9th ICLTC ▪ 22.06.2016

Segmenting or self-explanation prompts – the impact on learning with non-algorithmic worked examples

Katrin Schüßler, Jenna Koenen, & Elke Sumfleth

Outline

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

- Theoretical Framework & Research Questions
- Participants & Design
- Learning Materials
- Procedure
- Results & Discussion

UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

Theoretical Framework & Research Questions

Non-algorithmic Worked Examples

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

- CLT (Sweller, 2005), CTML (Mayer, 2009; 2014), CATLM (Moreno, 2005)
- Worked example principle (Renkl, 2014; Sweller & Cooper, 1985)
  - → reduce extraneous processing
  - → foster generative processing (Renkl, 2014)
- Segmenting principle (Gerjets, Scheiter, & Catrambone, 2006; Mayer, 2009; Renkl, 2013)
  - → manage essential processing
  - → pausing and temporal cueing (Spanjers, van Gog, Wouters, & van Merriënboer, 2012)
- Self-explanation principle (Renkl, 2014; Roy & Chi, 2005; Wylie & Chi, 2014)
  - → foster generative processing
  - → double edged effect of conceptual oriented prompting (Berthold, Röder, Knörzer, Kessler, & Renkl, 2011)

Non-algorithmic Worked Examples

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

- CLT (Sweller, 2014), CTML (Mayer, 2009; 2014), C
- Worked example principle (Renkl, 2014
  - → reduce extraneous processing
  - → foster generative processing (Renkl, 2014
- Segmenting principle (Gerjets, Scheiter, & C
  - → manage essential processing
  - → pausing and temporal cueing (Spanjers, v
- Self explanation principle (Renkl, 2014;
  - → foster generative processing
  - → double edged effect of conceptual orie
    Kessler, & Renkl, 2011)

1st Research Question:

How do
- segmentation (yes/no)
- prompting (yes/no)

influence
- cognitive load
- affective variables
- learning outcomes

when learning with non-algorithmic worked examples?

Multiple Ratings on Cognitive Load and Affective Variables

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

- one kind of short tasks (weekday problems)
- comparing ratings for each problem to one single rating at the end

1st Study (van Gog, Kirschner, Kester, & Paas, 2012)

- invested mental effort (Paas, 1992)

→ single ratings are higher than the average of multiple ratings

2nd Study (Schmeck, Opfermann, van Gog, Paas, & Leutner, 2015)

- invested mental effort (Paas, 1992)
- perceived task difficulty (Kalyuga, Chandler, Tuovinen, & Sweller, 2001)
- perceived interest (*"I like such puzzles and riddles"* (FAM), Rheinberg, Vollmeyer, & Burns, 2001)
- motivation (*"I would work on such problems in my free time"* (FAM), Rheinberg et al., 2001)

→ single ratings on cognitive load are higher than the average of multiple ratings

→ single ratings on affective variables do not differ from the average of multiple ratings

Multiple Ratings on Cognitive Load and Affective Variables

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

- one kind of short tasks (weekday proble
- comparing ratings for each problem to c

1) van Gog, Kirschner, Kester, & Paas, 2(
   - invested mental effort (Paas, 1992)

→ single ratings are higher than the average c

2) Schmeck, Opfermann, van Gog, Paas,
   - invested mental effort (Paas, 1992)
   - perceived task difficulty (Kalyuga et al., 2001)
   - perceived interest (*"I like such puzzles and riddles"*
   - motivation (*"I would work on such problems in my free*

→ single ratings on cognitive load are higher t

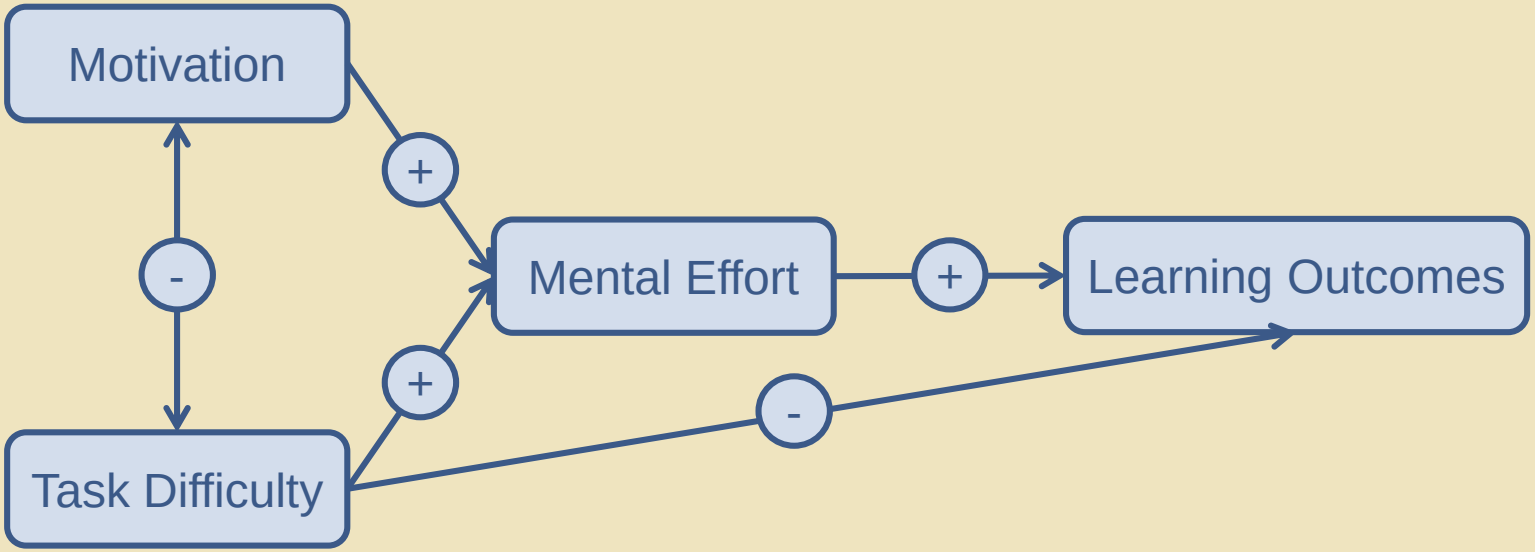
→ single ratings on affective variables do not
ratings

2nd Research Question:

How do
- invested mental effort
- perceived task difficulty
- motivation
- perceived understanding

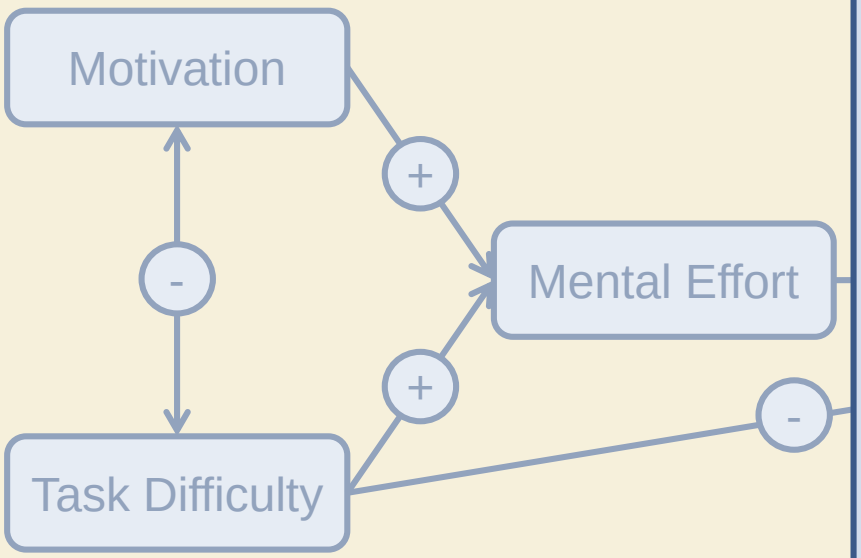
develop during studying one complex task?

