DZLM German Center for Mathematics Teacher Education

Leibniz Gemeinschaft

IPN Leibniz Institute for Science and Mathematics Education

Promoting teacher expertise for fostering at-risk students' understanding of basic concepts

An example for content-related PD research

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My agenda for this talk

What kind of empirical foundation do we need for professional development?

Why is content-related PD research so important?

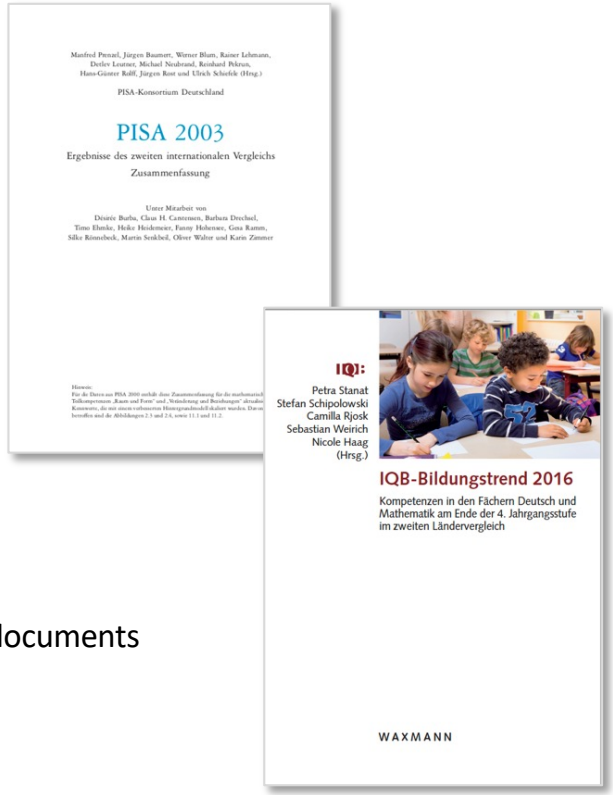
How can we achieve an empirical foundation?

Exemplified for the PD content “fostering at-risk students’ understanding of basic concepts”

I will start on the classroom level to show structural analogies in research needs and research approaches

Starting points of the project Mastering Math

since 2000 Large-Scale-Assessments: 20-25% of students are at risk of being left behind without access to mathematics (PISA 2003, IQB 2016 etc.)



Policy level

→ Fostering students' understanding as an mandatory teacher job in policy documents

Realization gap

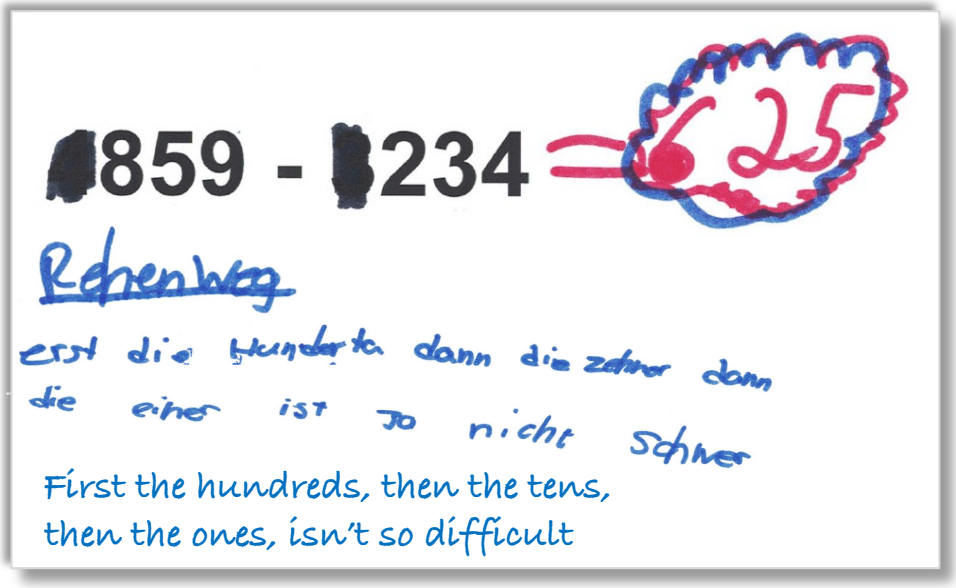
Classroom level

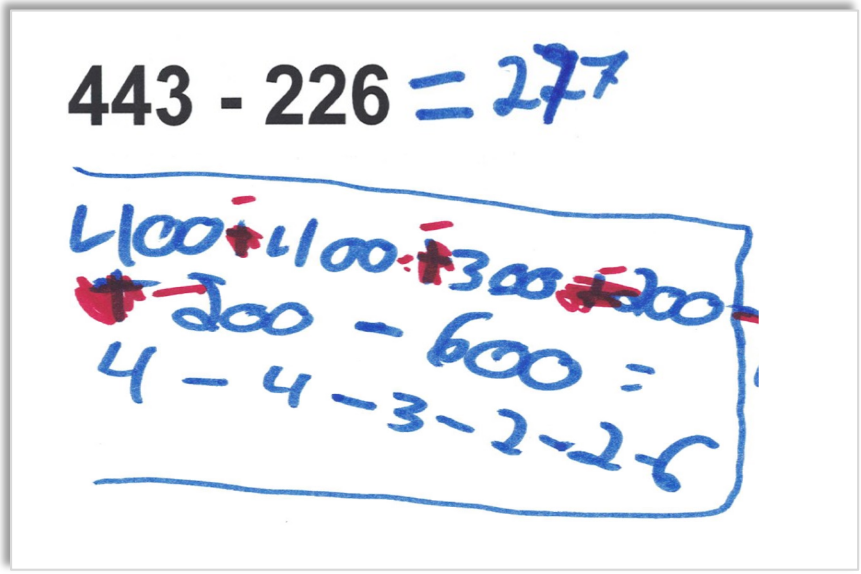
The case of Paul: How to foster at-risks students‘ mathematics learning?

