Pre-service teachers' self-efficacy for teaching simulations and mathematical modelling with digital tools

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Self-efficacy

- **representation of an individual assessment of one's opportunity and ability "to organise and execute the courses of action required to produce given attainments."** (Bandura 1997, S. 3)

- high self-efficacy of teachers crucial for coping with professional demands (Kunter 2013)

- quality of teaching strongly influenced by the individual self-efficacy characteristics of the teachers
- promoting self-efficacy as a central concern of teacher education (also domain-specific self-efficacy)

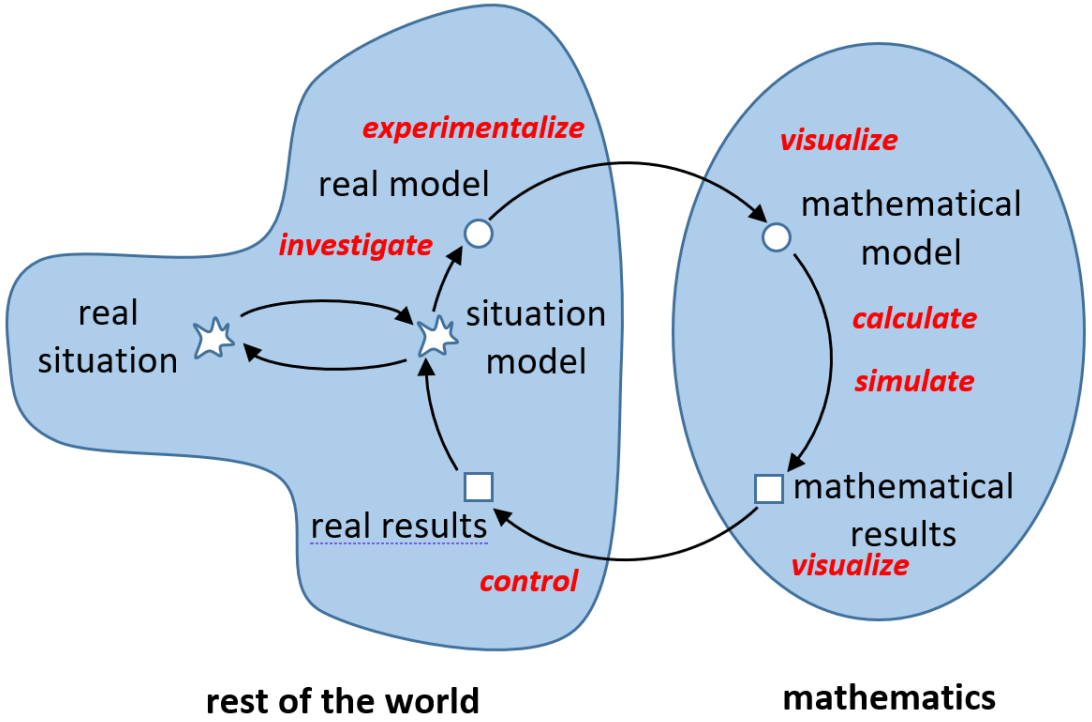
(Bandura 1997)

- positive development of pre-service mathematics teachers' self-efficacy for teaching mathematical modelling by participating in specific seminars with practical activities (Siller et al., submitted)

Using digital tools in mathematical modelling

- facilitate the discussion of complex, authentic real-life problems (e.g. by processing a larger amount of data).
- enable other emphases (e.g. on structuring and validation) in mathematics teaching.
- can be used in all processing phases of mathematical modelling.