Relation of Cognitive and Affective Variables and Learning Outcomes



Stebner, Dicke, Kühl, Thillmann, Wirth, & Leutner, 2015

Relation of Cognitive and Affective Variables and Learning Outcomes



Stebner, Dicke, Kühl, Thillmann, Wirth, & Leutner, 2015

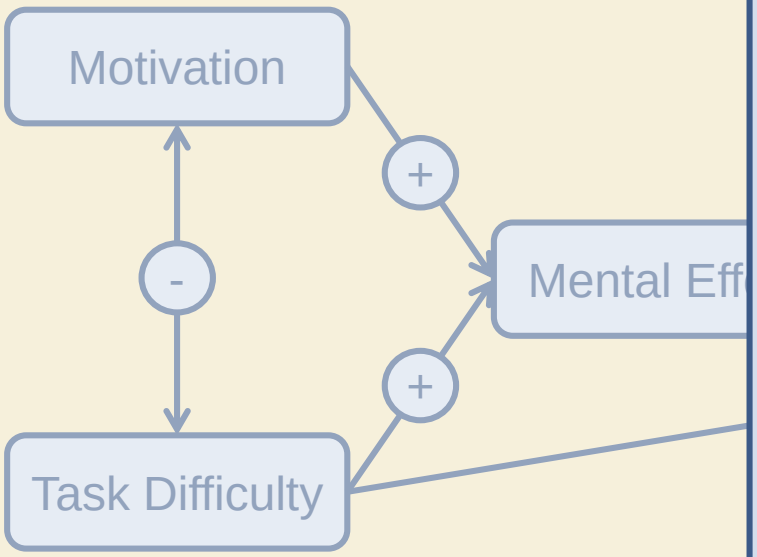
3rd Research Question:

How do multiple subjective ratings on

- perceived task difficulty
- invested mental effort
- motivation
- perceived understanding

relate to learning outcomes?

Relation of Cognitive and Affective Variables and Learning Outcomes



Stebner, Dicke, Kühl, Thillmann, Wirth, & Leutner, 201

4th Research Question:

How does the relation between multiple subjective ratings on

- invested mental effort
- perceived task difficulty
- motivation
- perceived understanding

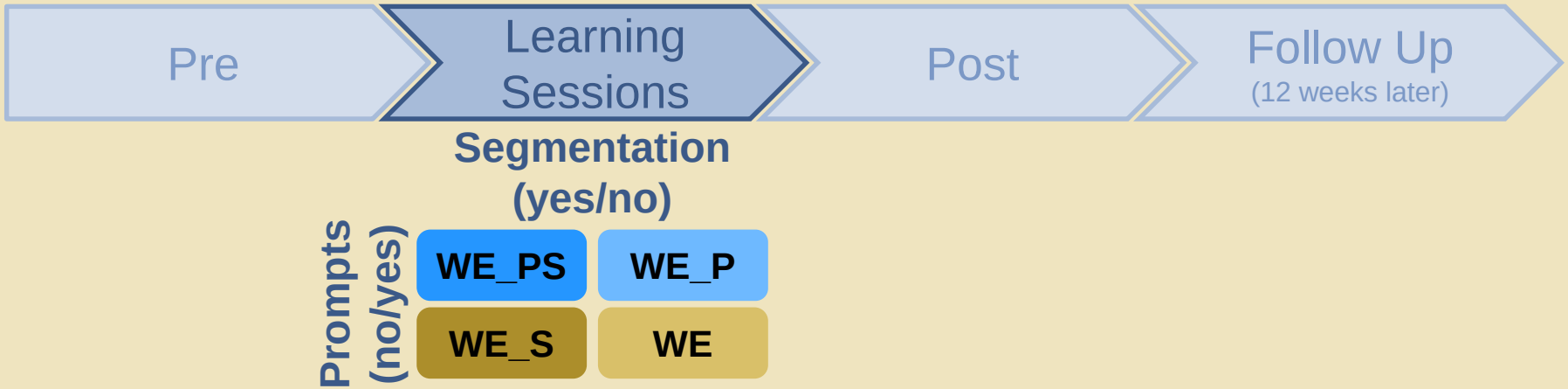
vary during studying one complex task?

UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

Participants & Design

Participants & Design



- 3 learning sessions
  - 1 worked example
  - 60 minutes study time (maximum)

- participants
  - 436 students (9th or 10th grade, German secondary schools (*"Realschule" & "Gymnasium"*), 49,8 % ♀, M_{age} = 14.17, *SD* = .63, randomly assigned to conditions)
  - low prior knowledge on acids (*expertise reversal principle,* Kalyuga, 2014)

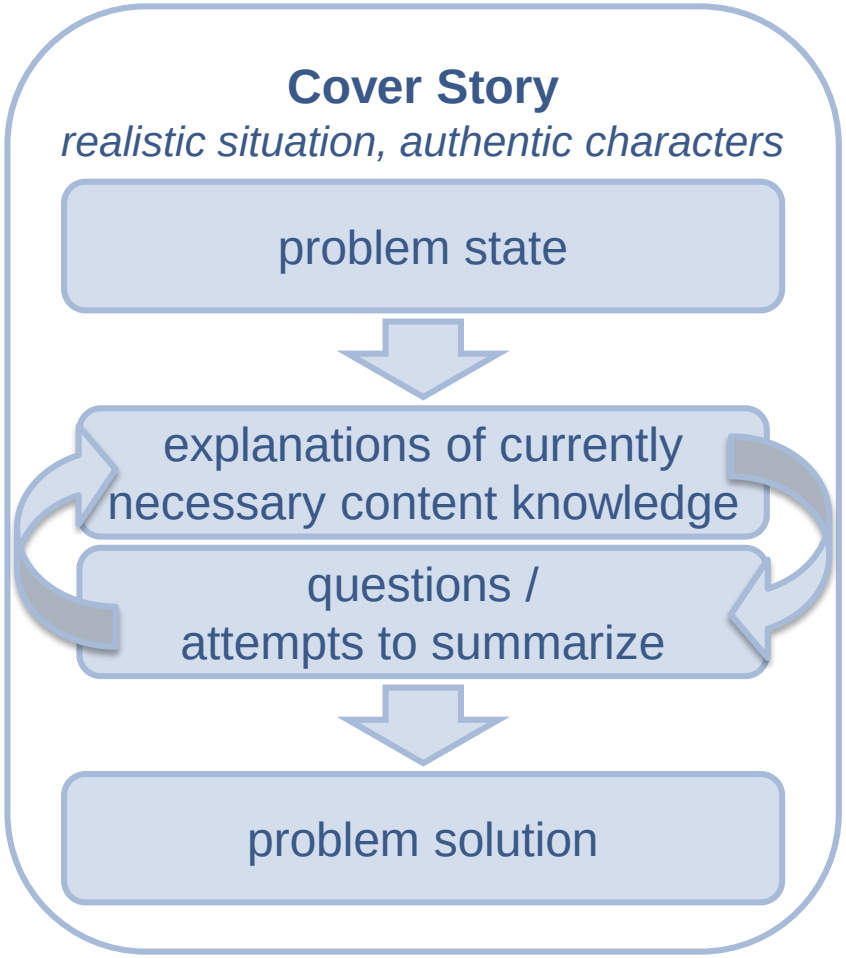
UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