Teacher Paul describes Suleika‘s struggle: (Grade 5)

Suleika can calculate the subtraction well, only the carries pose problems for her.

But we can handle this successfully by differentiated tasks: I only give her subtractions without carries.



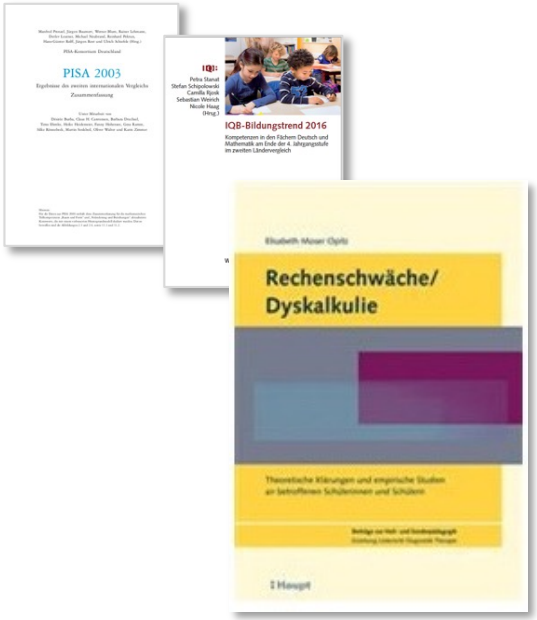


Suleika has no access to a basic concept: Place value understanding

Continued struggle due to missing learning opportunities!

“At risk”: the risk is in missing learnrng opportunities, not in students’ background (Jackson et al. 2017)

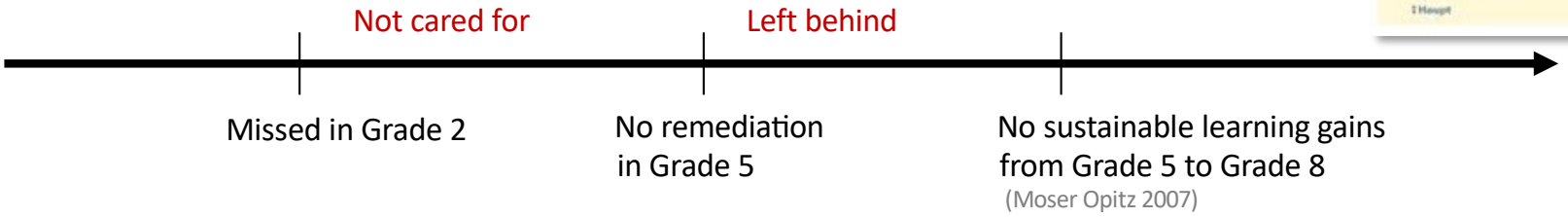
Empirical foundation for the classroom level



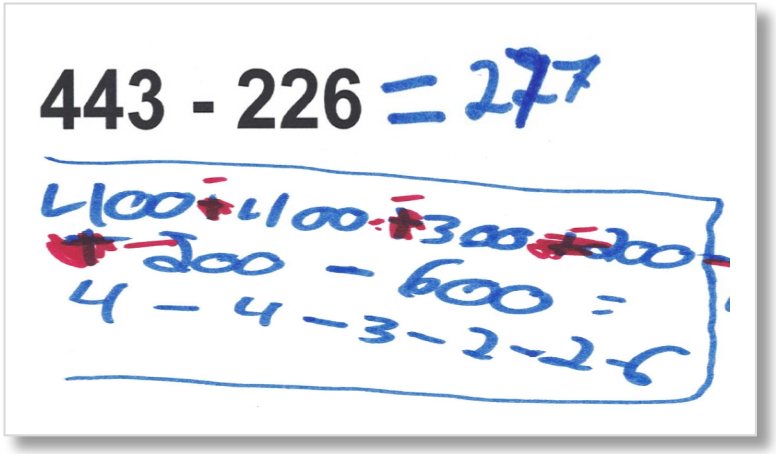
Identify and localize problem

since 2000 Large scale assessments: 20-25% of students are at risk of being left behind without access to mathematics (PISA 2003, IQB 2016 etc.)

