Measuring Dynamic Problem Solving: The MicroDYN Approach

Samuel Greiff & Joachim Funke
Definition of DPS

- DPS is understood as a primarily cross-curricular competency
- According to the PISA definition PS-competency involves “far more than the basic reproduction of accumulated knowledge”
- Thus, DPS-competency
  - is to be measured computer-based to capture interactive & dynamic aspects
  - does not depend heavily on prior knowledge & semantics (divergent validity)
  - is connected to & yet distinguishable from (fluid) intelligence
- Interactive & dynamic interaction between participant and task is mandatory
Definition of DPS

- Suggested extension for categories of problem types

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<table>
<thead>
<tr>
<th>Problem type</th>
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</thead>
<tbody>
<tr>
<td>Static</td>
</tr>
<tr>
<td>- Closed</td>
</tr>
<tr>
<td>- Open-ended</td>
</tr>
<tr>
<td>Dynamic</td>
</tr>
<tr>
<td>- Tasks constructed ad hoc</td>
</tr>
<tr>
<td>- Tasks embedded in generic framework</td>
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</tbody>
</table>
  - Linear equations: MicroDYN |
  - Finite automata: MicroFIN |
```
Definition of DPS

“DPS is the ability to identify the unknown structure of artefacts in dynamic, technology-rich environments to reach certain goals.”

- **Ability**
  DPS can be learned & altered (e.g. by training)

- **Identify structure & reach goals**
  Abstract requirements of (a) model building (knowledge acquisition) & (b) forecasting (knowledge application)

- **Unknown structure**
  DPS deals with new situations where a routine solution is not at hand

- **Artefact**
  Contrasts DPS to natural objects, (social) events, and so on

- Not explicitly mentioned but inherit in DPS are aspects of metacognition, i.e. monitoring & reflecting
Assessment of DPS

• Based on a formal system structure & embedded in an arbitrary semantic context, dynamic systems model a wide range of everyday activities
• MicroDYN: Systems with continuous variables
• MicroFIN: Systems with discrete variables
• MicroDYN & MicroFIN use *minimal complex systems* to ensure
  – varying difficulties
  – different levels of prior knowledge & varying semantics
  – scalability
• Dynamic systems have been used considerably in research and are well introduced in the literature
Everyday examples that can be modelled ...

by **MicroDYN**-systems:

• Managing monthly expenses  
• Driving a car  
• Conducting experiments  
• Producing groceries  
• Controlling machines  
• Thermostat  
• Dosaging medicine  
• Cooking & frying  
• Managing medical emergencies  
• Exercising fitness  
• and so on...

by **MicroFIN**-systems:

• Mobile phones  
• Microwaves  
• MP3-Player  
• Home theatres  
• Ticket vending machines  
• Radios  
• Remote controls  
• Car cockpit controls  
• Coffee machines  
• Washing machines  
• Digital Cameras  
• Safe  
• and so on...
The MicroDYN approach

- Main effect
- Eigendynamic
- Multiple effect
- Multiple dependence
- Side effect
- Exogenous variables
- Endogenous variables

The MicroDYN & MicroFIN Approach
University Heidelberg
The MicroDYN approach

- (A) Information Retrieval
  - „Explore the system.“
  - 180 seconds

- (B) Model Building
  - „Draw the connections between variables as you suppose.“
  - Simultaneously to (A)

- (C) Forecasting
  - „Reach given target values on the endogenous variables by entering correct values in the system.“
  - 60 seconds
The MicroDYN approach

- Dörner’s Theory of Operational Intelligence (1986)
- Theoretical foundation is obtained
- 3 facets of DPS are measured

<table>
<thead>
<tr>
<th>Problem characteristics</th>
<th>Requirements by the problem solver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intransparency</td>
<td>Information retrieval</td>
</tr>
<tr>
<td>Connectedness</td>
<td>Model building</td>
</tr>
<tr>
<td>Dynamics</td>
<td>Forecasting</td>
</tr>
<tr>
<td>Complexity</td>
<td>Reduction of information</td>
</tr>
<tr>
<td>Polytecly</td>
<td>Priority setting and evaluation</td>
</tr>
</tbody>
</table>
MicroDYN: Advantages

• Constructs derived from Cognitive Psychology
  – 3 facets theoretically derived & empirically tested
  – Intradimensional competence levels (experimentally derived)
  – Experimental background
• Requires dynamic interaction & evaluates overt behavior