Learning Materials

Learning Materials

Worked Example



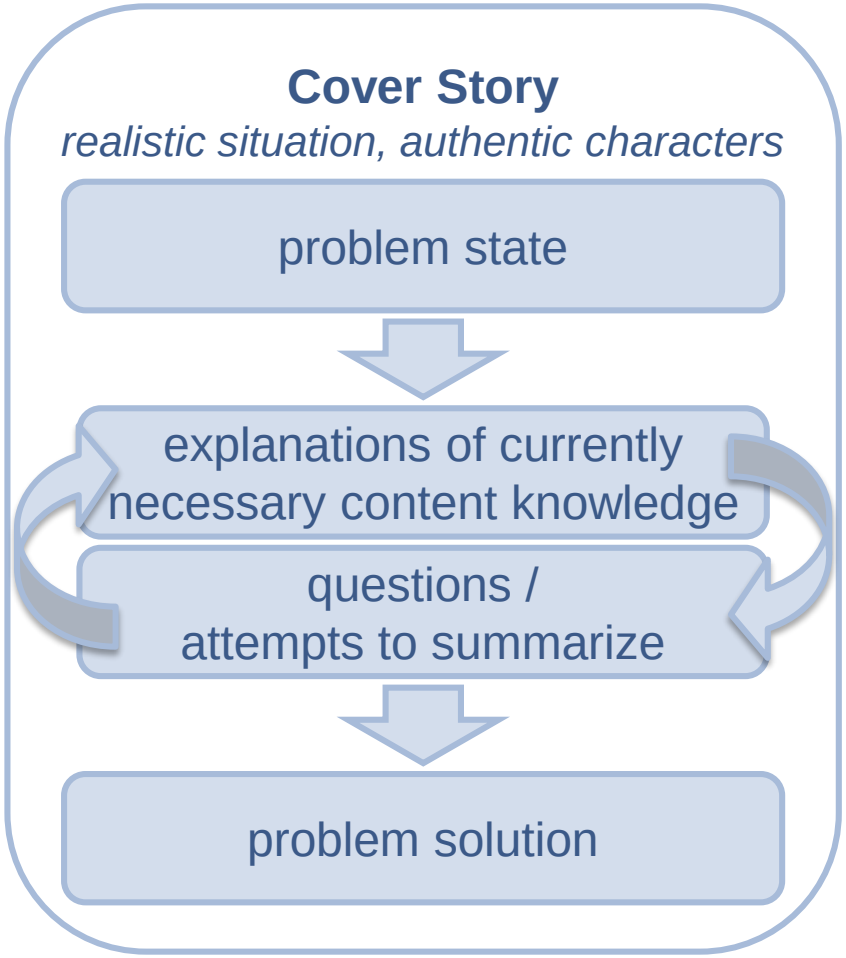
- paper-based
- content: acids, development of a first conceptual understanding (Reimann, 1997; Stark, 1999)

- personalization principle (Mayer, 2009)
- model-observer similarity principle (Renkl, 2013)
- explanation-help principle (Berthold & Renkl, 2010; Stark, 1999; Renkl, 2013; 2014)
- studying-errors principle (Große & Renkl 2004; 2007; Renkl, 2013; 2014)
- multimedia principle (Mayer, 2009)
- spatial contiguity principle (Mayer, 2009)
- signaling principle, i. e. color coding (Kalyuga, Chandler, & Sweller, 1999; Mayer, 2009; Renkl, 2014; van Gog, 2014)
- example-set principle (Renkl, 2014)

Learning Materials

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Worked Example



- offline prompt (Chi, De Leeuw, Chiu, & LaVancher, 1994)
- 2583-3967 words
- 14-33 pictures
- segmenting
  - presenting small units of information on one page
- prompting
  - asking learners to actively use parts of the newly acquired knowledge (anticipative reasoning) (Stark, 1999)

UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

Procedure

Procedure

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Day 1 (pre-test)

- demographic questionnaire
- prior knowledge
  - paper-pencil
  - 33 Multiple-Choice Single-Select Items

Day 2-4 (learning sessions)

- perceived task difficulty (Kalyuga et al., 2001)
- invested mental effort (Paas, 1992)
- perceived understanding
- motivation
  - 7-point scales
- learning time

Day 5 (post-test)

- learning outcomes

Procedure

"Please estimate how well you understood the last text passage."

not at all very well

1 2 3 4 5 6 7

Day 1 (pre-test)

- demographic questionnaire
- prior knowledge
  - paper-pencil
  - 33 Multiple-Choice Single-Select Items

Day 2-4 (learning sessions)

- perceived task difficulty (Kalyuga et al., 2001)
- invested mental effort (Paas, 1992)
- perceived understanding
- motivation
  - 7-point scales
- learning time

Day 5 (post-test)

- learning outcomes

Procedure

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

"Please estimate how well you understood the last text passage."

not at all — very well

1 2 3 4 5 6 7

"I enjoyed reading the last text passage."

the reverse is true — applies

1 2 3 4 5 6 7

Day 1 (pre-test)

- demographic questionnaire
- prior knowledge
  - paper-pencil
  - 33 Multiple-Choice Single-Select Items

Day 2-4 (learning sessions)

- perceived task difficulty (Kalyuga et al., 2001)
- invested mental effort (Paas, 1992)
- perceived understanding
- motivation
  - 7-point scales
- learning time

Day 5 (post-test)

- learning outcomes

Procedure

	Function	Predominantly …	Prompts	Segments
R1	introduction	cover story	0	1-2
R2	problem	cover story	1	1-2
R3	explanation of content knowledge	content knowledge	0	3-10
R4			1-2	1-3
R5	explanation of content knowledge	content knowledge	2-4	9-24
R6	reference to the problem	both	0	3-8
R7	decay	cover story	0	2-5

Day 1 (pre-test)

- demographic questionnaire
- prior knowledge
  - paper-pencil
  - 33 Multiple-Choice Single-Select Items

Day 2-4 (learning sessions)

- perceived task difficulty (Kalyuga et al., 2001)
- invested mental effort (Paas, 1992)
- perceived understanding
- motivation
  - 7-point scales
- learning time

Day 5 (post-test)

- learning outcomes

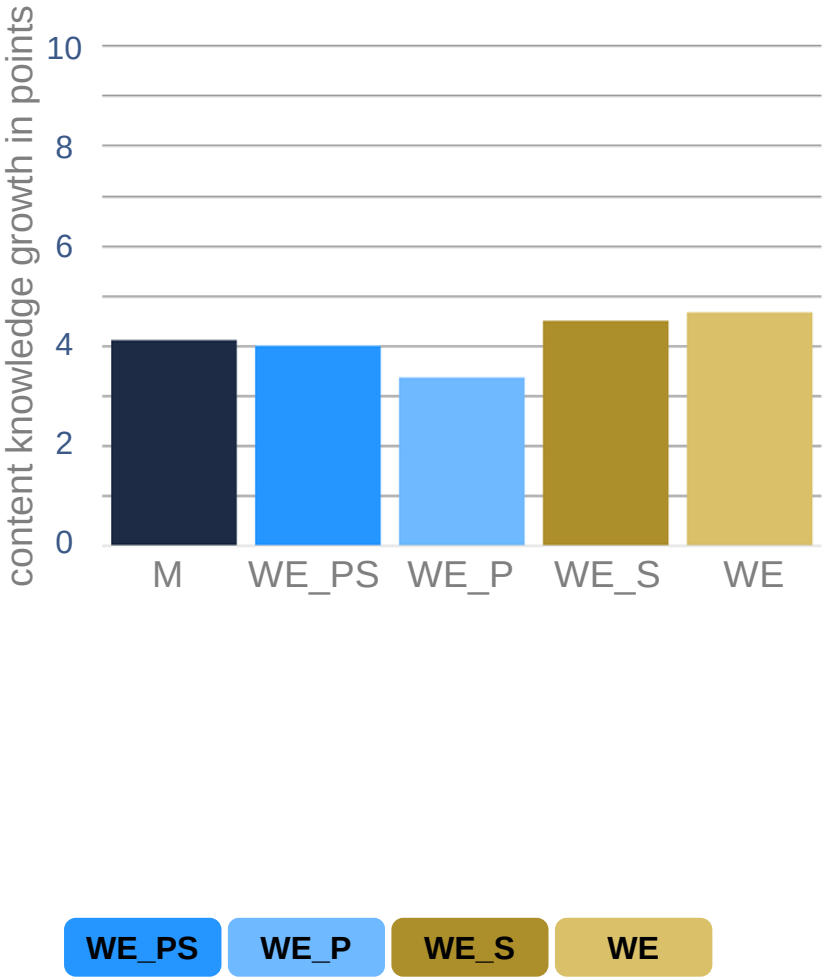
UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