2005-07 Interview study and tests for identifying relevant basic **concepts** and empirical evidence for their predictive power



Basic concept:
place value understanding



(Cobb & Jackson 2021)

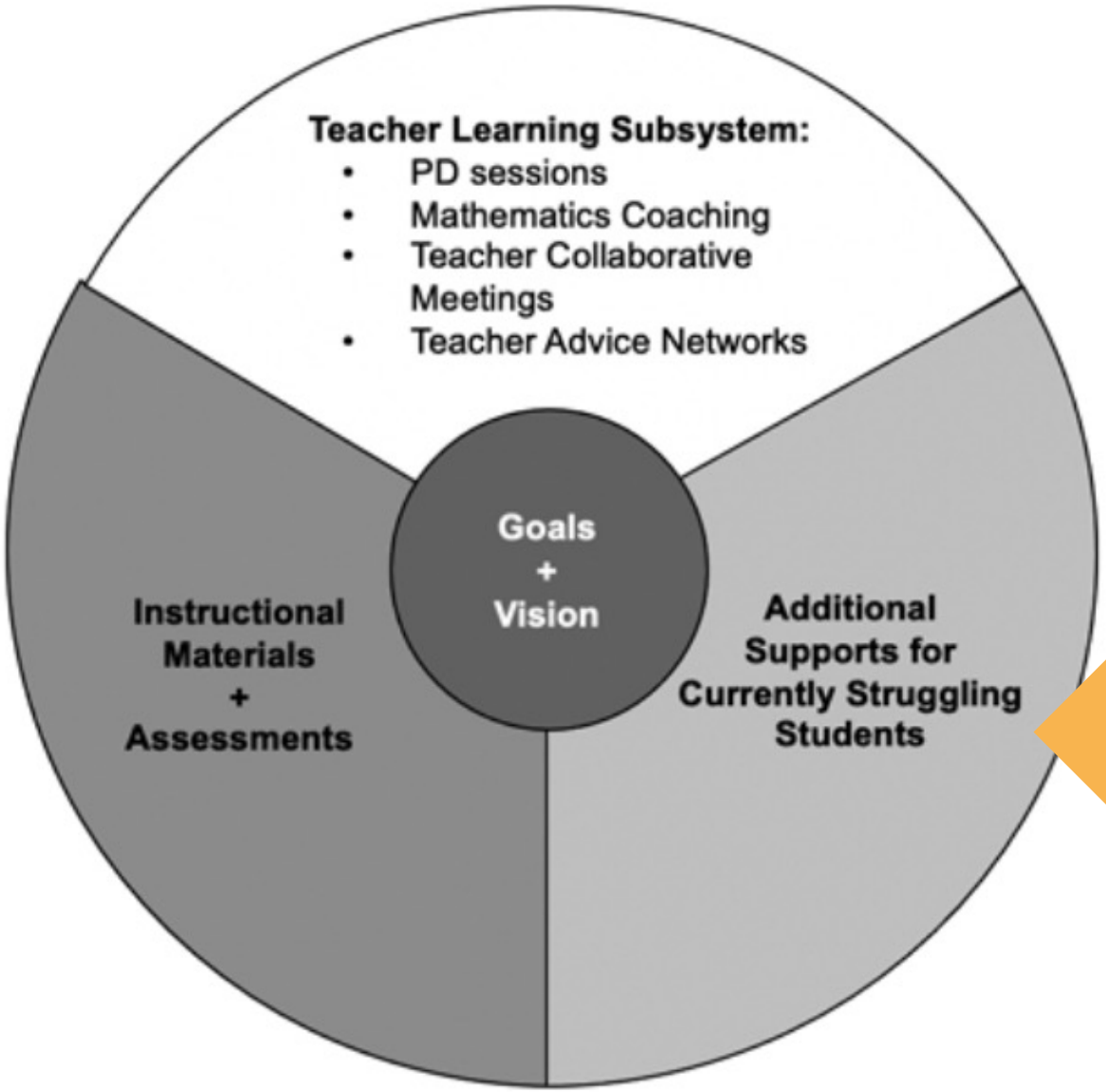


FIGURE 1 Elements of a coherent instructional system

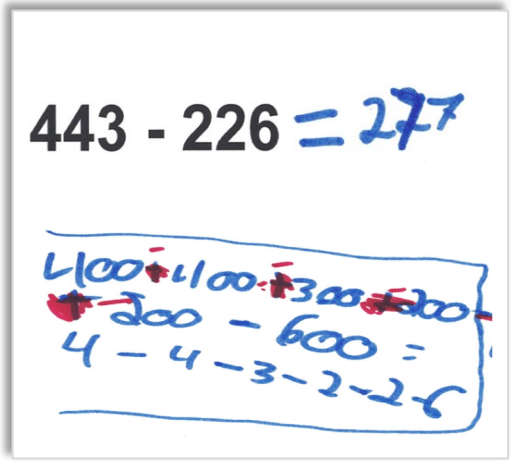
Empirical foundation for the classroom level

Identify and localize problem

since 2000 Large scale assessments: 20-25% of students are at risk of being left behind without accesss to mathematics (PISA 2003, IQB 2016 etc.)

