Universität Stuttgart
Institute for Diversity Studies in Engineering

Using The Covid 19 Pandemic Context to Teach Systems Thinking to Engineering Students

Meike Tilebein

AIM 2021 Conference
Facing Uncertainty in Higher Education in IE&M due to Pandemic Crisis: Towards a New Education Paradigm

Novi Sad, Serbia
September 16-19, 2021

Based on a paper by Prof. Dr. Meike Tilebein and
M.A. Dipl.-Ing. (FH) Jan Wunderlich, and Prof. Dr. Ralf Tenberg (TU Darmstadt)
presented at the 2021 International System Dynamics Conference:
Using Archetypes to Teach Systems Thinking in an Engineering Master's Course.
https://proceedings.systemdynamics.org/2021/papers/P1235.pdf

!DS
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Agenda

1. Systems Thinking as a Challenge in Higher Education
2. Considerations on Student Motivation and Learning
3. Course Design of a Digital Seminar in Systems Thinking and Findings from Running it
4. Implications for Teaching Systems Thinking in Engineering Higher Education

Systems Thinking Skills (Richmond, 1993)

#	FOCUS ON		AS OPPOSED TO
1	dynamic thinking as thinking in: **behavioral patterns**	⟺	**events**
2	closed-loop thinking as in: seeing the **feedback loop structure** of a system	⟺	**one-way relations**
3	approaching systems from a generic view to first see their **commonalities**	⟺	**specifics**
4	structural thinking as an accurate **stock-and-flow thinking**		
5	operational thinking: real-world variables and mechanisms		
6	continuum thinking that is closely related to computer-based continuous modelling and simulation		
7	scientific thinking that calls for rigorous hypothesis-testing.		

Richmond (1993)

Previous Research on Stock-and-Flow Performance of Domain Experts (5th sem.) and Domain Novices (1st sem.) in Different Knowledge Domains

Kapmeier, F., Happach, R.M., Tilebein, M. (2017):
Bathtub Dynamics Revisited: An Examination of Déformation Professionelle in Higher Education,
in: Systems Research and Behavioral Science Vol. 3 (3), pp. 227-249. DOI: 10.1002/sres.2407

Déformation Professionelle

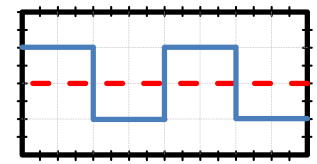
- Tendency to look at and analyze problems according to the conventions and principles of one's own profession and discipline, forgetting any broader perspective (Payne and Patel, 2014)
- Narrow problem solving and over-commitment to norms and practices (Moore, 1969)
- Among the top five decision-making biases (Payne and Patel, 2014)

SF Performance Test Graphic Integration: Original Bathtub Cover Story plus 2 Additional Cover Stories (Business / Engineering Domain resp.)

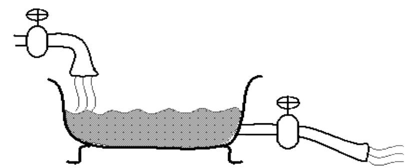
Kapmeier, F., Happach, R.M., Tilebein, M. (2017): DOI: 10.1002/sres.2407

Legend:
inflow
outflow

Square wave



Control Group:
Bathtub
Booth Sweeney & Sterman (2000)

