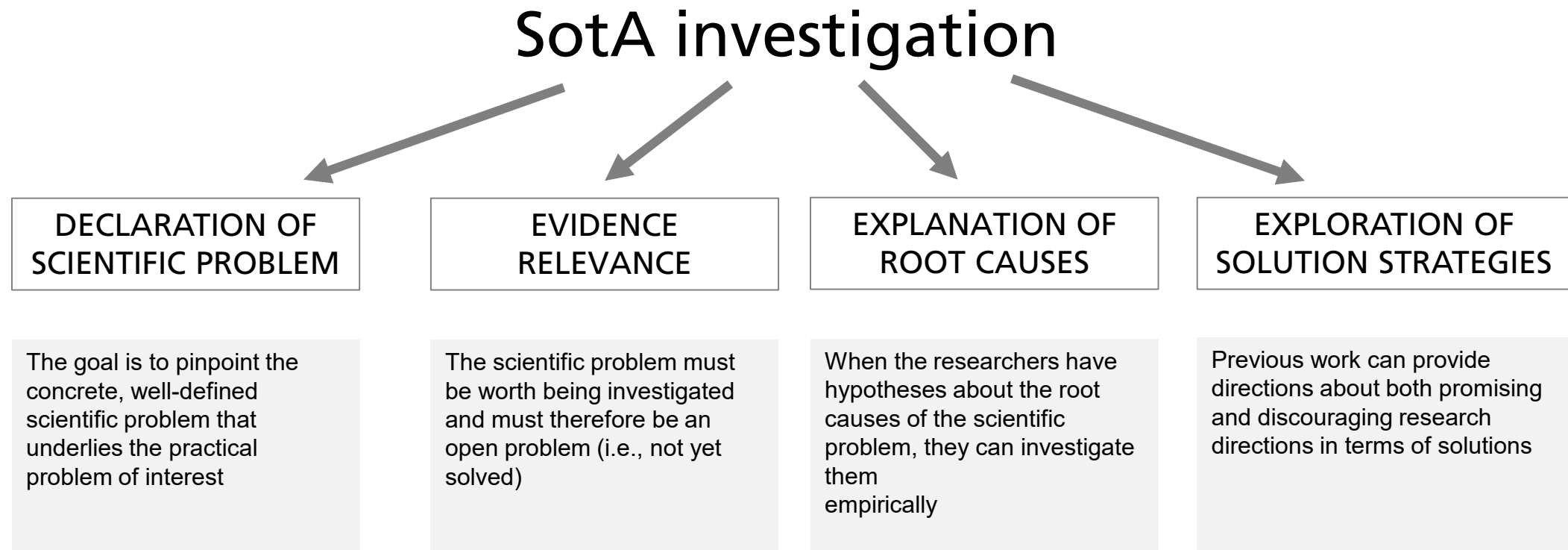
Also known as “research problem”/“research challenge”

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# How does the state of the art (SotA) address the problem?