Results

Content Knowledge

Content Knowledge Growth

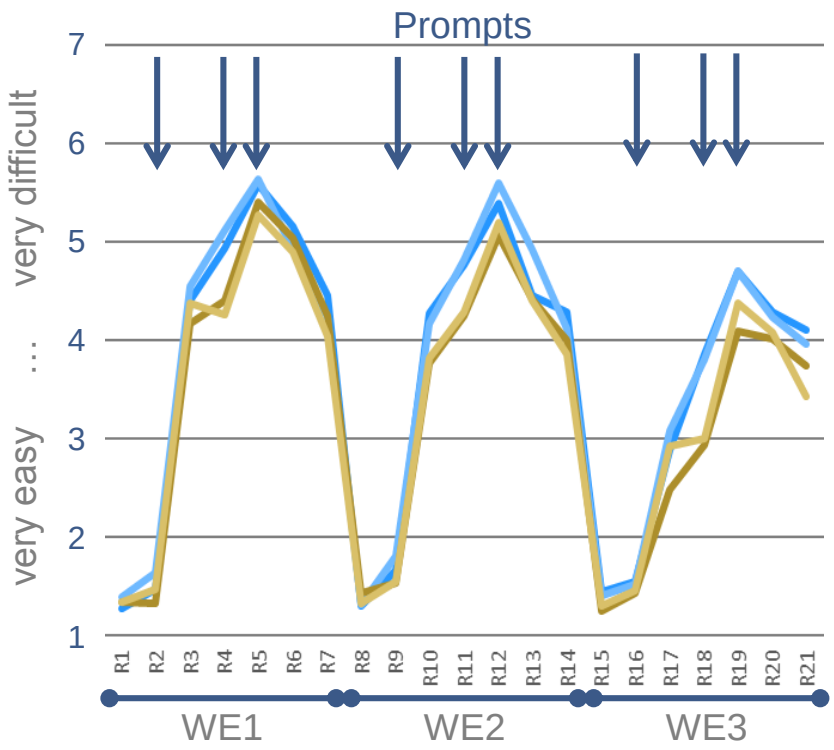


WE_PS **WE_P** **WE_S** **WE**

- 33 Items, Multiple-Choice Single-Select
- $\alpha_{pre} = .403$, $\alpha_{post} = .822$
- *t-test pre-post (dependent)*
  $t(435) = 16.59$, $p < .001$, $d = 0.847$
- *ANOVA & Post-Hoc (LSD)*
  no differences between conditions

Perceived Task Difficulty

Perceived Task Difficulty



WE_PS **WE_P** **WE_S** **WE**

- *RM_ANOVA & Post-Hoc (LSD)*
  $F(3,334) = 2.79$, $p = .040$, $\eta_p^2 = .024$

  WE_PS > WE_S ($p = .025$) and WE ($p = .028$)

  Combining prompts and segmentation increases task difficulty compared to conditions without prompts

Preliminary Discussion

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

1st Research Question:

How do
- segmentation
- prompting

influence
- learning
- learning outcomes

from non-algorithmic worked examples?

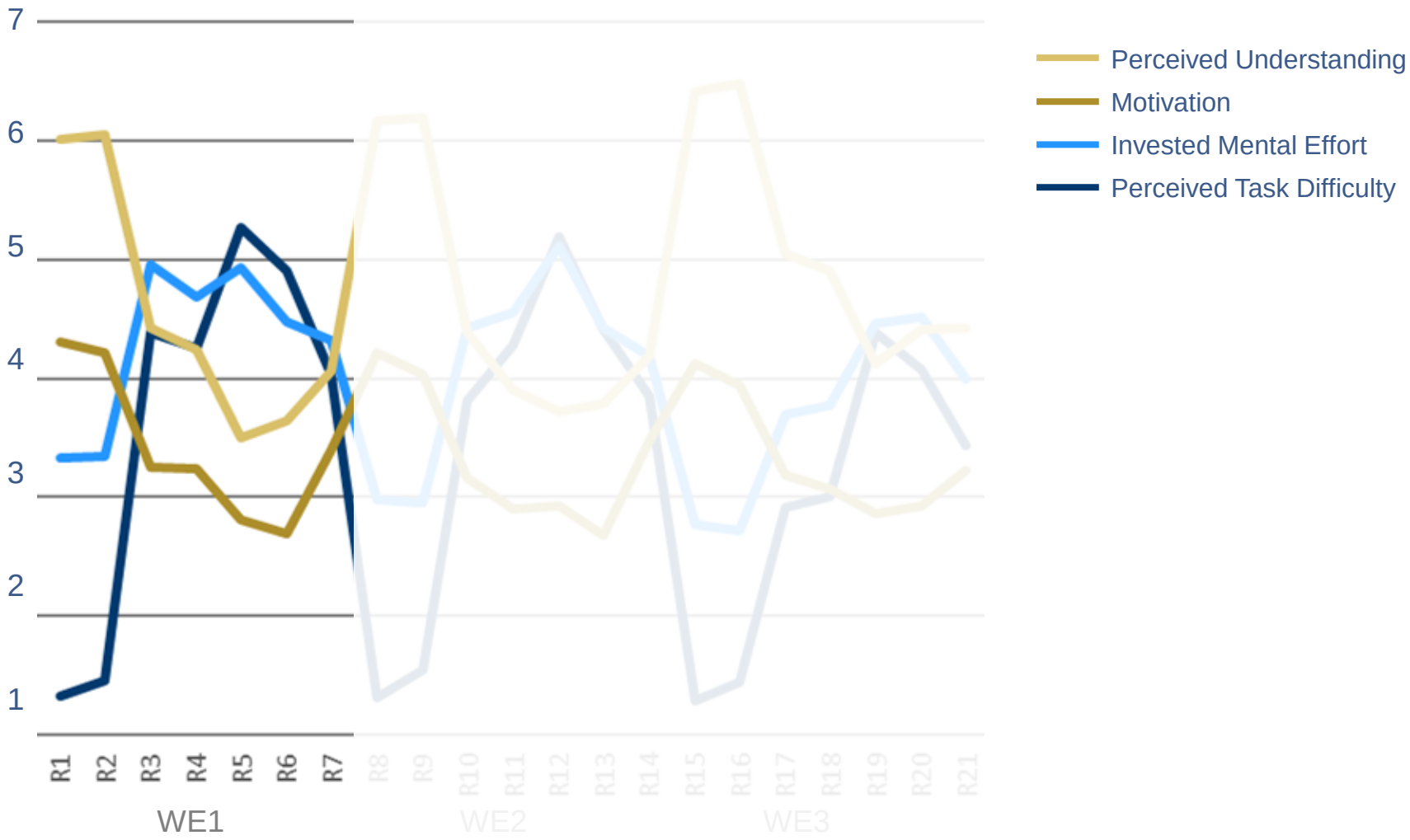
- learning outcomes
  - significant growth of content knowledge
  - no differences between conditions
- learning
  - prompting increases
    - perceived task difficulty
    - learning time
  - prompting and segmentation do not affect
    - invested mental effort
    - motivation
    - perceived understanding
    - instructional efficiency (Paas & van Merriënboer, 1993; van Gog & Paas, 2008)