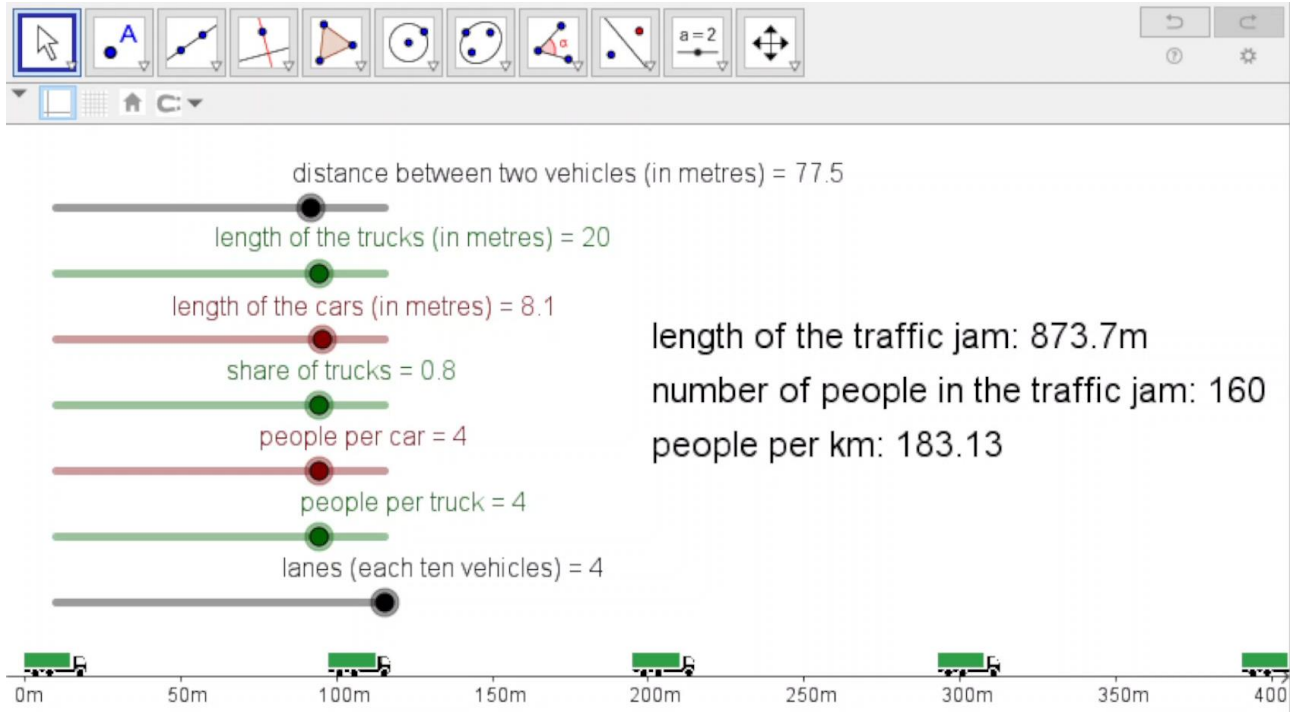
(Greefrath & Siller 2017)



red: what 'does' the digital tool (for example)?

(Greefrath 2011; Greefrath & Siller 2017)