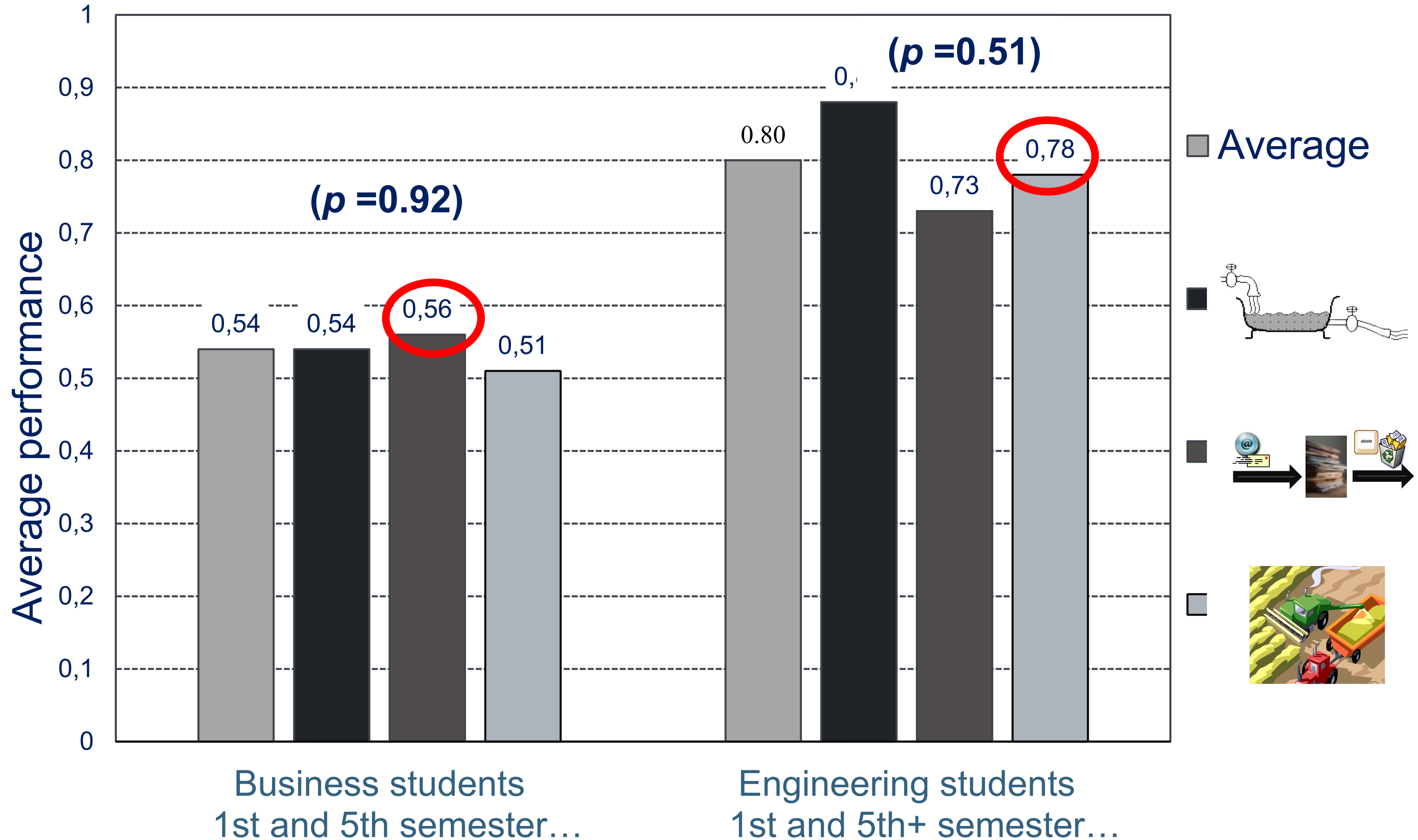


Experimental Group 1:
Online Applications
Kapmeier, Happach & Tilebein (2014)

Experimental Group 2:
Harvester
Kapmeier, Tilebein & Happach (2015)