→ neither prompting nor segmentation improved learning

Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

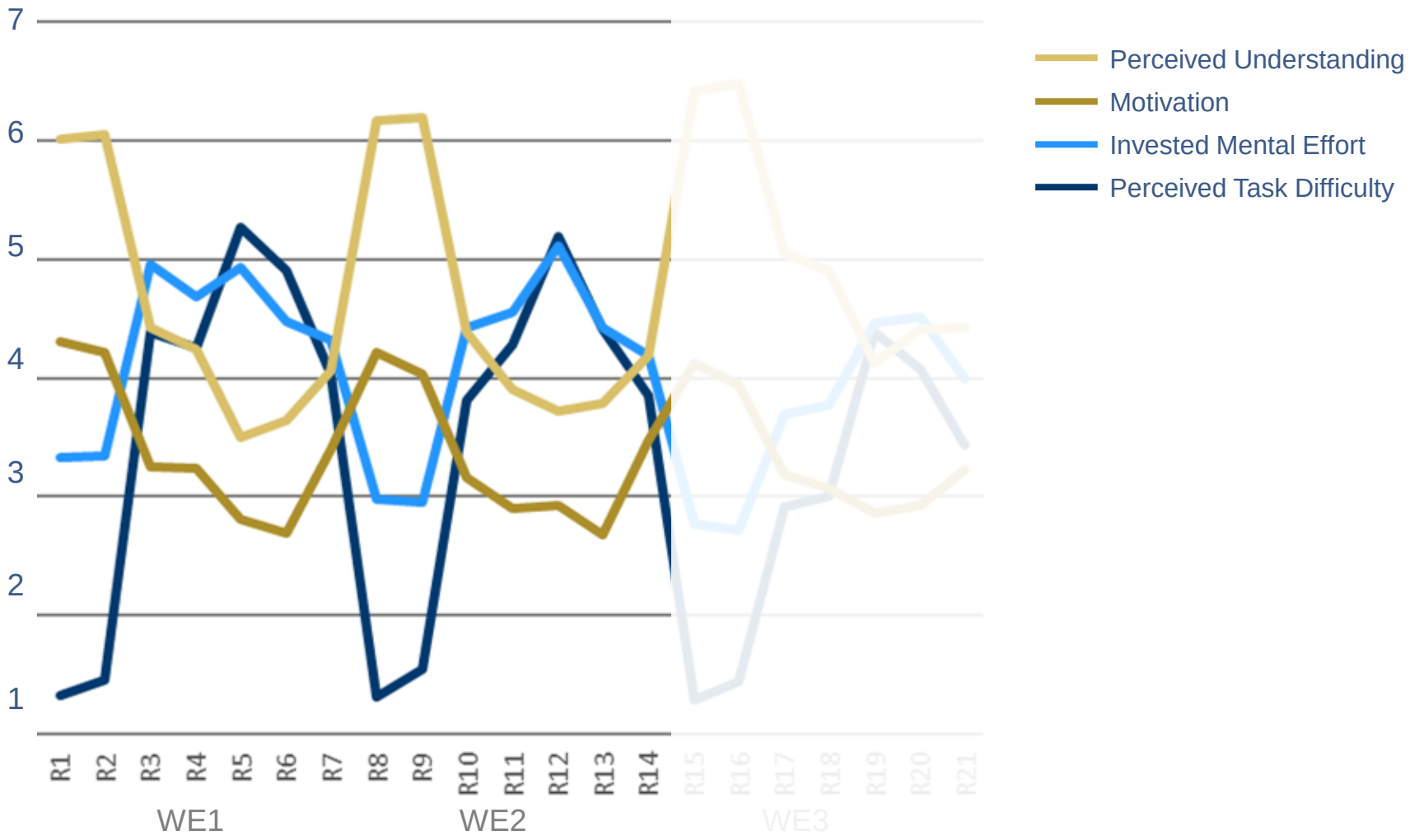
Development of Multiple Ratings



Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

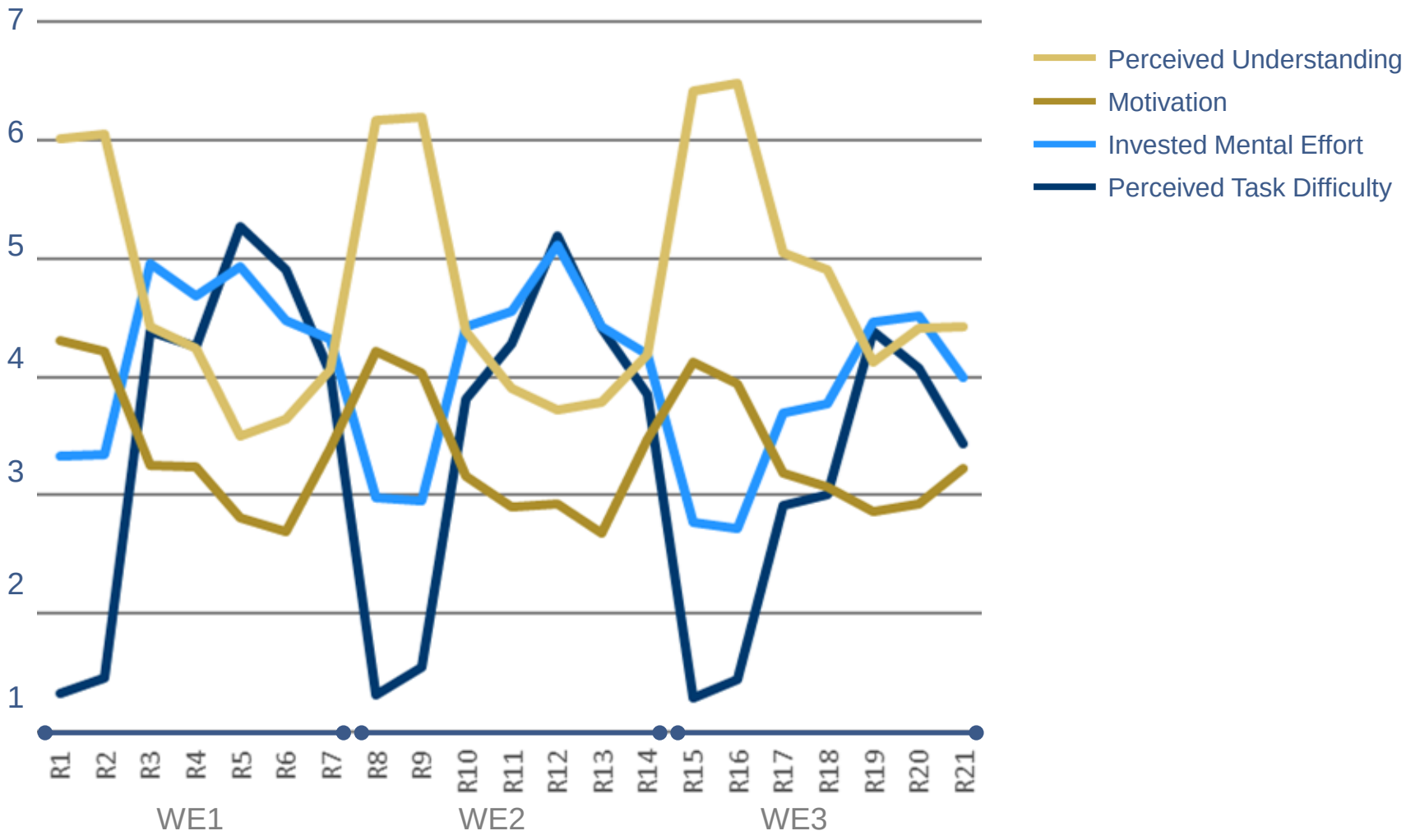
Development of Multiple Ratings



Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

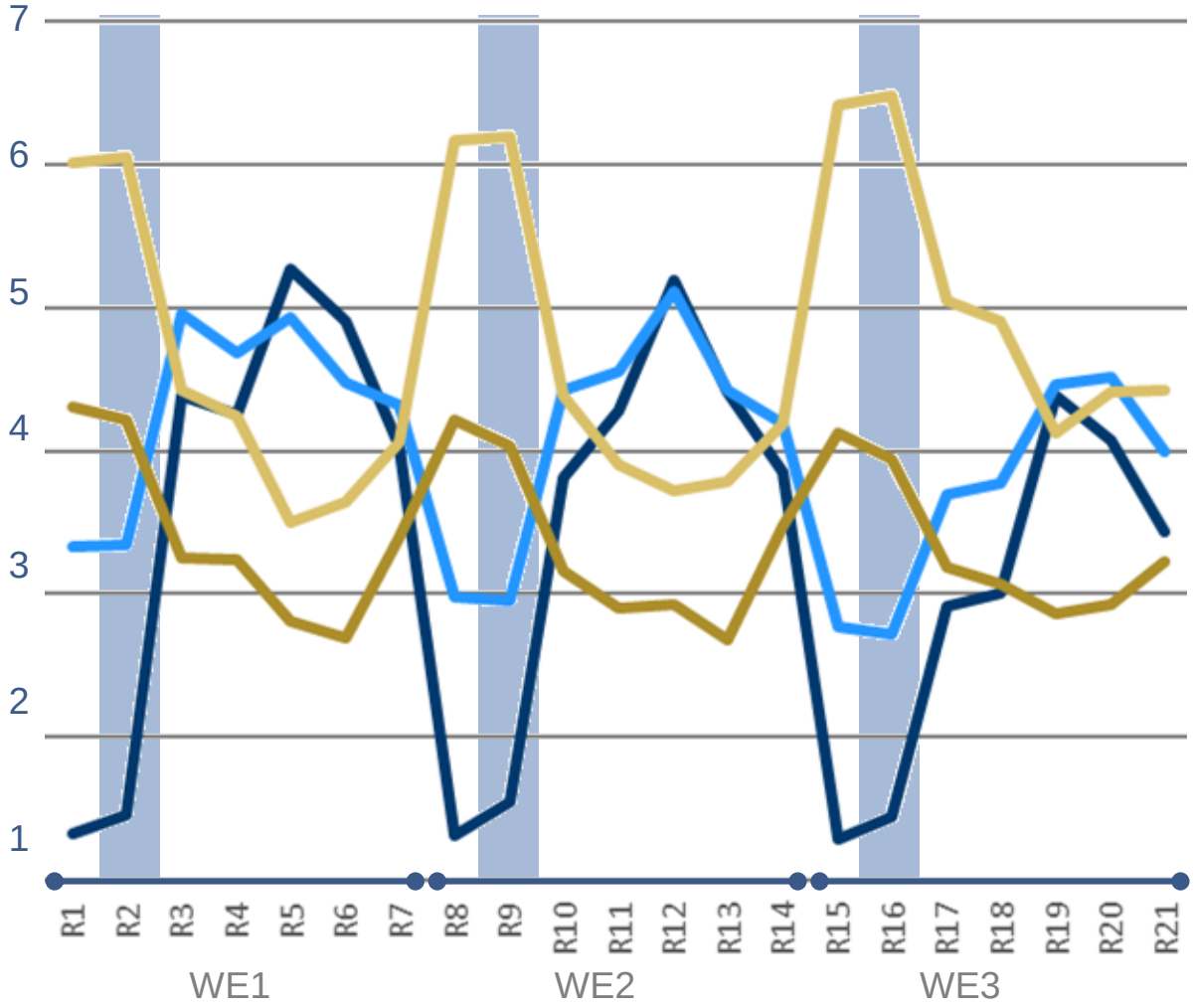
Development of Multiple Ratings



Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Development of Multiple Ratings



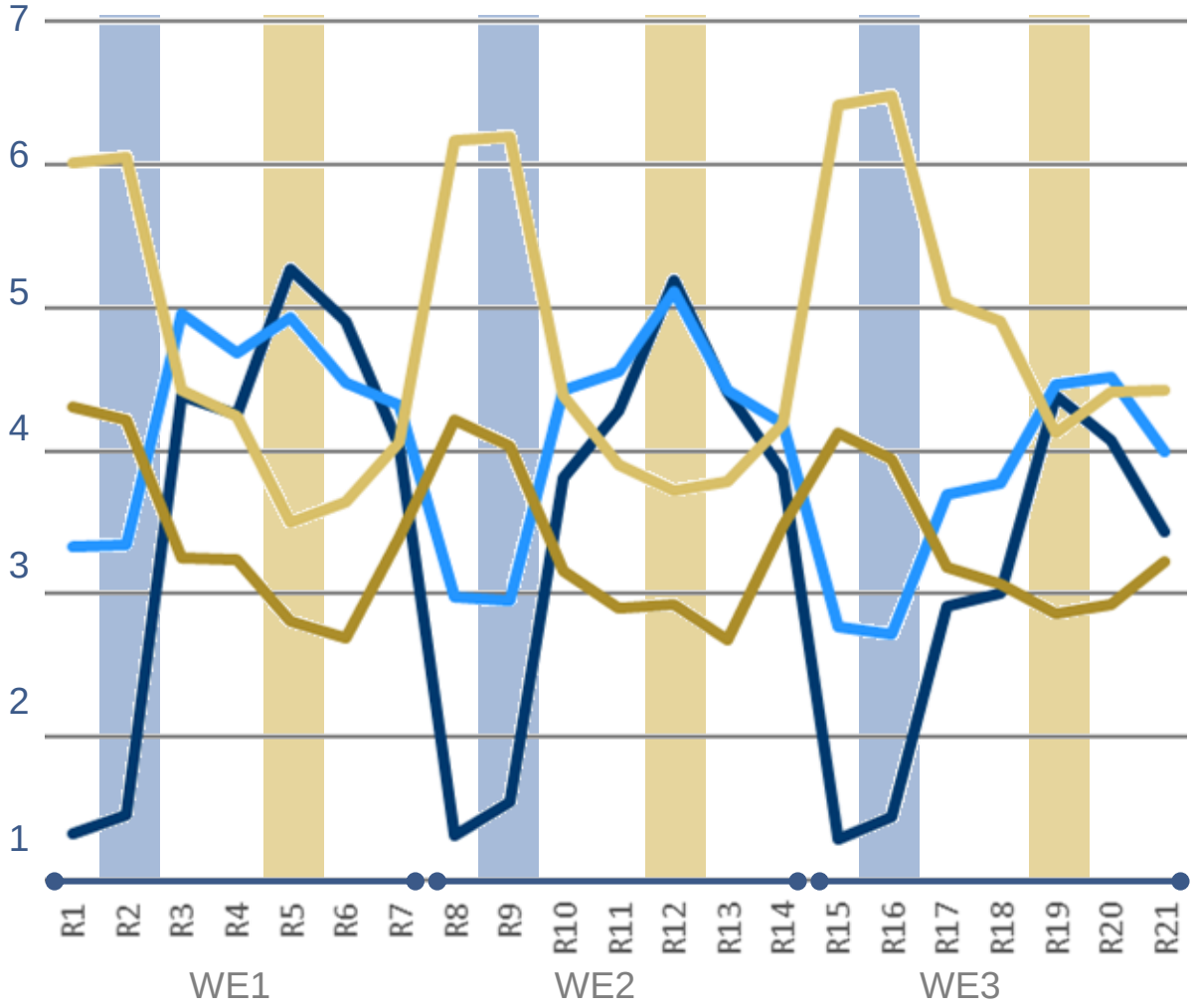
Perceived Understanding
Motivation
Invested Mental Effort
Perceived Task Difficulty

introduction,
cover story predominantly

Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Development of Multiple Ratings



Perceived Understanding
Motivation
Invested Mental Effort
Perceived Task Difficulty