2005-07 Interview study and tests for identifying relevant basic concepts and empirical evidence for their predictive power

2009-11 Development of standardized measures BasisMathG – Screening for identifying students without access to basic concepts and skills
(published later as Moser-Opitz, Prediger et al. 2016, Hogrefe)



Empirical foundation for the classroom level

Identify and localize problems

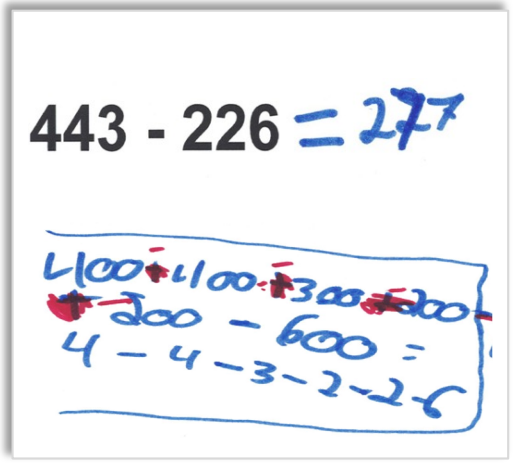
since 2000 Large scale assessments

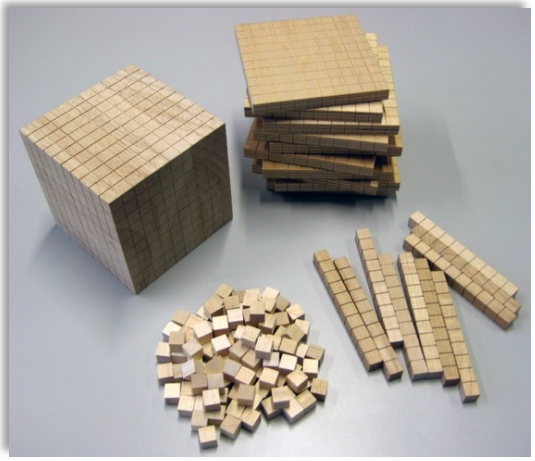
2005-07 Interview study and tests

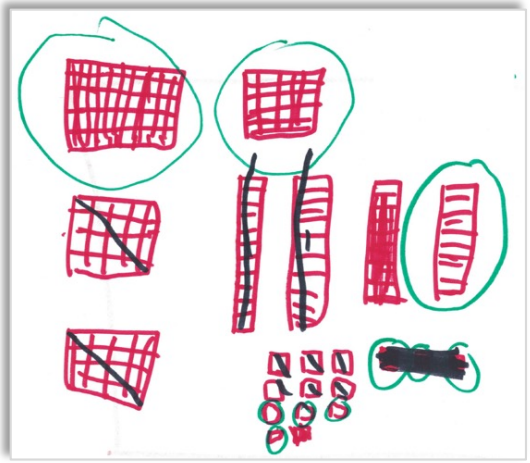
2009-11 Development of standardized screening

Design conceptual remediation program

2004-07 Design experiments for specifying basic concepts and enhancing them







443 = 400 + 40 + 3

4 Hundreds

4 Tens

3 Ones

Thereof take away:

226 = 200 + 20 + 6

2 Hundreds

2 Tens

6 Ones

Empirical foundation for the classroom level

Identify and localize problems

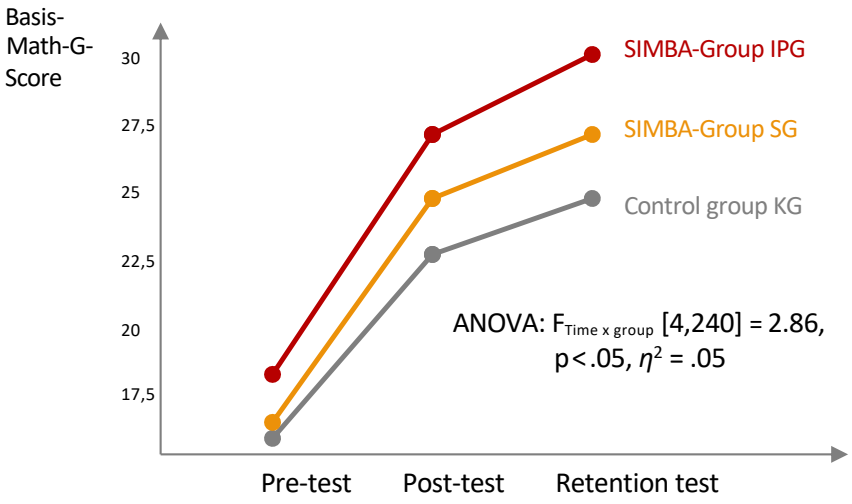
Design and evaluate conceptual remediation program

2004-07 Design experiments for specifying the basic concepts and enhancing them

2009-12 Empirical evidence for efficacy in quasi-experimental controlled trial (under laboratory conditions)

(Moser Opitz, Prediger et al. 2017 in Journal for Learning Disabilities)

→ significantly higher learning gains



Empirical foundation for the material implementation strategy

Identify and localize problems

Design and evaluate conceptual remediation program

2004-07 Design experiments for specifying the basic concepts and enhancing them

2009-12 Empirical evidence for efficacy in quasi-experimental controlled trial (under laboratory conditions)

Implementation at scale?