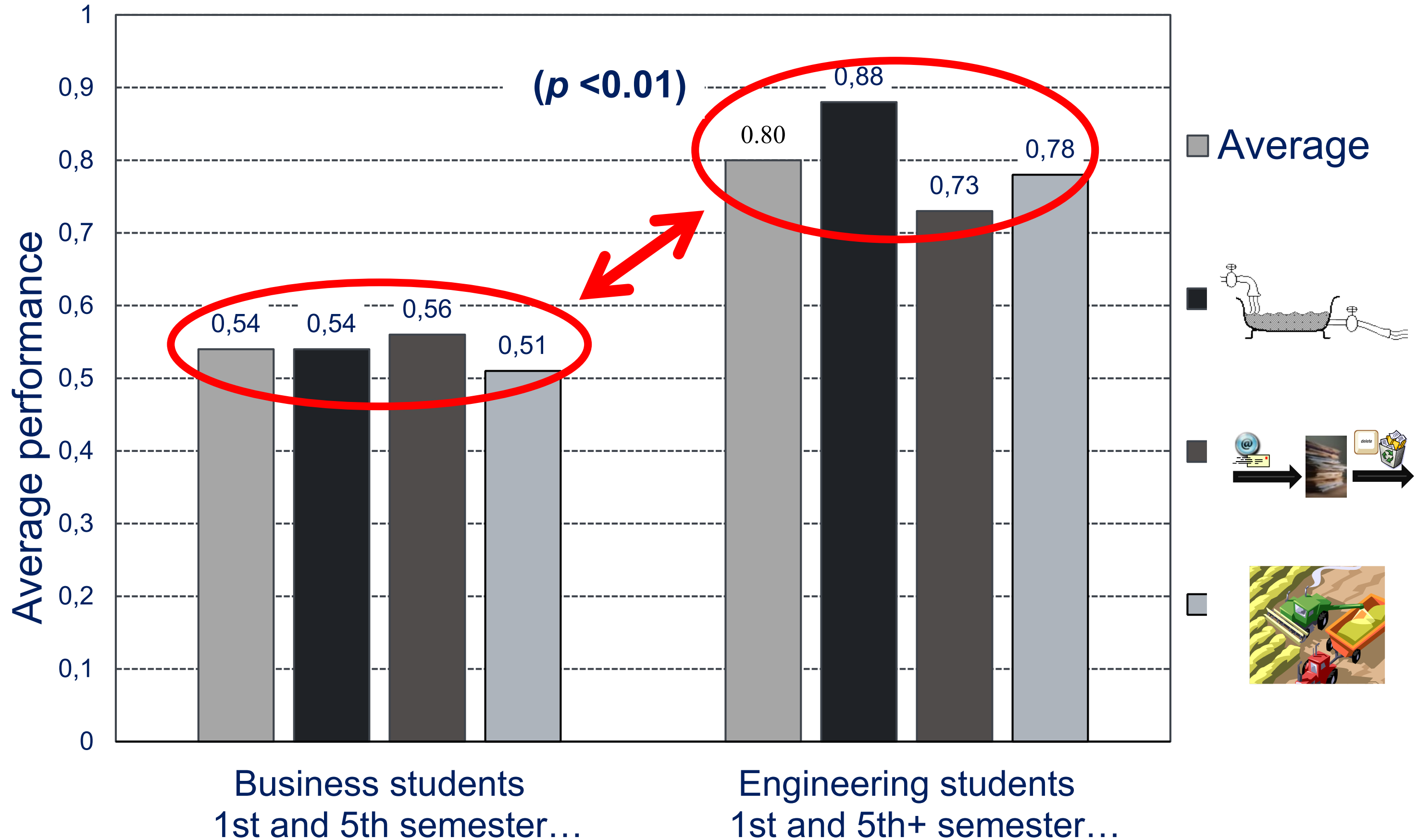
Results Proposition 1: SF Performance Increases when Problem Context is Embedded in the Students' (Business 37/37, Engineer. 58/35) Field of Study