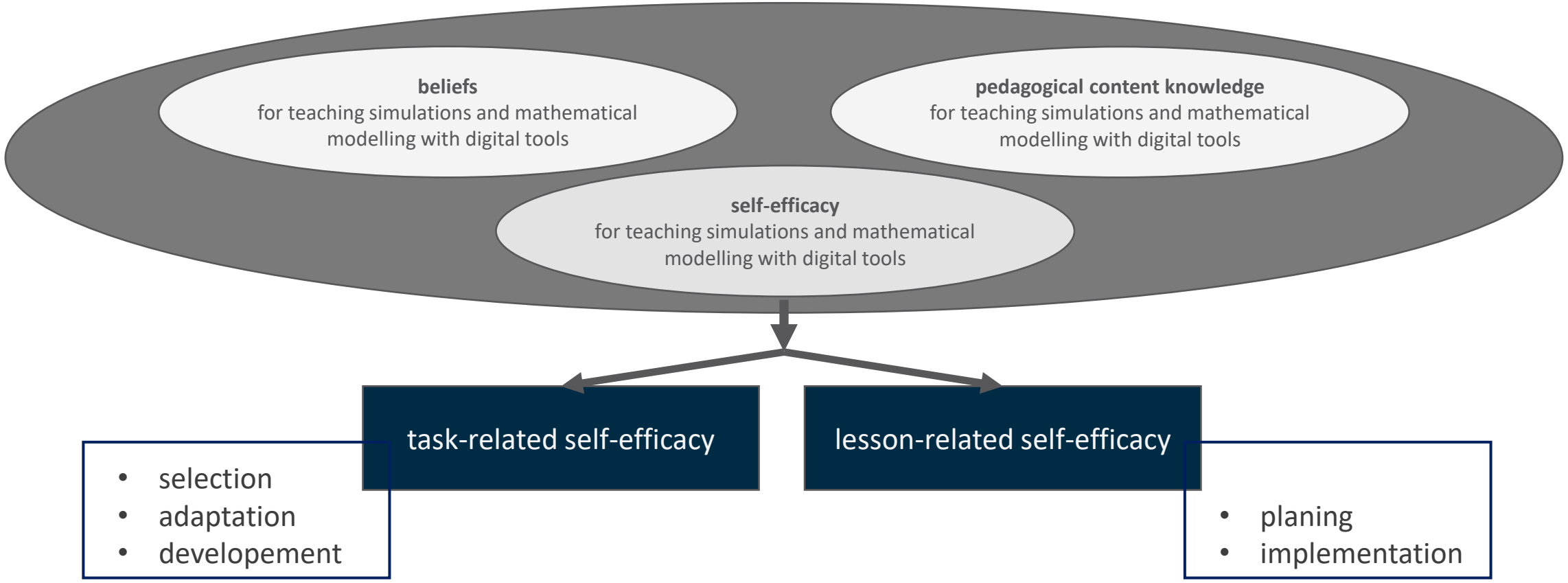
Simulations



- are based on a previously developed mathematical model.
- serve as a digital representation of aspects of reality-related issues in the form of graphics, tables, symbolic expressions or similar forms of representation.
- support, for example, by actively changing parameters the finding of solutions in an experimental setting.
- contribute to the exploration of extra-mathematical content for which an analytical solution is not (yet) possible.

(Greefrath & Siller 2017, Podworny 2019)

Self-efficacy as an aspect of professional competence



Baumert & Kunter (2013); Thurm & Barzel (2020, 2022); Wess et al. (2021)

Promoting self-efficacy

Enactive mastery experiences: promotion through experiences of success

→ By achieving realistic formulated goals, leaners recognise the value of their own abilities and skills and can use them purposefully.

Verbal persuasion: promotion through meaningful feedback

→ Learners notice their own learning progress (based on own efforts, knowledge and skills), which leads to more motivation and increasing self-efficacy.

Vicarious experience: promotion through transmission of competencies, comparison with attainments of others

Physiological and affective states: promotion through judgement of the own capabilities, strength, and vulnerability

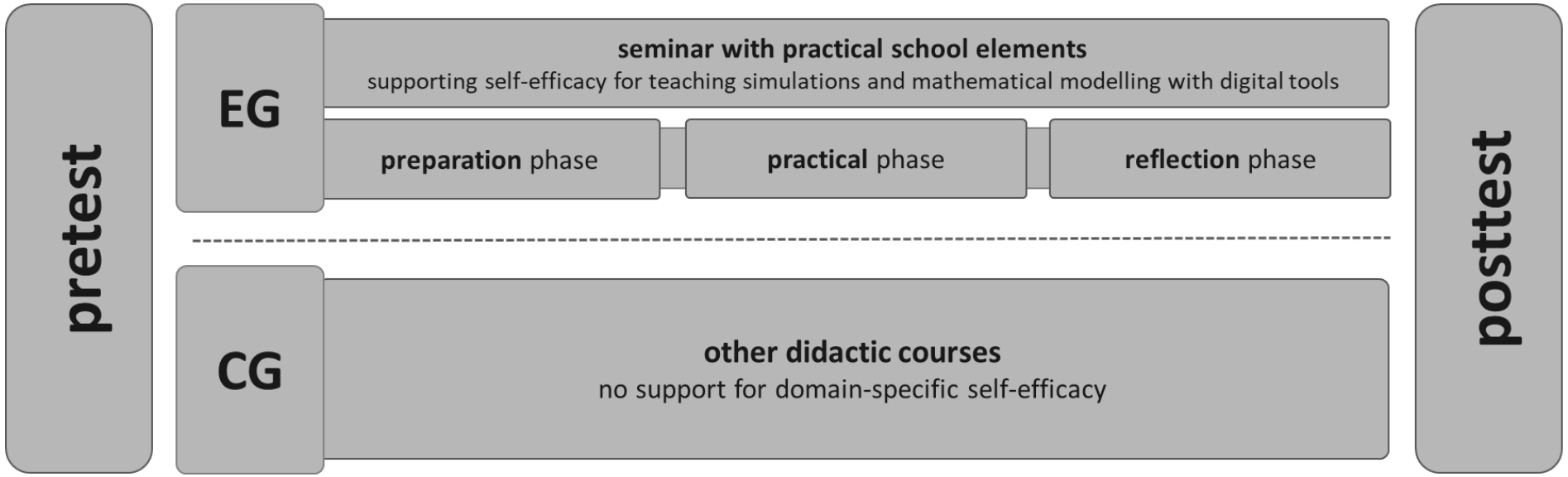
(Bandura 1997)

Research question

How does pre-service mathematics teachers' self-efficacy for teaching simulations and mathematical modelling with digital tools develop through participation in a seminar with practical school elements in comparison to pre-service mathematics teachers who do not receive a specific intervention for this domain-specific self-efficacy?