2010-17 **Mastering Math:** Redesign the laboratory remediation program into curriculum resources for everyday use in classrooms

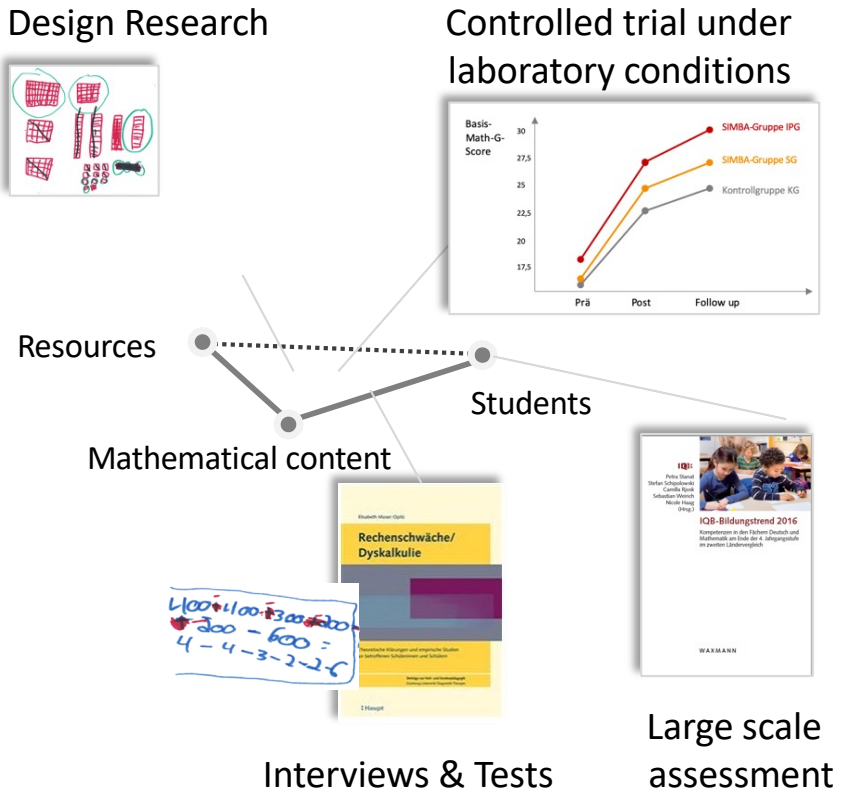
- developed in iterative cycles of design, design experiment and re-design
  (Selter, Prediger, Nührenbörger, Hußmann 2014)
- multiple involvement of mathematics teachers, consulting us how the curriculum resources can best support their work
- in total 21 years of work in Design Research (7 x 3 years)

Mastering Math

How can an empirical foundation of programs for struggling students be achieved?

Classroom level

Always by combining several research approaches



How can implementation of a program be achieved?

Curriculum ressources alone do not do good teaching

Focus on mathematics teachers is crucial (Cohen, Raudenbush, Ball 2003; Desimone 2009)

Classroom level

Material Strategy

Resources

Mathematics teachers

Personell strategy

Systemic strategy

Establish communitiies of inquiry

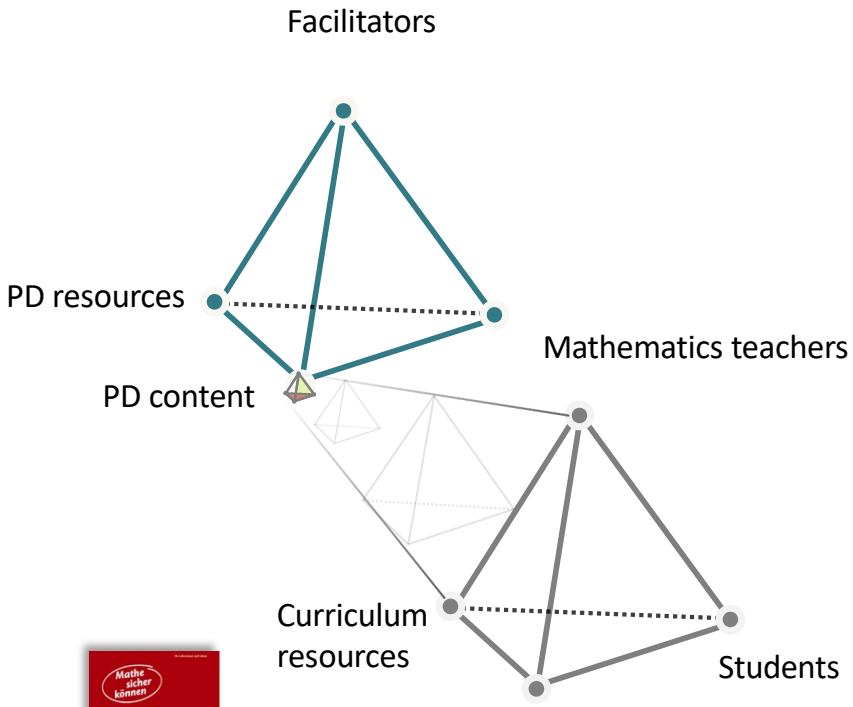
(Jaworski, 2006; Bonsen et al. 2010)

Mathematical content

Students

Teacher PD level – structural analogy of relevant components

Teacher PD level



Classroom level

Designing a PD program and PD resources

Modules of the Mastering Math PD program with action and reflection

Teacher PD

Classroo

Sandwich-Phasen

Baustein 1
Einführung in Prinzipen & Organisation zu Diagnose und Förderung von Verstehensgrundlagen – am Beispiel Multiplizieren

Distanzphase
Durchführung der Diagnose zum Stellenwertverständnis

Baustein 2
Auswertung der Diagnosen und inhaltliche Planung der Förderung zum Stellenwertverständnis; methodische Gestaltung der Förderung

Distanzphase
Durchführung der Förderung zum Stellenwertverständnis

Baustein 3
Auswertung der Fördererfahrungen, Vertiefung zur Gesprächsführung, Hintergründe zum nächsten Thema Zahlenstrahl