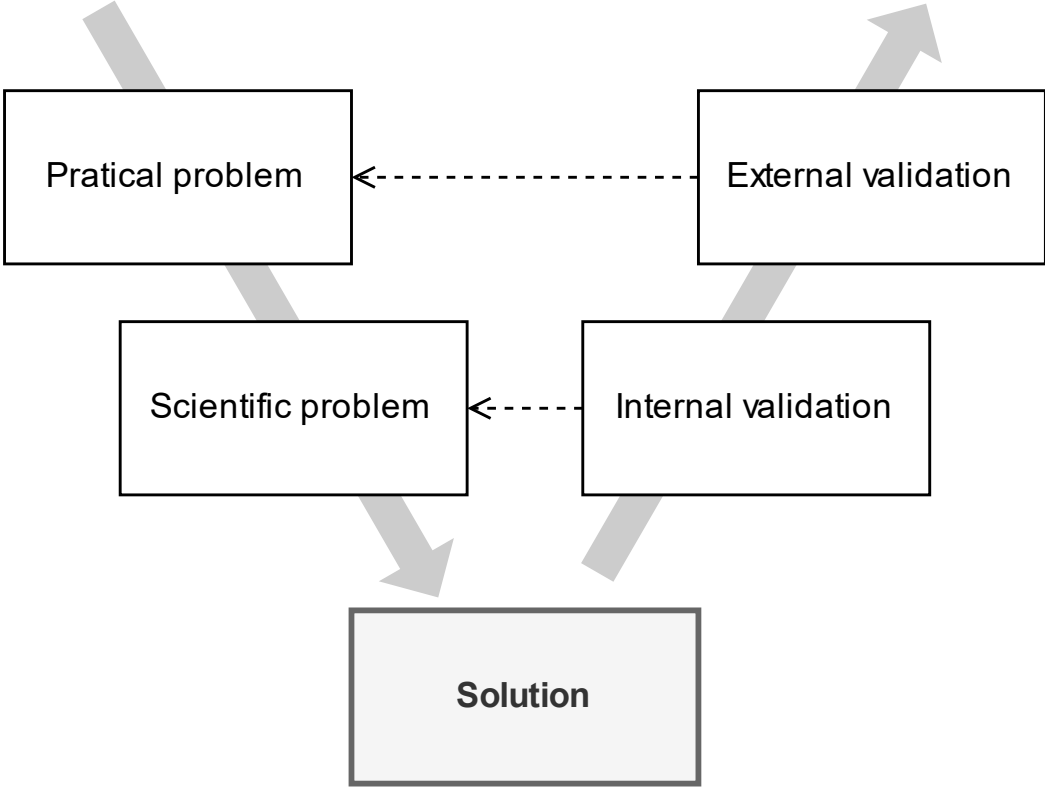
Guiding question to “scientific problem”

# The investigation of the SotA may serve diverse purposes



Typical empirical strategy for investigating scientific problems: systematic literature reviews

# The third stage is “solution”



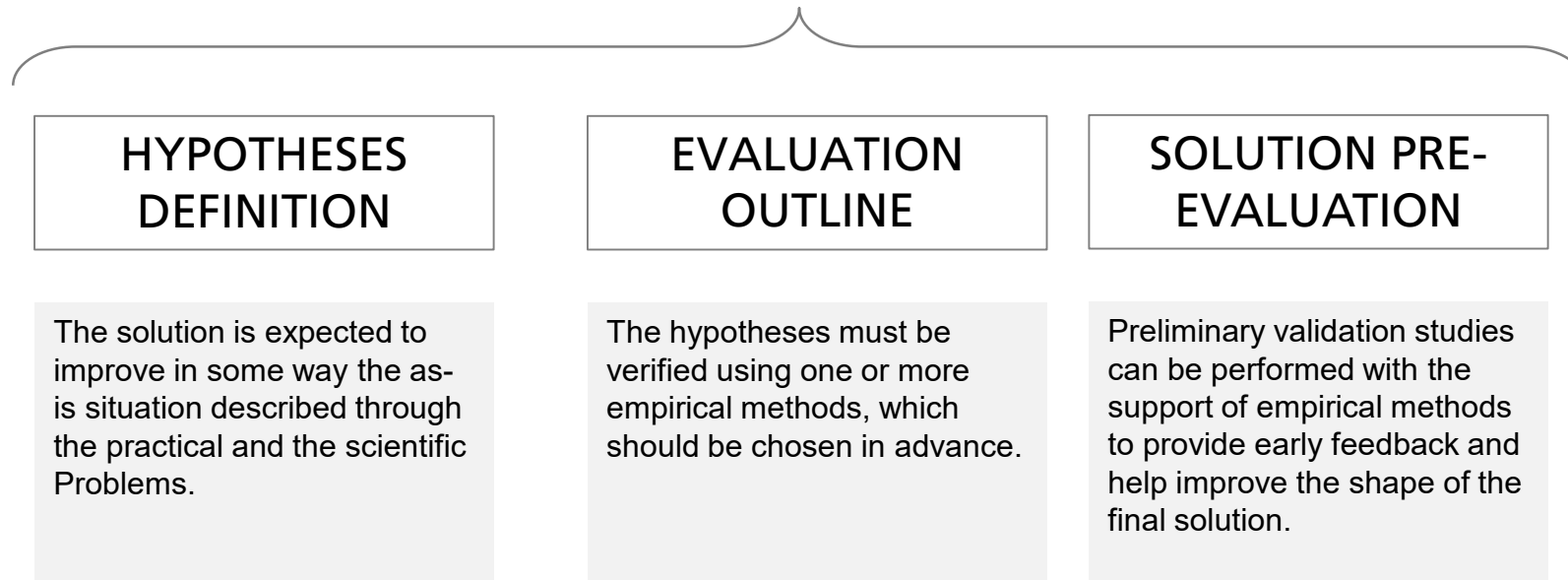
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# What is the research goal and what solution strategy can be used?