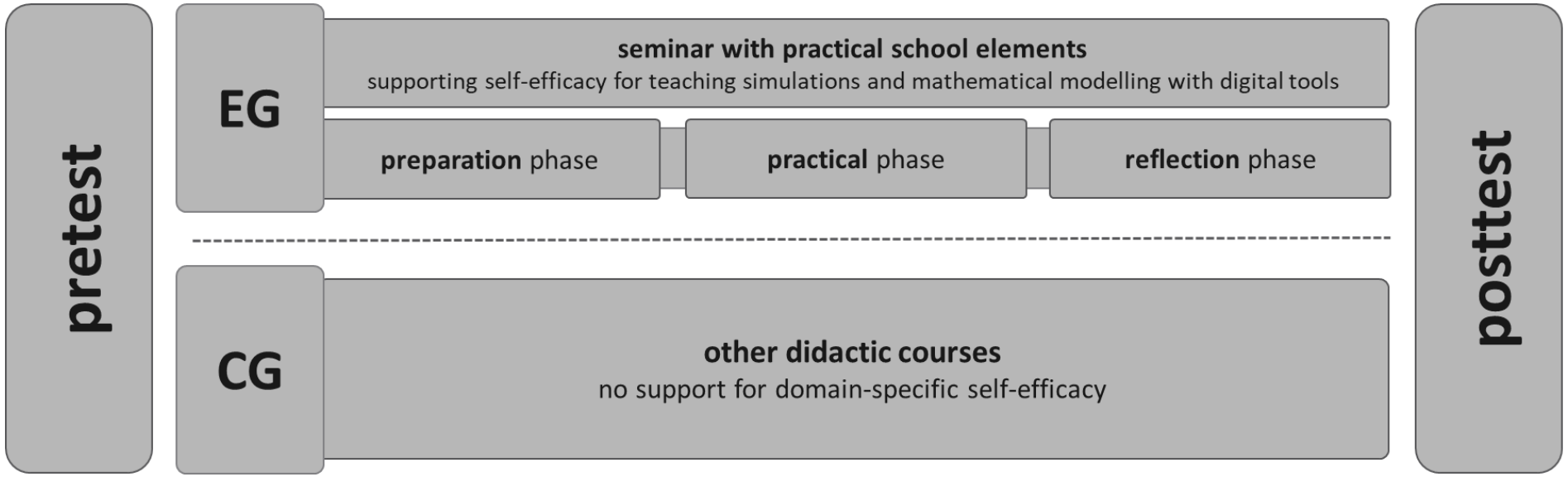
Methodical framework: research design and sample

- quasi-experimental intervention study: pre-post design with two groups
- data from 146 pre-service mathematics teachers at the universities of Wuerzburg and Muenster at the beginning and end of a semester