Kapmeier, F., Happach, R.M., Tilebein, M. (2017): DOI: 10.1002/sres.2407



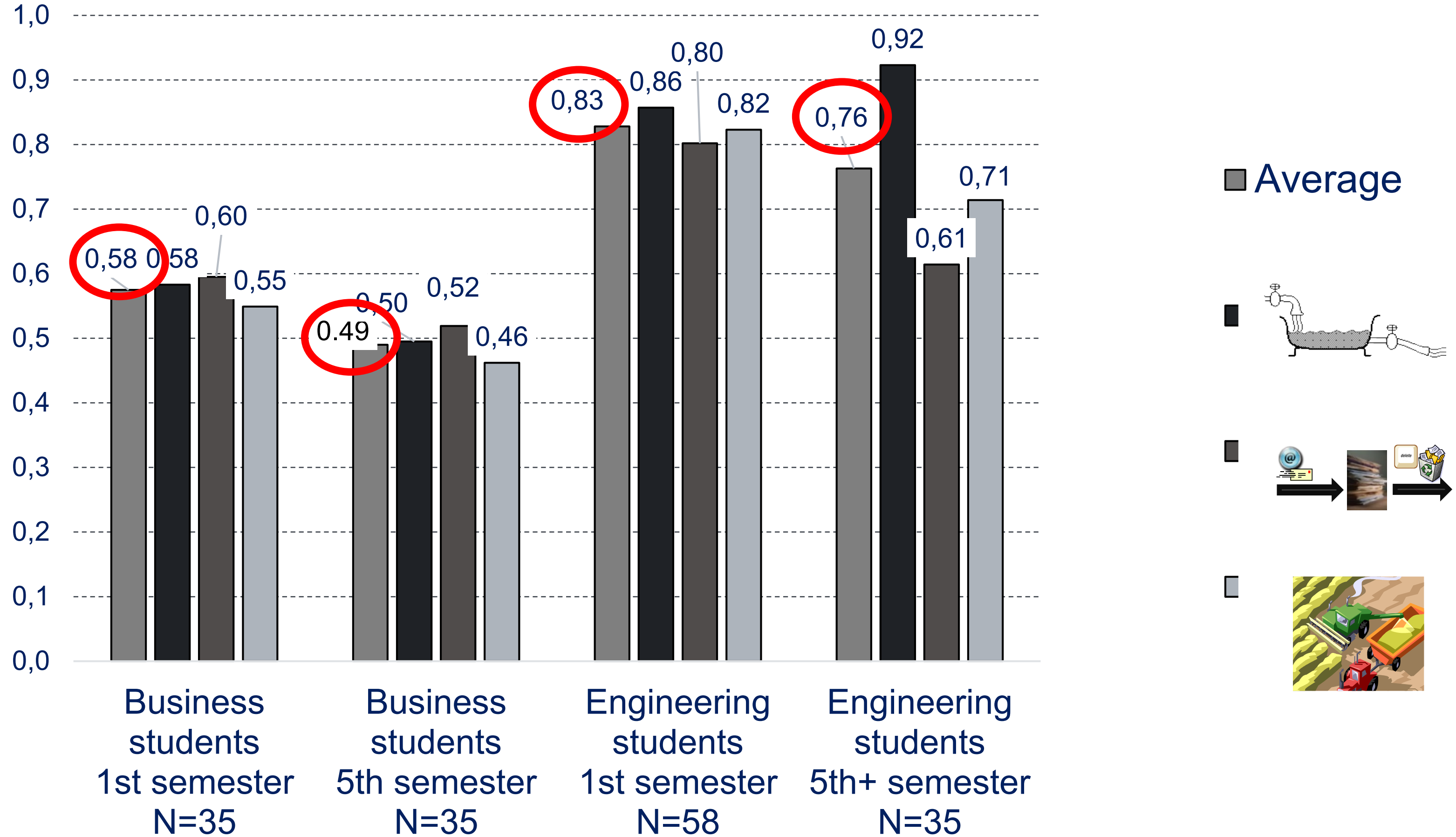
Results Proposition 2: Engineering Students on Average Perform Better on SF Tasks Than Business Students

Kapmeier, F., Happach, R.M., Tilebein, M. (2017): DOI: 10.1002/sres.2407



Proposition 3: Less Advanced Students Show Better SF Performance on Average Than More Advanced Students Within the Same Domain

Kapmeier, F., Happach, R.M., Tilebein, M. (2017): DOI: 10.1002/sres.2407



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Richmond (1993)

Teaching Systems Thinking: System Dynamics Modelling and Simulation

USING MODELS

Microworlds / Simulators as interactive learning environments

- test policies in lab environment
- black-box models

MODELLING

Modelling NOVICE

- exploring existing models
- copying models
- adding structure
- correcting or improving structure
- modelling a canned content description
- modelling problems with vivid, well-known structure and dynamics
- modelling personally chosen problems

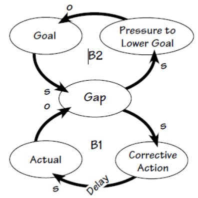
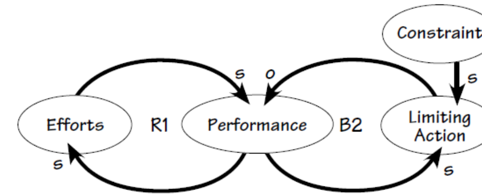
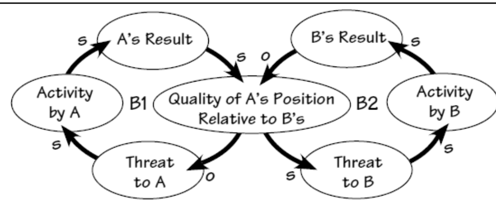
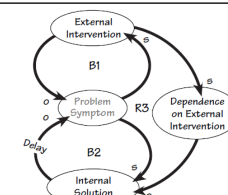
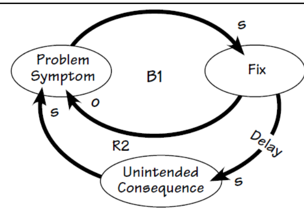
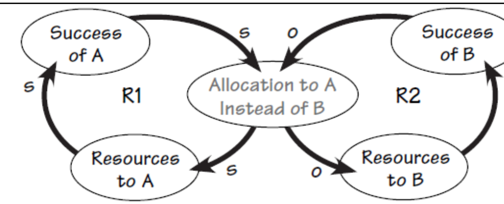
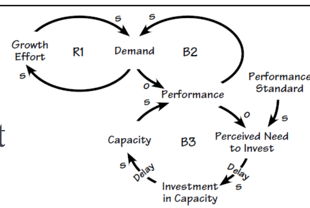
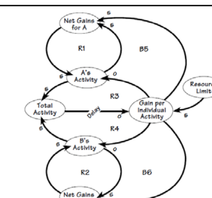
Modelling EXPERT