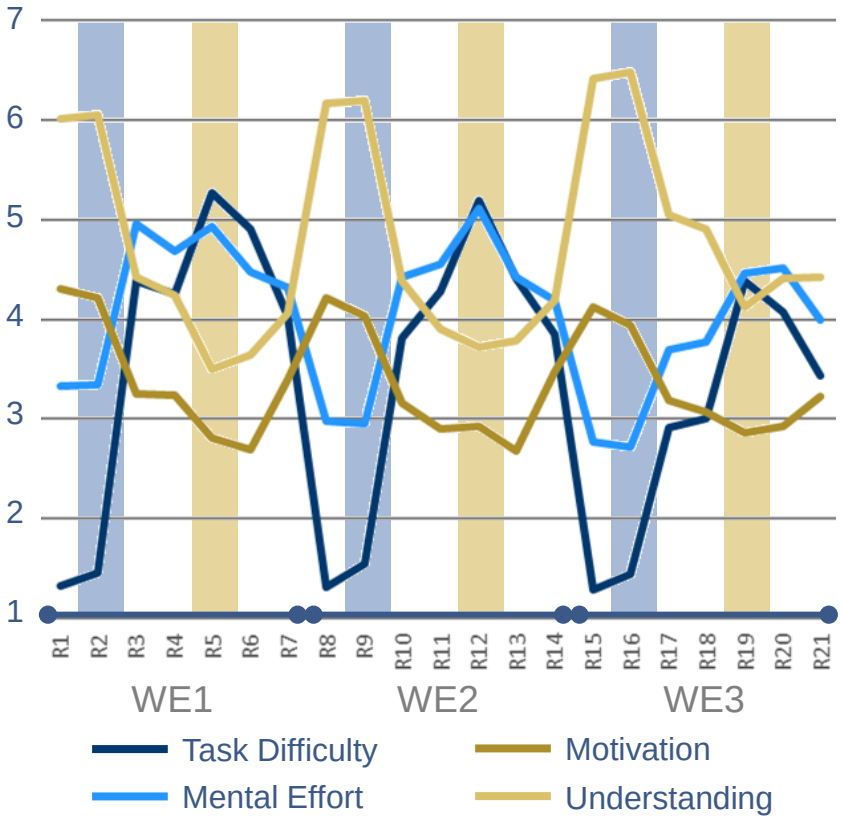
introduction,
cover story predominantly

predominantly explanation
of content knowledge

Development of Multiple Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Development of Multiple Ratings



introduction, cover story predominantly

predominantly explanation of content knowledge

		learning outcomes
perceived task difficulty	M_{R2}	-.230**
	M_{R5}	-.336**
motivation	M_{R2}	.148**
	M_{R5}	.390**
perceived understanding	M_{R2}	.314**
	M_{R5}	.574**
invested mental effort	M_{R2}	-.181**
	M_{R5}	.108*

N = 338, ** $p \leq 0.01$, * $p \leq 0.05$, Pearson-Correlation

Preliminary Discussion

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

2nd & 3rd Research Question:

How do multiple subjective ratings on

- invested mental effort
- perceived task difficulty
- motivation
- understanding

develop during studying one complex task?