Designing a PD program and PD resources

Germany has 33 0000 schools
so scaling up is needed

Teacher PD level

Product: PD modules
dzlm.de/2000

Classroom level

Design Research on PD level

Further steps of transfer

Germany has 33 0000 schools
so scaling up is needed

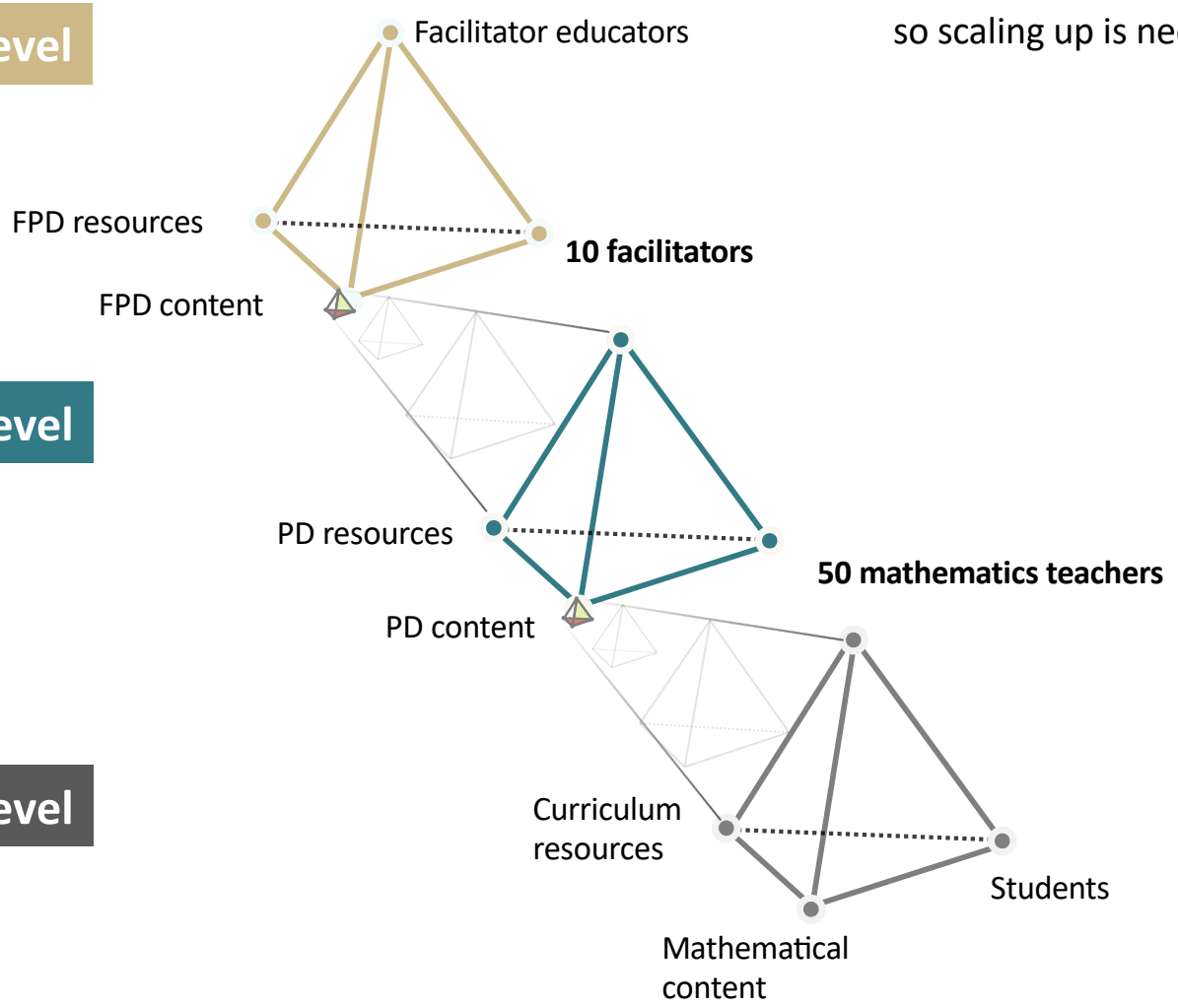
Facilitator PD level

Successive and nested design by Design Research

Teacher PD level

Successive and nested design by Design Research

Classroom level



Prediger, S., Roesken-Winter, B., & Leuders, T. (2019). Which research can support PD facilitators? Research strategies in the Three-Tetrahedron Model for content-related PD research. *Journal for Mathematics Teacher Education, 22*(4), 407-425. doi:10.1007/s10857-019-09434-3