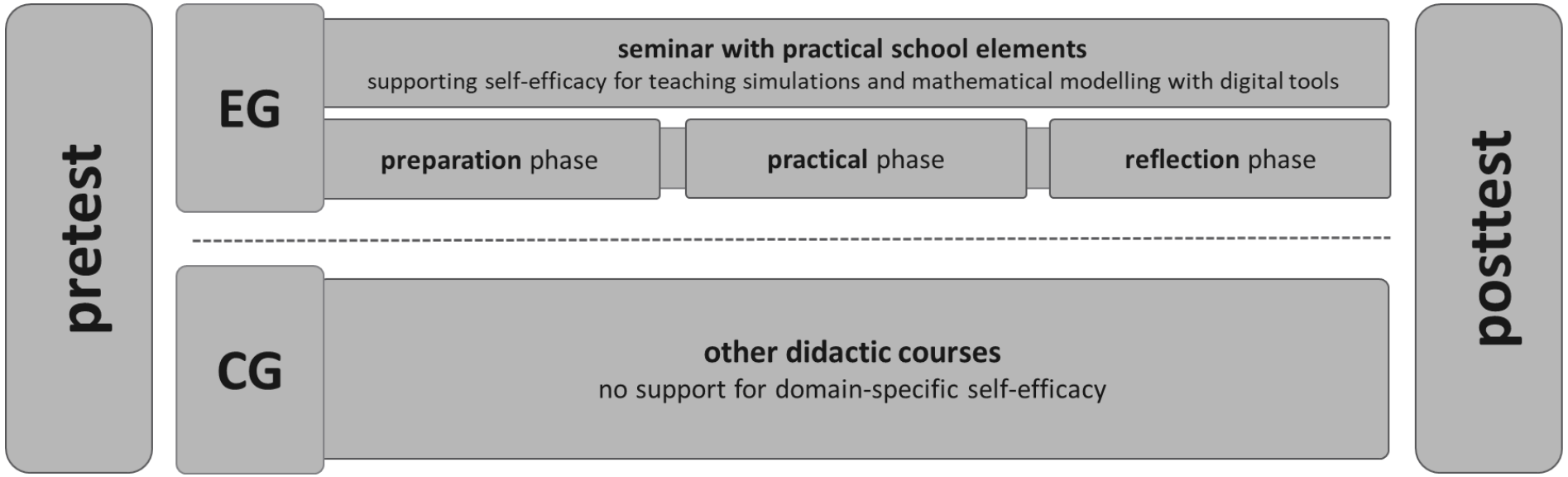
Methodical framework: research design and sample

- experimental group (EG): 80 pre-service mathematics teachers who took part in our seminar and thus received specific intervention for self-efficacy for teaching simulations and mathematical modelling with digital tools



Methodical framework: research design and sample

- control group (CG): 66 pre-service mathematics teachers who participated in courses with other thematic orientations during the same period and did not receive specific intervention on this domain-specific self-efficacy



Methodical framework: research design and sample

	Number	Sex	Age		Semester		Abitur grade	
		m/f/d/n. s.	M	SD	M	SD	M	SD
EG	80	28/51/0/1	22.24	3.84	6.25	3.00	1.78	0.49
CG	66	28/38/0/0	23.58	3.18	8.45	3.24	1.90	0.51
Total	146	56/89/0/1	22.84	3.60	7.25	3.29	1.84	0.50

Methodical framework: test instrument

- two scales of a test instrument that captures aspects of professional competence for teaching simulations and mathematical modelling with digital tools (→ Gerber & Quarder 2022)
- scale *tasks*: six items; scale *lesson*: six items
- statement to which the personal degree of agreement is expressed via a six-point Likert scale (1 = strongly disagree; 6 = strongly agree).