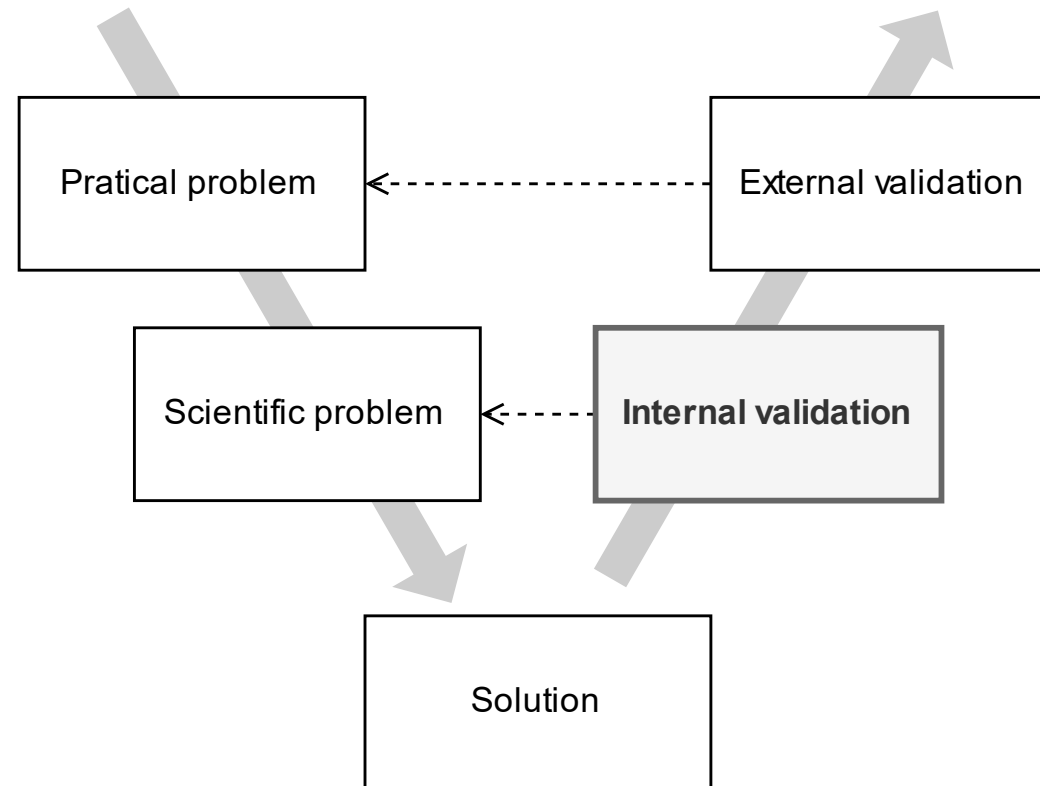
Guiding questions to “solution”

# In the solution stage, empirical methods aren't applied (but empirical work happens)

## Empirical work @ solution stage



# The fourth stage is “internal validation”



Also known as “academic validation”/“scientific benefit”

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# What benefits does the solution offer in terms of addressing the scientific problem?

