

#### 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"



# What is the practical problem faced by practitioners?

Guiding question to "practical problem"



#### The investigation of the practical problem may serve different purposes



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"



## 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"





### 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

#### HYPOTHESES DEFINITION

The solution is expected to improve in some way the asis situation described through the practical and the scientific Problems.

#### EVALUATION OUTLINE

The hypotheses must be verified using one or more empirical methods, which should be chosen in advance. SOLUTION PRE-EVALUATION

Preliminary validation studies can be performed with the support of empirical methods to provide early feedback and help improve the shape of the final solution.



#### The fourth stage is "internal validation"



Also known as "academic validation"/"scientific benefit"



## 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

HYPOTHESES DEFINITION/REFINING	EVALUATION DESIGN	PERFORMING AND REPORTING
After implementing the solution (and before the execution of the experimental procedure), the researcher is ready to define/review the initial hypotheses and check whether they can be refined or whether new hypotheses should actually be considered.	If the evaluation procedure was not designed in the late phase of the solution stage, it has to be defined in the early stages of the internal evaluation.	The chosen empirical strategy is carried out, data is collected and analyzed, and the results are documented.

Typical empirical strategy during internal validation: controlled experiments



#### The fifth stage is "external validation"



Also known as "industry validation"/"practical benefit"



## 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



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



It is natural that potential research ideas, or at least research directions, emerge when a given problem is under investigation. Developing the solution may lead to refining the hypotheses and/or introducing new ones. These therefore need to be double-checked in light of the practical and scientific problems. Sometimes the academic validation tests hypotheses related to the practical problem, and the industry validation tests hypotheses of the scientific problem. Depending on the nature of the problem and/or the scope and time constraints of the research, either internal or external validation will be performed.



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





#### References

[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.