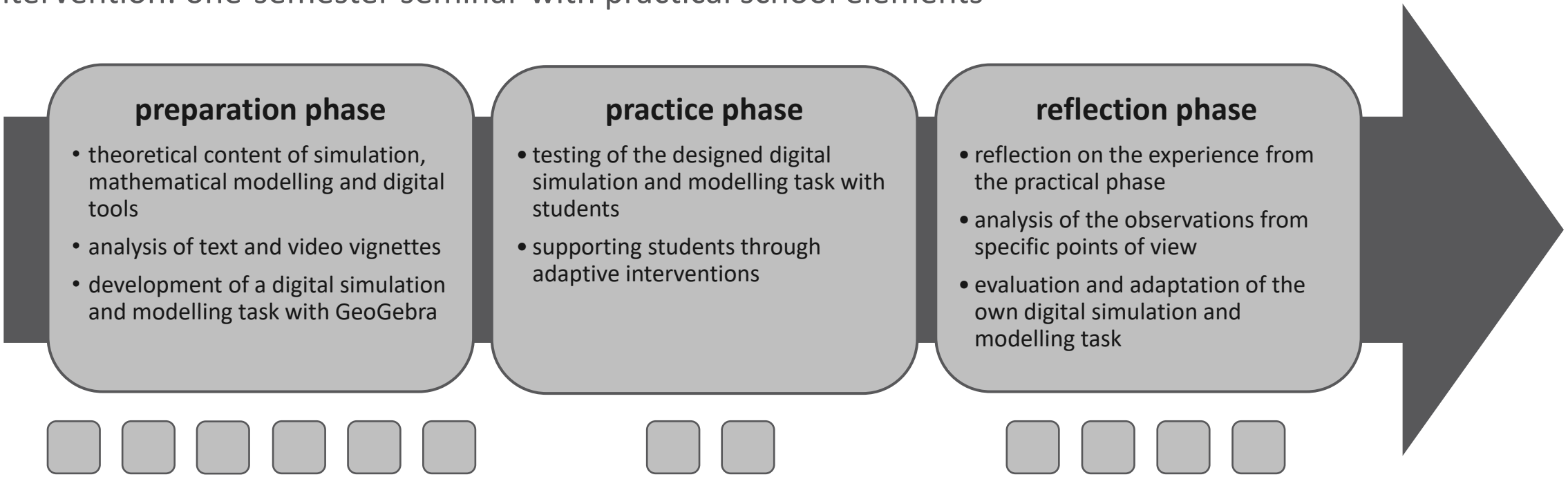
Methodical framework: test instrument

Scale	Item number	Example item	Cronbach-alpha
Task-related self-efficacy	6	I am confident that I can work out multiple ways of solving a modelling task in which digital tools are used.	.89
Lesson-related self-efficacy	6	I am confident that I can carry out teaching phases in which digital tools are used for mathematical modelling.	.90

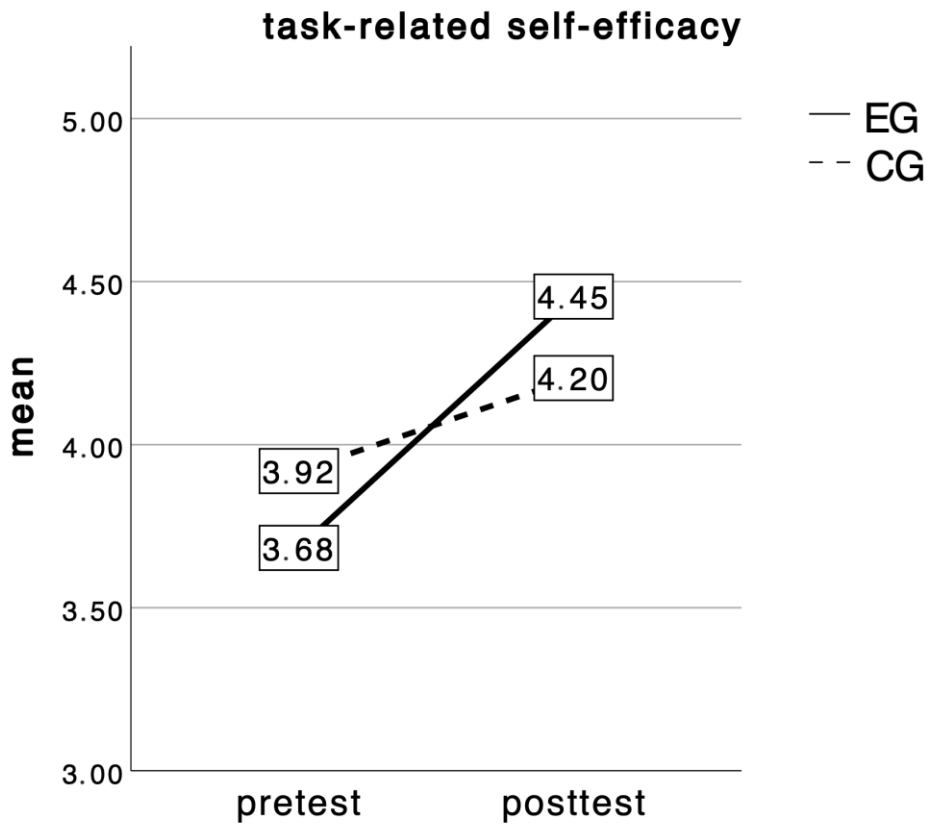
- reliabilities (evaluated with Cronbach's alpha): high; indicate reliable results especially in group comparisons