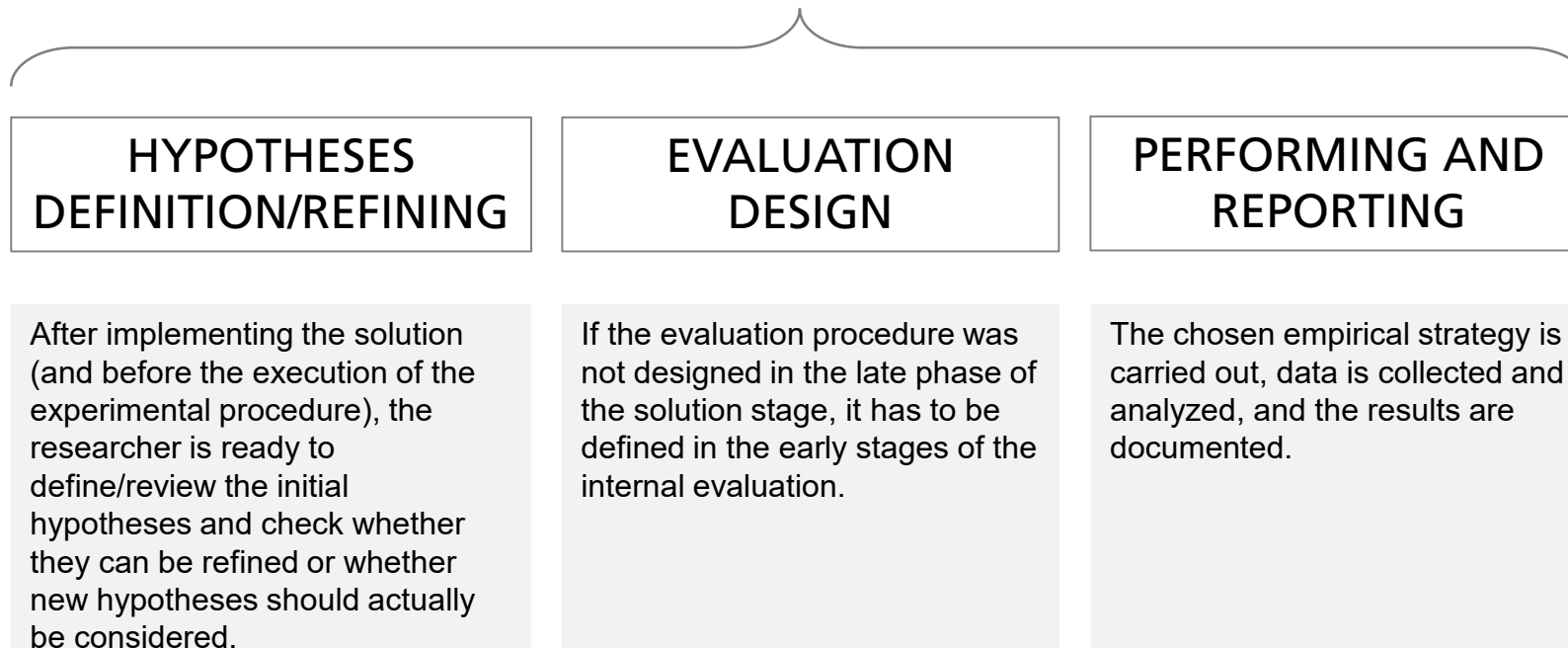
Guiding question to “internal validation”



**Internal validation is about applying one or more empirical methods to test the hypotheses of the implemented solution to address the scientific problem.**