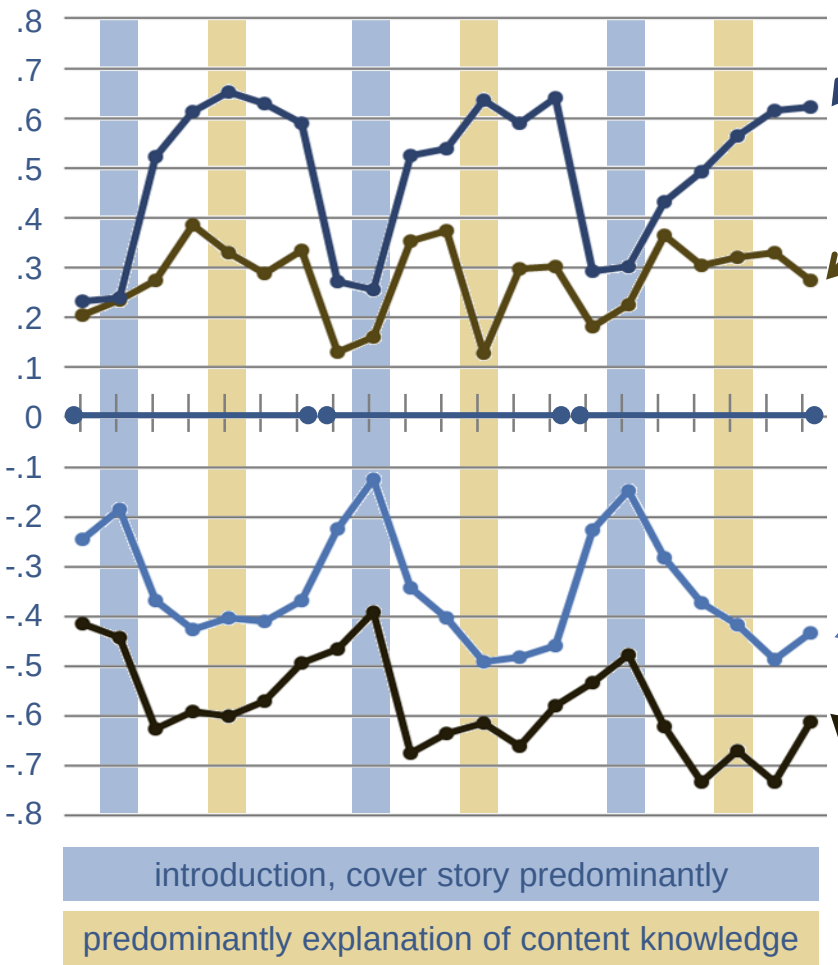
relate to learning outcomes?

- differences between ratings (R2 and R5)
- contrary developments for cognitive load and affective ratings
- stronger relations to learning outcome for later ratings (R5) on task difficulty, motivation and understanding
- relation between mental effort and learning outcomes changes from negative (R2) to positive (R5)

Development of the Relation of Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Correlation of Multiple Ratings



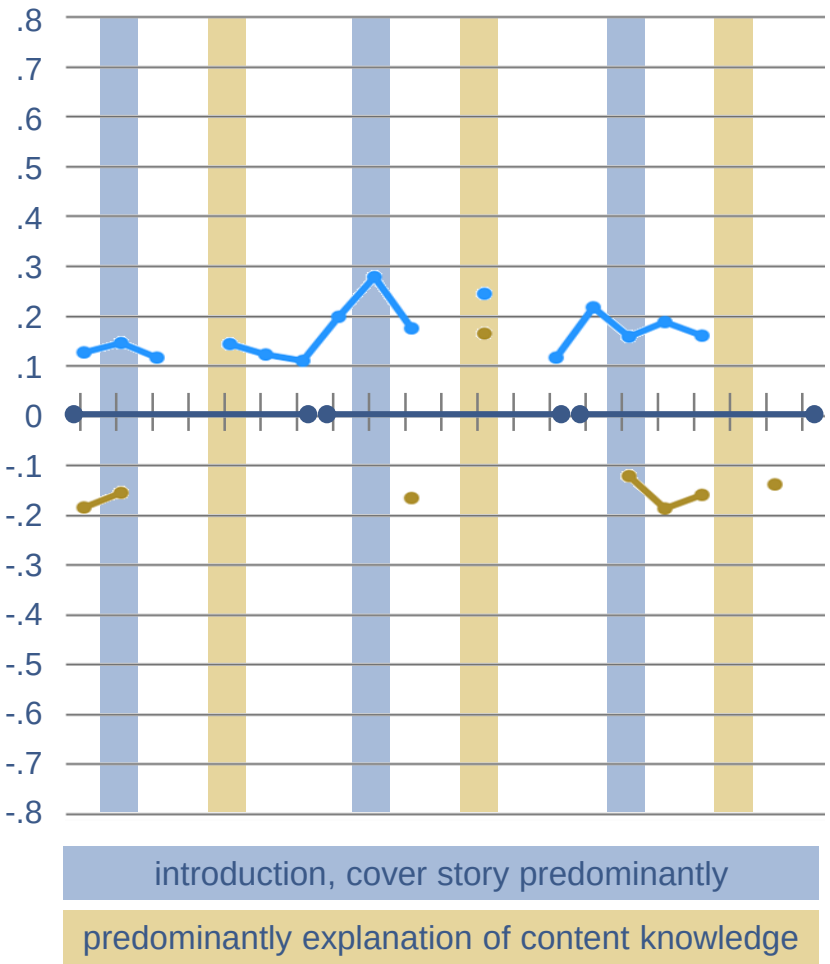
- **Motivation & Understanding**
  - positive relation
  - especially true when cognitive load is high
- **Task Difficulty & Mental Effort**
- **Motivation & Task Difficulty**
  - negative relation (Stebner et al., 2015)
  - especially true when cognitive load is high
- **Task Difficulty & Understanding**
  - especially true when cognitive load is high

N = 338, $p \leq 0.05$, Pearson-Correlation

Development of the Relation of Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Correlation of Multiple Ratings



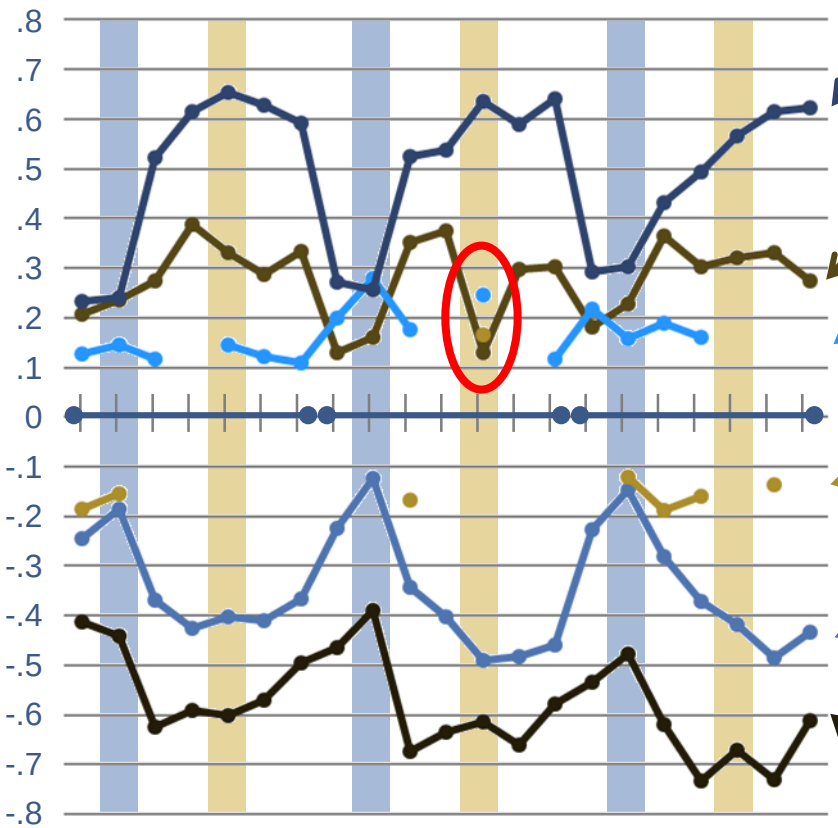
- **Motivation & Mental Effort**
  positive relation (Stebner et al., 2015) but not consistent
- **Mental Effort & Understanding**
  no strong, consistent relation

N = 338, $p \leq 0.05$, Pearson-Correlation

Development of the Relation of Cognitive and Affective Ratings

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Correlation of Multiple Ratings



- **Motivation & Understanding**
  - positive relation
  - especially true when cognitive load is high
- **Task Difficulty & Mental Effort**
- **Motivation & Mental Effort**
  - positive relation (Stebner et al., 2015) but not consistent
- **Mental Effort & Understanding**
  - no strong, consistent relation
- **Motivation & Task Difficulty**
  - negative relation (Stebner et al., 2015)
  - especially true when cognitive load is high
- **Task Difficulty & Understanding**
  - especially true when cognitive load is high

N = 338, $p \leq 0.05$, Pearson-Correlation

Preliminary Discussion

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

4th Research Question:

How does the relation between multiple subjective ratings on

- invested mental effort
- perceived task difficulty
- motivation
- understanding

vary during studying one complex task?