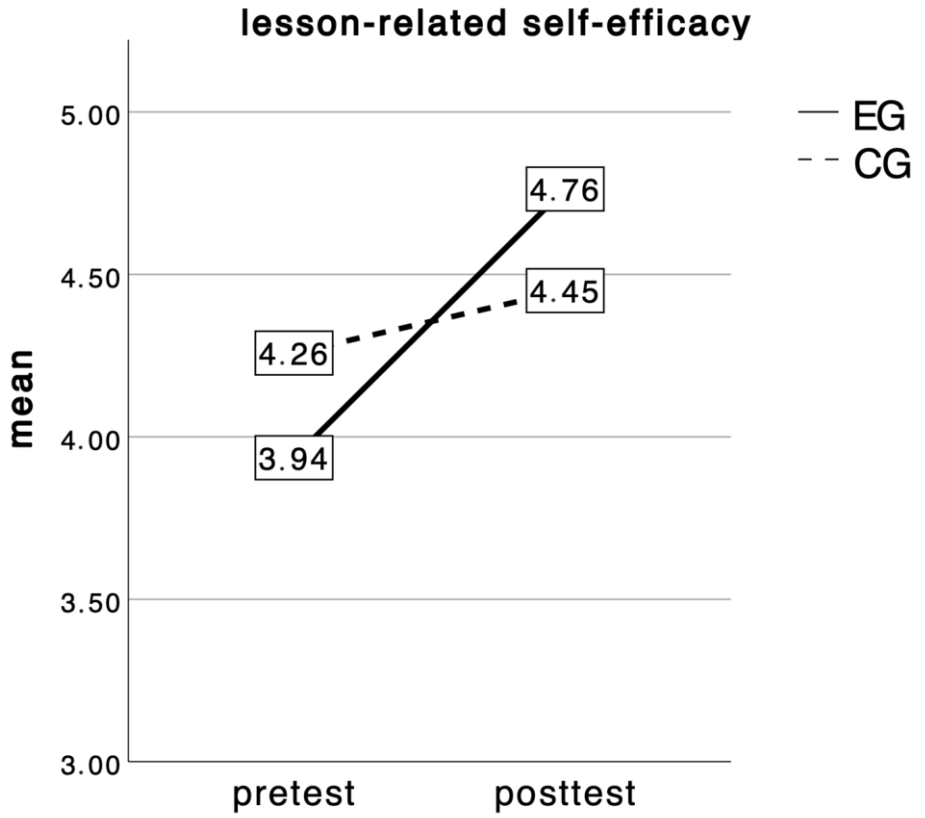
Methodical framework: intervention

- promote self-efficacy for teaching simulations and mathematical modelling with digital tools
- intervention: one-semester seminar with practical school elements



Results: descriptive





from 1 = strongly disagree
to 6 = strongly agree

Results: inductive

- for both dimensions *tasks* and *lessons*: regression analyses
- linear model equation: $posttest = b_0 + b_1 \cdot pretest + b_2 \cdot group$
  (For group membership, the experimental group was coded with one and the control group with zero)
- necessary prerequisites for these analyses were fulfilled

Results: inductive

task-related self-efficacy:

- group membership was a significant predictor ($\beta = .21,\ \ p < .001$) for the posttest scores, with pretest scores held constant
- model specified in this way clarified 26 percent of the differences in the task-related self-efficacy at the second time of measurement ($R^2 = .26,\ \ F(2,143) = 25.14,\ \ p < .001$)

Criterion	Coefficient	b	SE	β	p
Posttest	Intercept	2.29	0.30		.000
	Pretest	0.49	0.07	. 49	.000
	Group	0.37	0.13	. 21	.005

Results: inductive

lesson-related self-efficacy:

- group membership – controlling for pretest scores – was found to be a significant predictor ($\beta = .28,\ p < .001$) for the posttest results
- the two predictors accounted for 21 percent of the differences in lesson-related self-efficacy at the second time of measurement ($R^2 = .21,\ F(2,143) = 18.88,\ p < .001$)

Criterion	Coefficient	b	SE	β	p
Posttest	Intercept	3.05	0.27		.000
	Pretest	0.33	0.06	. 41	.000
	Group	0.42	0.11	. 28	.000

Discussion

- study on the effectiveness of university seminars in promoting self-efficacy in the teaching area of simulations and mathematical modelling with digital tools
- two promotion possibilities according to Bandura (1997): ena*ctive mastery experiences* and *verbal persuasion*
- data collection: two measurement points (at the beginning and end of the semester) in closed response formats
- no individual qualitative investigation of the reasons for the change in self-efficacy

Discussion

- theoretical and practical occupation with tasks and practical teaching elements within the framework of a seminar were able to promote the self-efficacy in the dimensions of *tasks* and *lesson*
- regression analysis: the data collected suggested a significant predictive power of group membership with a small practical relevance for the scores in the posttest in both dimensions

Discussion

- control croup: no *specific* support in form of our seminar, but parts of the control group may have attended other didactic courses
- outlook:
  - larger, cumulative sample
  - investigation of further aspects

Thank you for your attention!