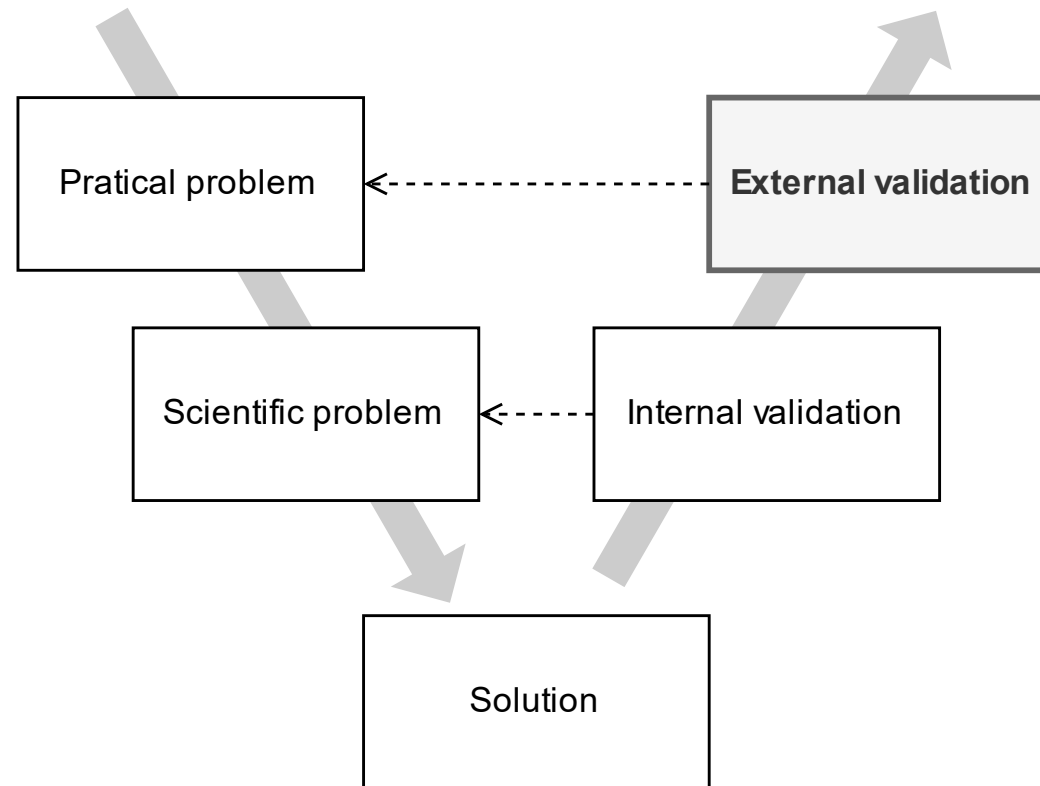
# Empiricism at the internal validation stage include several activities

## Empiricism @ internal validation



Typical empirical strategy during internal validation: controlled experiments

# The fifth stage is “external validation”



Also known as “industry validation”/“practical benefit”

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# To what extent is the solution beneficial in practice?

Guiding questions to “external validation”