Richardson (2014a, 2014b, 2014c)

M. Tilebein, J. Wunderlich, R. Tenberg: Using Archetypes to Teach Systems Thinking in an Engineering Master's Course

- **Full paper accepted at 2021 ISDC, extended abstract at https://proceedings.systemdynamics.org/2021/papers/P1235.pdf**
- Systems Thinking can help to solve complex problems in different domains including engineering. Roughly, it can be defined as "a paradigm for viewing reality based on the primacy of the whole and relationships" (Maani 2020 p. 418). Training in Systems Thinking is recommended for individuals of all ages and all stages of professional and personal development, and it is strongly advocated that decision-makers (in business, politics etc.) are trained in Systems Thinking. Accordingly, there are extensive efforts to teach, promote and apply Systems Thinking as early as kindergarten and school age (Fisher 2018, Forrester 1994, 2016), in Higher Education at universities throughout the world (https://systemdynamics.org/degree-courses/), as well as in a wide range of professional fields (Hossain et al. 2020). Richmond (1993) identifies seven distinct Systems Thinking skills in his highly influential article, and different frameworks have been proposed for the development and assessment of competencies towards proficiency in Systems Thinking (e.g. Plate and Monroe, 2014; Schaffernicht and Groesser, 2016), which typically reflect learning outcomes related to both qualitative and quantitative competencies' aspects. While such development frameworks enable an in-depth skills assessment, they do not necessarily prescribe a path for teaching. Kunc (2012) distinguishes two approaches to develop improved understanding of dynamically complex problems: One is *Using Models* (e.g. microworlds as interactive learning environments) and the other is *Modelling*, as in creating both qualitative and quantitative models, which is often the focus of System Dynamics courses.
- For an engineering master's program, we designed a seminar course to teach Systems Thinking based on qualitative modelling. The seminar spans a time of 15 weeks, encompasses 180 hours of students' workload and is a follow-up to a 360 hours workload System Dynamics lecture course that is to a large extent based on the textbook by Sterman (2000). For the seminar we use archetypes as conceptual models and the Covid-19 pandemic as problem context.
- In the paper we describe design considerations based on existing Systems Thinking teaching literature and on theory on students' motivation to learn (Deci and Ryan, 1993; Prenzel, 1997) as well as on our own experience with running seminar courses. We then describe the details of the course design which consists of nine distinguishable stages, and we report findings from running it.
- Based on students' evaluation and the materials they produced throughout the course, our findings (1) support our design assumptions regarding student motivation, (2) give insights on students' struggling with understanding and applying archetypes, and (3) suggest further development of course design. With this we want to provide a course blueprint and contribute to the discussion of how to teach Systems Thinking in Higher Education.

Archetypes (Senge, 1990)

<table>
<tr><th>Archetype Name</th><th>Structure</th><th>Archetype Name</th><th>Structure</th></tr>
<tr><td>Drifting Goals</td><td>
</td><td>Limits to Success</td><td>
</td></tr>
<tr><td>Escalation</td><td>
</td><td>Shifting the Burden/Addiction</td><td>
</td></tr>
<tr><td>Fixes That Fail</td><td>
</td><td>Success to the Successful</td><td>
</td></tr>
<tr><td>Growth and Underinvestment</td><td>
</td><td>Tragedy of the Commons</td><td></td></tr>
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Implications for Teaching Systems Thinking Skills in Engineering Higher Education

Higher education in a specific knowledge domain leads to acquiring not only the body of knowledge of the respective domain but also domain-specific skills, methods, dispositions, values, actions, and attitudes.

- Mathematical skills are important basic skills
  - domain specific stock-and-flow performance
- Be aware of déformation professionelle:
  - performance difference in S/F test observable already after 2 years in higher education
- Students' motivation (and learning, consequently) is high when they
  - perceive their own autonomy / choose problems according to their personal interests
  - experience their own competencies
  - are socially engaged in discussions

Given that today's complex real world problems cannot be entirely solved by one individual or one specific discipline but need knowledge from different domains:

How can we make use of our insights to contribute to a New Education Paradigm?

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Vielen Dank!

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