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References I

Bandura, A. (1997). *Self-efficacy: the exercise of control*. New York: W.H. Freeman.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (ed.), *Self-efficacy beliefs of adolescents* (pp. 307–337). Greenwich, CT: Information Age Publishing.

Baumert, J., & Kunter, M. (2013). The coactiv model of teachers' professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (ed.), *Cognitive activation in the mathematics classroom and professional competence of teachers: results from the COACTIV project* (pp. 25–48). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4614-5149-5

Blömeke, S., Gustafsson, J.-E., & Shavelson, R. J. (2015). Beyond Dichotomies: Competence Viewed as a Continuum. *Zeitschrift für Psychologie*, *223*(1), 3–13. https://doi.org/10.1027/2151-2604/a000194

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd edition). New Jersey: Lawrence Erlbaum Associates.

Gerber, S., & Quarder, J. (2022). *Erfassung von Aspekten professioneller Kompetenz zum Lehren des Simulierens und mathematischen Modellierens mit digitalen Werkzeugen. Ein Testinstrument*. Universität Würzburg. https://opus.bibliothek.uni-wuerzburg.de/27359

References II

Greefrath, G. (2011). Using technologies: New possibilities of teaching and learning modelling – Overview. In G. Kaiser, W. Blum, R. Borromeo Ferri, & G. Stillman (Hrsg.), *Trends in Teaching and Learning of Mathematical Modelling: ICTMA14* (S. 301–304). Springer. https://doi.org/10.1007/978-94-007-0910-2

Greefrath, G., & Siller, H.-S. (2017). Modelling and simulation with the help of digital tools. In G. A. Stillman, W. Blum, & G. Kaiser (ed.), *Mathematical Modelling and Applications* (pp. 529–539). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-62968-1_44

Kunter, M. (2013). Motivation as an aspect of professional competence: research findings on teacher enthusiasm. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (ed.), *Cognitive activation in the mathematics classroom and professional competence of teachers: Results from the COACTIV project* (pp. 273–289). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4614-5149-5

Niss, M., Blum, W., & Galbraith, P. (2007). Introduction. In W. Blum, P. L. Galbraith, H.-W. Henn, & M. Niss (ed.), *Modelling and Applications in Mathematics Education. The 14th ICMI study* (pp. 3–32). New York: Springer. https://doi.org/10.1007/978-0-387-29822-1_1

Podworny, S. (2019). *Simulationen und Randomisierungstests mit der Software TinkerPlots: Theoretische Werkzeuganalyse und explorative Fallstudie*. Wiesbaden: Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-25911-2

References III

Siller, H.-S., Greefrath, G., Wess, R., & Klock, H. (submitted). Pre-service teachers' self-efficacy for teaching mathematical modelling. In G. Greefrath, S. Carreira, & G. A. Stillman (ed.), Advancing and Consolidating Research on Applications and Modelling in Mathematics Education—Approaches from ICME 14.

Thurm, D., & Barzel, B. (2020). Effects of a professional development program for teaching mathematics with technology on teachers' beliefs, self-efficacy and practices. *ZDM Mathematics Education*, *52*(7), 1411–1422. https://doi.org/10.1007/s11858-020-01158-6

Thurm, D., & Barzel, B. (2022). Teaching mathematics with technology: a multidimensional analysis of teacher beliefs. *Educational Studies in Mathematics*, *109*(1), 41–63. https://doi.org/10.1007/s10649-021-10072-x

Weinert, F. E. (2001). Concept of competence: A conceptual clarification. In D. S. Rychen & L. H. Salganik (ed.), *Defining and selecting key competencies* (pp. 46–65). Kirkland, WA: Hogrefe & Huber.

Wess, R., Klock, H., Siller, H.-S., & Greefrath, G. (2021). *Measuring professional competence for the teaching of mathematical modelling: a test instrument*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-78071-5