# Empiricism in the external validation includes the same activities of internal validation

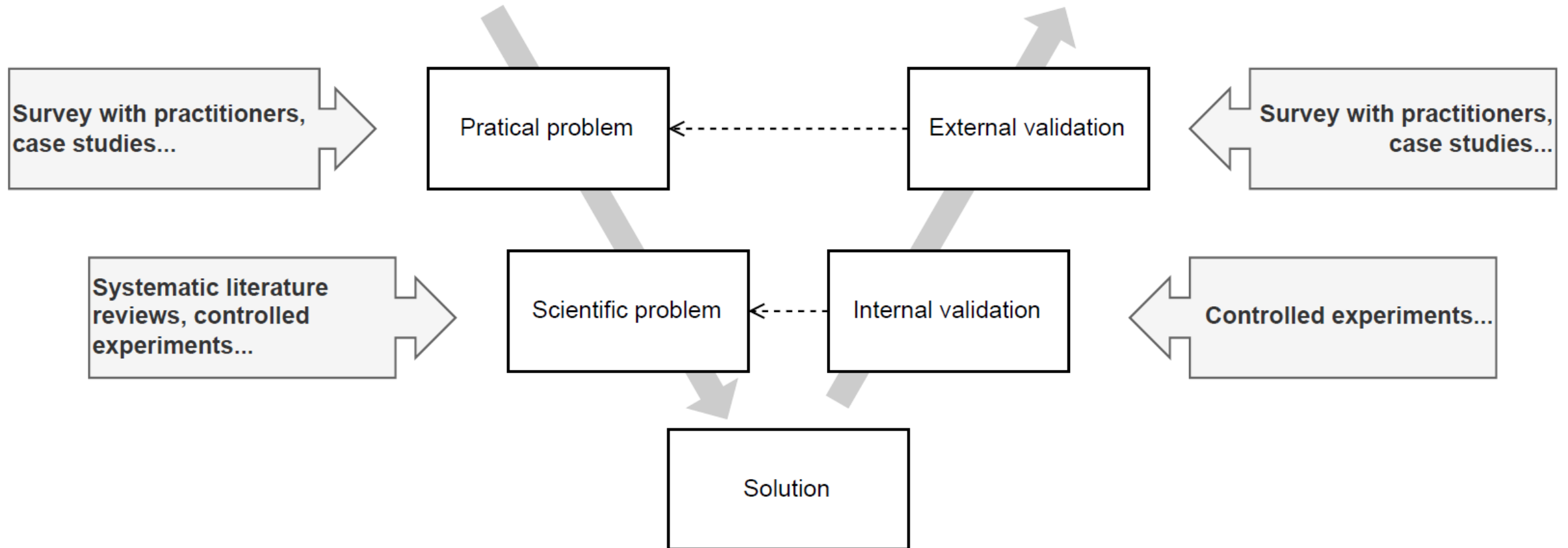
## Empiricism @ internal validation



## Empiricism @ external validation

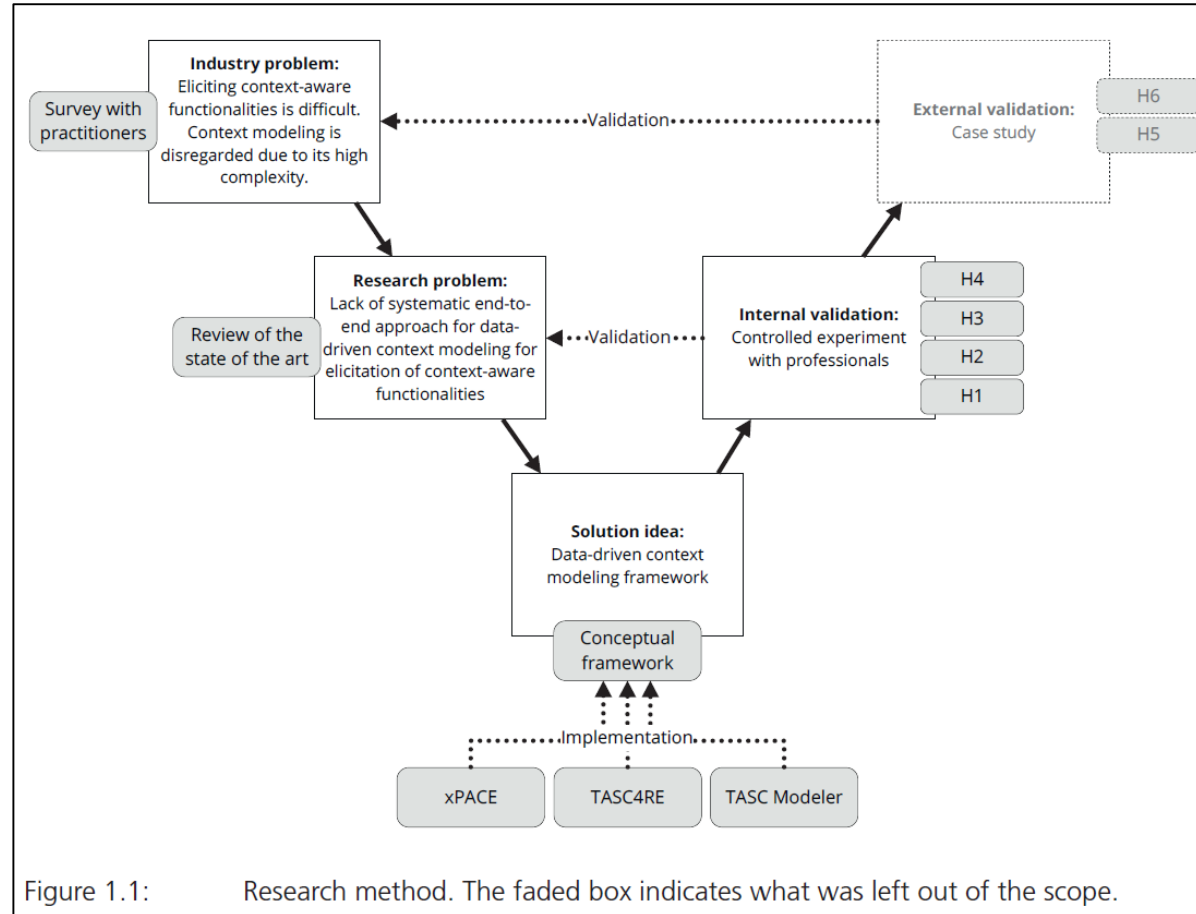
Typical empirical strategies during external validation: case studies, surveys with practitioners

# There are typical empirical strategies used in each stage of the framework



Please note that these are *typical* strategies, not the only strategies.