Further steps of transfer

Systemic implementation architecture

Facilitator PD level

Successive and nested design by Design Research

FPD resources

FPD conte

Teacher PD level

Successive and nested design by Design Research

Classroom level

Levels	Major tasks on each level	Support offered by Mastering Math team (6 researchers, 1 coordinator)
Level of school districts	7 School districts • Recruit 40 schools to participate in the project • Pay 9 network facilitators to accompany teacher communities in the schools and to establish networks of schools in each district	• Negotiate with school districts to install the project • Qualify the network facilitators to facilitate the network communication and meetings (focus on main principles of material- and community-based strategies)
Level of schools as institutions	40 secondary comprehensive schools • Jointly commit themselves as being a Mastering Math school • Provide teaching resources for extra courses (1-3 lessons per week, depending on size of school) • Establish reliable communication time for teacher communities in schools (regularly visited by network facilitator)	• Negotiate with principals to install reliable structures for courses and teachers' community meetings • Sign written contracts with each school to establish reliable mutual expectations
Level of teacher communities in schools	40 teacher communities in schools • Regularly meet in the school, partly with the school's network facilitator • Discuss experiences of noticing and supporting students • Increasingly include the Mastering Math teaching approach in their teaching repertory (also in regular classrooms)	Qualify and accompany the 9 network facilitators to • accompany teacher communities and enhance cooperation • support inclusion of the teaching approach and teaching materials • support teachers in interpreting diagnostic tasks and in overcoming obstacles in the courses
Level of classrooms	90–120 teachers • Commit themselves as Mastering Math project members who work within the teaching approach and with the provided teaching materials • Teach one of the Mastering Math courses with 8-10 students each	• Provide teaching material to support teachers in noticing and fostering students' basic conceptual understanding
Level of students	343 low-achieving students in intervention • are selected out of 3,837 students in the 40 schools involved based on their basic needs • come to one lesson of a Mastering Math course per week in addition to regular classes (similarly in the control schools)	• Provide standardized screening tool to select students with basic conceptual needs • Pre- and post-test for assessing effectiveness

Prediger, Fischer, Selter, & Schöber (2019) in Educational Studies in Mathematics, 102(3), 361-378.