- consistent relation over 21 ratings between
  - motivation and understanding
  - task difficulty and mental effort
  - motivation and task difficulty
  - task difficulty and understanding
- no consistent relation over 21 ratings between
  - mental effort and motivation (15/21)
  - mental effort and understanding (8/21)
  - the significant relation is missing especially at points of high task difficulty
- one conspicuous point
  - mental effort and task difficulty decreases
  - mental effort and motivation increases
  - mental effort and understanding changes from negative to positive

Discussion

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

- Neither Prompting nor Segmentation fostered learning
  - Prompts lead to an increase of cognitive load (overload?) and learning time (extraneous processing?)
  - Segmentation was self-paced, multiple-ratings provide segmentation for the no-segmenting conditions
- Classroom setting
- Design principles are mainly proved for algorithmic examples and interrelations of the design principles are only partly examined (Renkl, 2014)
- Multiple subjective ratings
  - Contrary developments for cognitive load and affective ratings within one complex task
  - Changing relation between mental effort and learning outcomes from negative (R2) to positive (R5)
  - No consistent relation between mental effort and motivation / understanding (at points of high task difficulty)

UNIVERSITÄT DUISBURG ESSEN

Open-Minded

Thank you,

for your Attention!

Müller-Reitz-Stiftung

https://www.uni-due.de/chemiedidaktik/09_sonstiges_downloads_loesungsbeispiele.php

UNIVERSITÄT
DUISBURG
ESSEN

Open-Minded

References

References

Berthold, K. & Renkl, A. (2010). How to foster active processing of explanations in instructional communication. *Educational Psychology Review*, *22*(1), 25-40.

Berthold, K., Röder, H., Knörzer, D., Kessler, W., & Renkl., A. (2011). The double-edged effects of explanation prompts. *Computers in Human Behavior*, 27, 69-75.

Chi, M. T. H., De Leeuw, N., Chiu, M.-H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, *18*(3), 439-477.

Gerjets, P., Scheiter, K. & Catrambone, R. (2006). Can learning from molar and modular worked examples be enhanced by providing instructional explanations and prompting self-explanations? *Learning and Instruction*, *16*(2), 104-121.

Gog, T. van, Kirschner, F., Kester, L. & Paas, F. (2012). Timing and frequency of mental effort measurement: Evidence in favor of repeated measures. *Applied Cognitive Psychology, 26*, 833-839.

Gog, T. van & Paas, F. (2008). Instructional efficiency: Revisiting the original construct in educational research. *Educational Psychologist, 43*, 16-26.

Große, C. S. & Renkl, A. (2004). Learning from worked examples: What happens if errors are included? In P. Gerjets, J. Elen, R. Joiner & P. Kirschner (Eds.), *Instructional design for effective and enjoyable computer-supported learning,* (356-364), Tübingen, Germany: Knowledge Media Research Center.

Große, C. S. & Renkl, A. (2007). Finding and Fixing errors in worked examples: Can this foster learning outcomes?, *Learning and Instruction, 17*, 612-634.

Kalyuga, S. (2014). The expertise reversal principle in multimedia learning. In R. E. Mayer (Ed.), *Cambridge Handbook of Multimedia Learning. Second Edition.* (576-598). Cambridge, UK: Cambridge University Press.

Kalyuga, S., Chandler, P., Tuovinen, J. & Sweller, J. (2001). When problem solving is superior to studying worked examples. *Journal of educational psychology*, *93*(3), 579-588.

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. Applied Cognitive Psychology, 13, 351-371.

Mayer, R. E. (2009). *Multimedia Learning – Second Edition.* New York: Cambridge University Press.

Mayer, R. (2014). Cognitive Theory of Multimedia Learning. In: R. E. Mayer (Ed.), *Cambridge Handbook of multimedia learning – second Edition,* (43-71). Cambridge, UK: Cambridge University Press.

Moreno, R. (2005). Instructional Technology – Promise and Pitfalls. In: In Pyllikzillig, L. M., Bodvarsson, M., & Bruning, R. (Eds.), Technology-Based Education: Bringing Researchers and Practitioners Together (pp. 1-19), Greenwich, CT: Information Age.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive load approach. *Journal of Educational Psychology, 84*, 429-434.

Paas, F. G. W. C & van Merrienboer, J. J. G. (1993). The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and Performance Measures. Human Factors, 35(4), p. 737-743.

Reimann, P. (1997). *Lernprozesse beim Wissenserwerb aus Beispielen: Analyse, Modellierung, Förderung*. Bern, CH: Huber.

Renkl, A. (2014). The Worked Example Principle in Multimedia Learning. In: R. E. Mayer (Ed.), *Cambridge Handbook of multimedia learning – second Edition,* (391-412). Cambridge, UK: Cambridge University Press.

Renkl, A. (2014). Toward an Instructionally Oriented Theory of Example-Based Learning. *Cognitive Science*, *38*(1), 1-37.

References

Rheinberg, F., Vollmeyer, R. & Burns, B.D. (2001). FAM: Ein Fragebogen zur Erfassung aktueller Motivation in Lern- und Leistungssituationen. *Diagnostika 2,* 57-66.

Roy, M. & Chi, M. T. H. (2005). The self-explanation principle in multi-media learning. In: R. E. Mayer (Ed.), *Cambridge Handbook of multimedia learning,* (271-287). Cambridge, UK: Cambridge University Press.

Schmeck, A., Opfermann, M., Gog, T. van, Paas, F. & Leutner, D. (2015). Measuring cognitive load with subjective rating scales during problem solving: Differences between immediate and delayed ratings. *Instructional Science, 43*, 93-114.

Spanjers, I.E.A., Gog, T. van & Merrienboer, J.J.G. van (2012). Segmentation of worked examples: Effects on cognitive load and learning. *Applied Cognitive Psychology, 26*, 352-358.

Stark, R. (1999*). Lernen mit Lösungsbeispielen. Einfluss unvollständiger Lösungsbeispiele auf Beispielelaboration, Lernerfolg und Motivation*. Göttingen: Hogrefe.

Stebner, Dicke, Kühl, Leutner, & Wirth (June, 2015). The interplay between topic interest, perceived task difficulty, invested mental effort, and performance when learning with multimedia – validation of a theoretical model. Annual International Cognitive Load Theory Conference (ICLTC - 2015), Fort Collins, USA.

Sweller, J. (2005). Implications of Cognitive Load Theory for Multimedia Learning. In: R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (19-30). New York, Cambridge University Press.

Sweller, J. & Cooper, G. A. (1985). The Use of Worked Examples as a Substitute for Problem Solving in Learning Algebra. C*ognition and Instruction, 2*(1), 59-89.

Van Gog, T. (2014). The signaling (or Cueing) principle in Multimedia Learning. In: R. E. Mayer (Hrsg.), *Cambridge Handbook of multimedia learning. Second Edition* (p. 263-278). Cambridge, UK: Cambridge University Press

Wylie, R., & Chi, M. T. H. (2014). The Self-Explanation Principle in Multimedia Learning. In: R. E. Mayer (Ed.), *Cambridge Handbook of multimedia learning – second Edition,* (413-432). Cambridge, UK: Cambridge University Press.