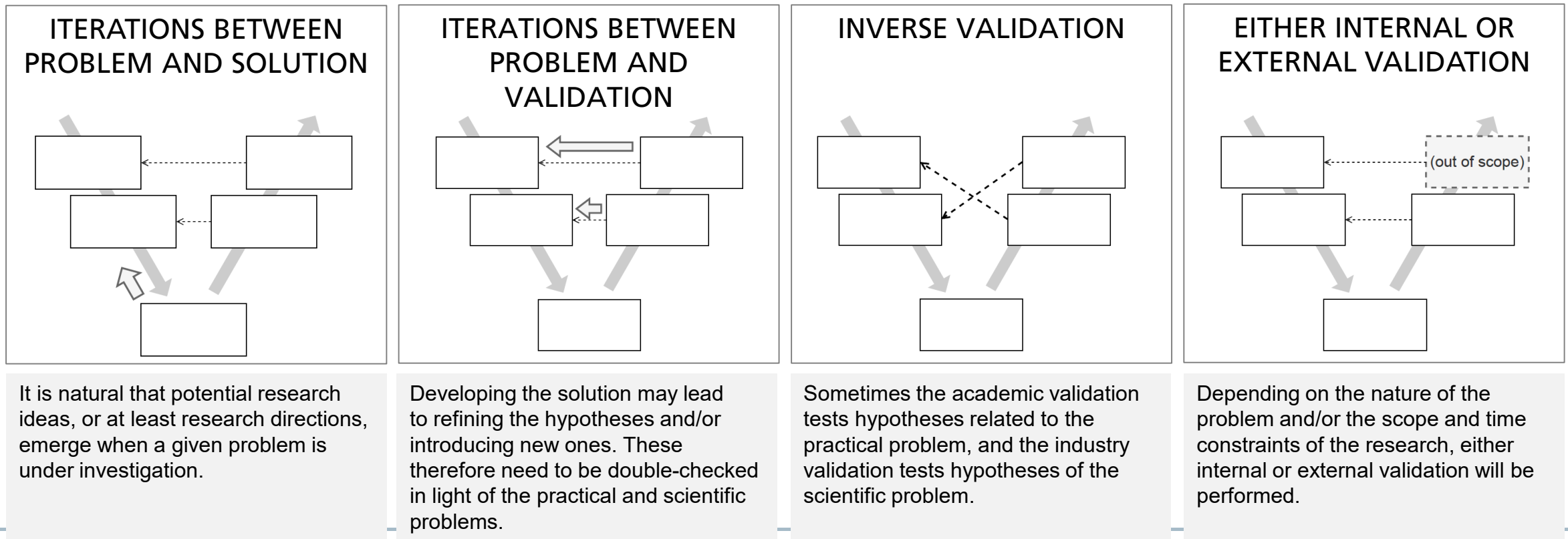
# Example from a PhD thesis



Example of the empirical V-Model being used to describe the research method in a PhD thesis. Source: [4]