• Difficulty can be freely varied
• Overarching frame of reference (item commensurability)
• Successful participation with HEIFI in PISA 1999 (national German extension)
• Ease of change (in Itembuilder & Execution Environment)
Conceptual issues

• **Necessities on a macro level:**
  – Common framework & overarching frame of reference
  – Theoretically bound & empirically tested items
  – Systematic approach in formulating items

• **Necessities on a micro level:**
  – Influence of item characteristics on difficulty
  – Competence levels
  – Systematic approach in varying item characteristics & tailoring items to certain levels of competency (scalability)
Tentative results
Tentative results

![Diagram of correlations between model building, forecasting, information retrieval, HEIFI knowledge, HEIFI control, school achievement, and their respective R^2 values.

- Model building to School achievement: R^2 = .41** (p = .08)
- Forecasting to School achievement: R^2 = .39** (p = .10)
- Information retrieval to HEIFI knowledge: R^2 = .28** (p = .09)
- Information retrieval to HEIFI control: R^2 = .71** (p = .11)
- Model building to Forecasting: .73** (p = .07)
- Model building to Information retrieval: .75** (p = .05)
- Forecasting to Information retrieval: .69** (p = .07)
- Forecasting to HEIFI knowledge: .40* (p = .22)
- Forecasting to HEIFI control: .48** (p = .18)
- Information retrieval to HEIFI knowledge: .36* (p = .18)
- Information retrieval to HEIFI control: .36** (p = .15)
<table>
<thead>
<tr>
<th></th>
<th>$\chi^2$</th>
<th>df</th>
<th>$p$</th>
<th>$\chi^2/df$</th>
<th>CFI</th>
<th>TLI</th>
<th>RMSEA</th>
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</thead>
<tbody>
<tr>
<td>MicroDYN 3-dimensional</td>
<td>40.47</td>
<td>28</td>
<td>.06</td>
<td>1.45</td>
<td>.98</td>
<td>.98</td>
<td>.06</td>
</tr>
<tr>
<td>MicroDYN, HEIFI &amp;</td>
<td>76.26</td>
<td>53</td>
<td>.02</td>
<td>1.44</td>
<td>.97</td>
<td>.96</td>
<td>.07</td>
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<tr>
<td>school achievement</td>
<td></td>
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The MicroDYN and MicroFIN Approach
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Climatic change

Space Shuttle

Ecological Scenarios
Economic Scenarios
Medical Scenarios

Samuel Greiff
February 8th – 12th 2010
<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>2x2-systems</th>
<th>3x3-systems</th>
<th>4x4-systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low complexity</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
<td><img src="image3.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Medium complexity</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td><img src="image5.png" alt="Diagram" /></td>
<td><img src="image6.png" alt="Diagram" /></td>
</tr>
<tr>
<td>High complexity</td>
<td><img src="image7.png" alt="Diagram" /></td>
<td><img src="image8.png" alt="Diagram" /></td>
<td><img src="image9.png" alt="Diagram" /></td>
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</table>
What do we want to measure?

- Knowledge, intelligence & DPS are distinct constructs
- The assessment design needs to target the separation of these constructs
  - “You get out, what you put in”
  - to capture cross-curricular DPS a valid design is needed

⇒ DPS requires to explore a system systematically, create a mental model & control the systems independent of semantic embedment & prior knowledge
References


Thank you for your attention
Appendix: Screenshots MicroDYN

• Screenshots of all MicroDYN-Items in German with varying semantic embedment & realism
Airplane

Gepäck

Benzin

Flugdauer

Abgasmenge

Alles löschen

zurück

Ausführen!

Beende Steuerphase

Modell

Gepäck

Flugdauer

Benzin

Abgasmenge
Fitness Drink

Mesana

0 2 4

Belus

0 2 4

Geschmack

0 2 4

stärkende Wirkung

0 2 4

Alles löschen

zurück

Ausführen!

Beende Steuerphase

Modell

Mesana → Geschmack

Belus → stärkende Wirkung
Issues in item development

Climate
First Aid

- Sarol
- Rexol
- Menol

Herzschlag
- 0
- 2
- 4

Atmung
- 0
- 2
- 4

Zahl weißer Blutkörperchen
- 0
- 2
- 4

Alles löschen
zurück
Ausführen!

Beende Steuerphase
Deodorant

Miral

Carumin

Norilan

sportlich

süßlich

frisch

18

14

14

Alles löschen  zurück  Ausführen!

Beende Steuerphase

Modell

Miral 运动
Carumin 甜蜜
Norilan 清新
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Issues in item development