# The V-Model may be followed sequentially, but variations exist

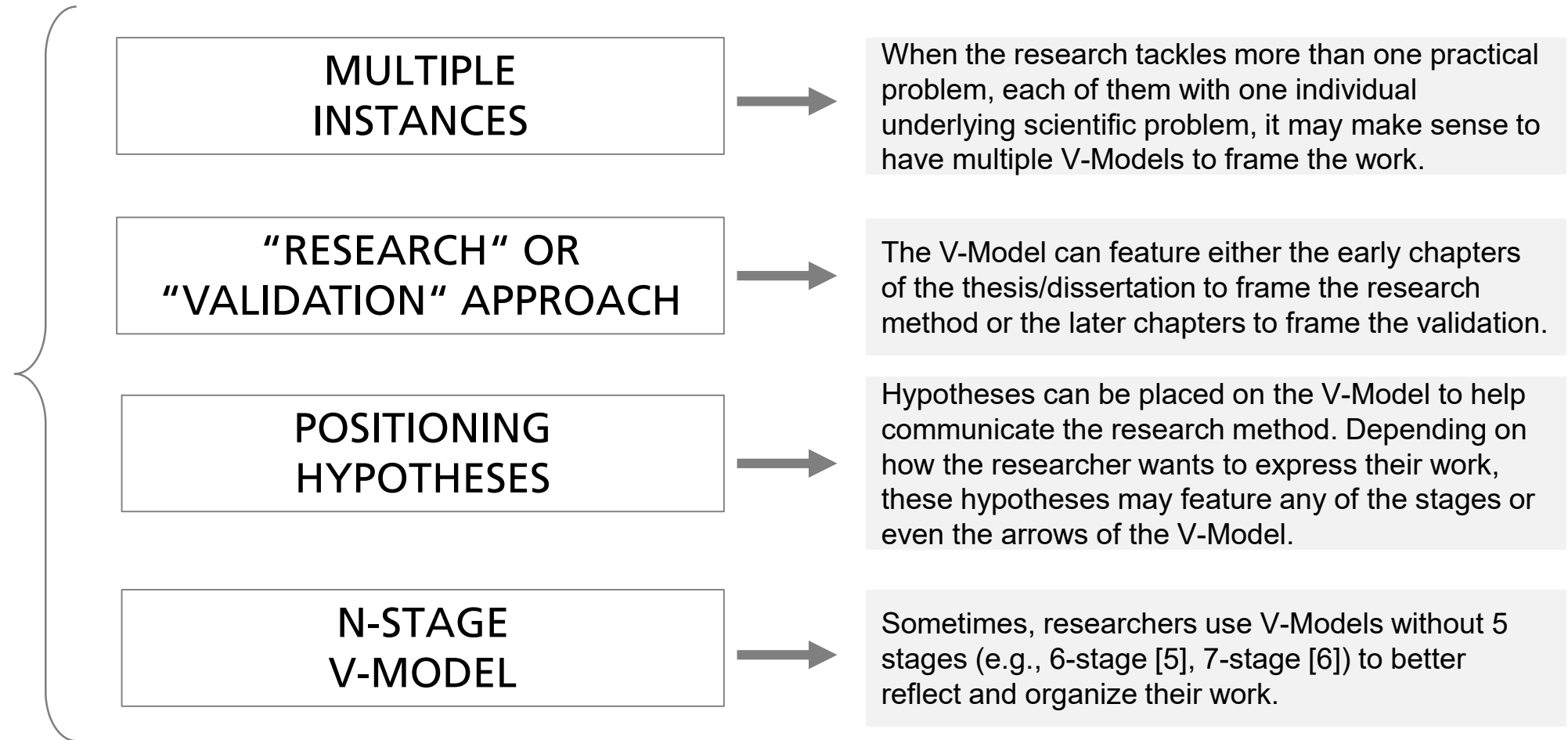
## Variations





# There are alternative usage patterns beyond the 5-stage empirical V-Model

## Alternative usage patterns



# References

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- [1] P. Rook. Controlling software projects. *Software engineering journal*, 1(1):7–16, 1986.
- [2] S. Mathur and S. Malik. Advancements in the v-model. *International Journal of Computer Applications*, 1(12):29–34, 2010.
- [3] V. Basili. The experimental paradigm in software engineering. In *Experimental Software Engineering Issues: Critical Assessment and Future Directions*, pages 1–12. Springer, 1993
- [4] R. Falcão. *Data-driven context modeling for the elicitation of context-aware functionalities*. Fraunhofer Verlag, 2023.
- [5] M. Anastasopoulos. *Evolution Control for Software Product Lines: An Automation Layer over Configuration Management*. Fraunhofer IRB Verlag, 2014.
- [6] O. Armbrust. *The SCOPE approach for scoping software processes*. Fraunhofer Verlag, 2010.