First study of implementation effectiveness

Facilitator PD level

Successive and nested design by Design Research

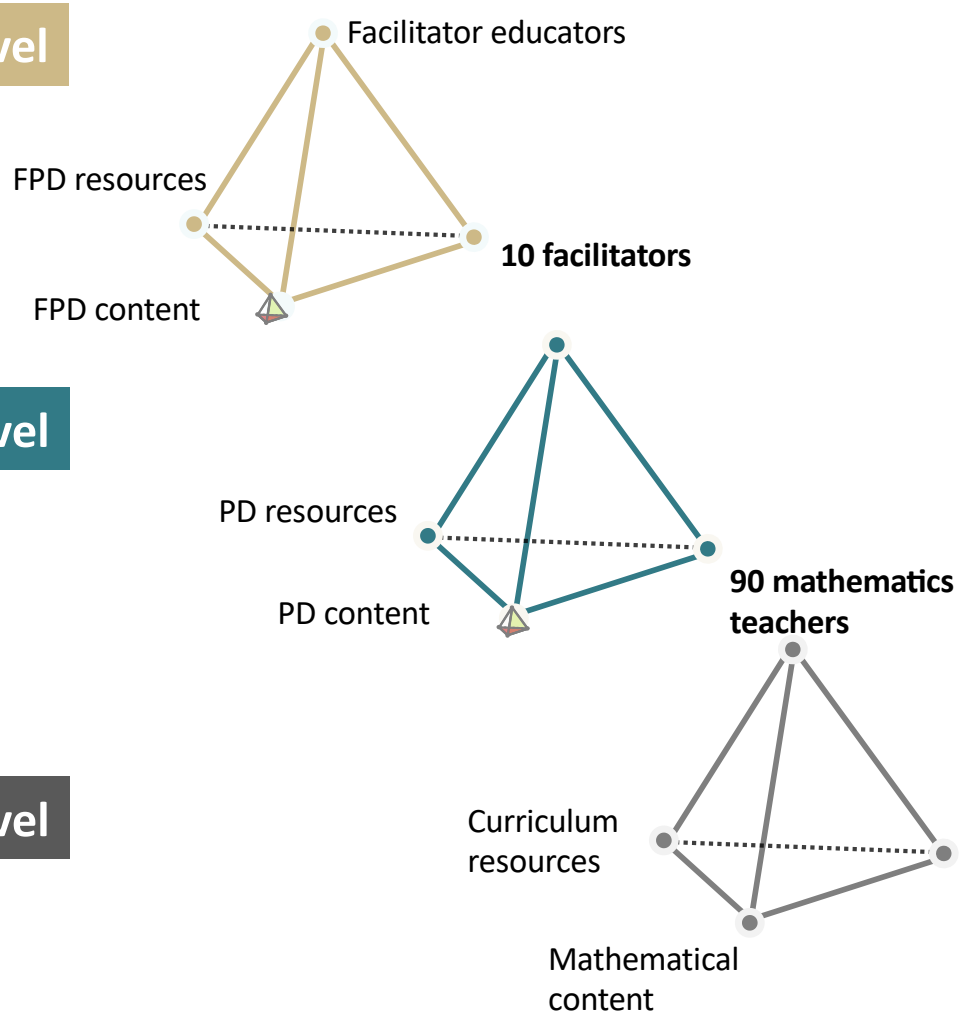
Effectiveness research down the levels

Teacher PD level

Successive and nested design by Design Research

Effectiveness research down the levels

Classroom level



Evaluation in large field study

IPN

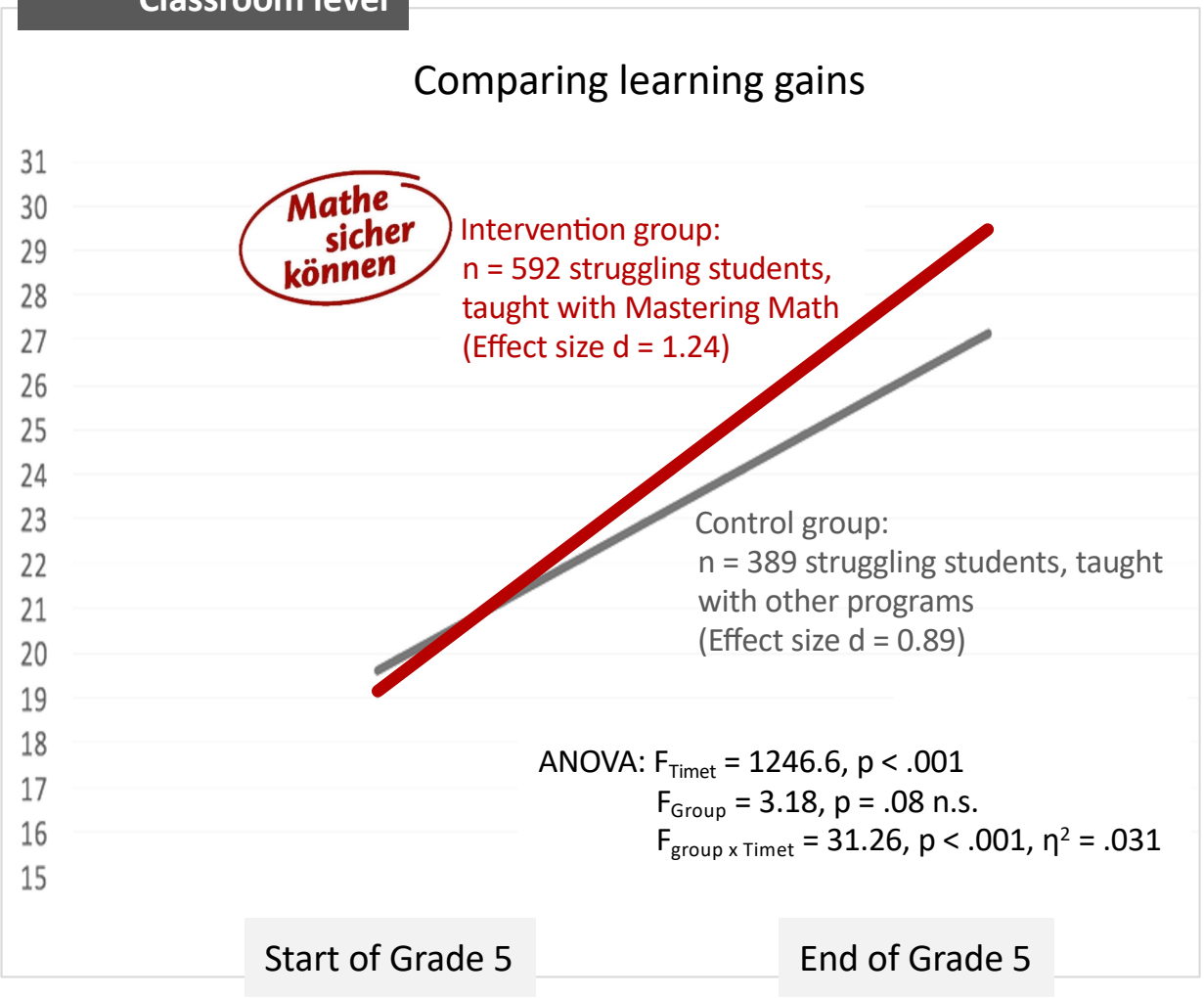
Facilitators‘ self-reports and process reports

Teachers‘ self-reports on received support and further support needs

Students‘ learning gains

Empirical evidence for effects in students‘ learning gains

Classroom level



Evaluation in large field study

IPN

Facilitator PD level

Facilitators‘ self-reports and process reports

Teacher PD level

Teachers‘ self-reports on received support and further support needs

Classroom level

Students‘ learning gains

Highly significantly better leanring gains with impressive effect sizes

But: substantial differences between teachers

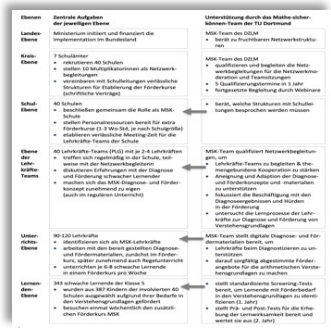
→ further PD research needed to improve targetedness of teachers‘ PD program

Prediger, Fischer, Selter, & Schöber (2019) in Educational Studies in Mathematics, 102(3), 361-378.

Implementation in five federal states (NRW, HH, BE, HB, RP)

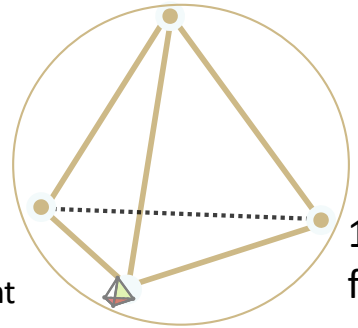
2019-2023: 5 federal states,
6 different systemic conditions

adaptions of systemic implementation structure needed



Facilitator PD level

Facilitator educators



FPD resources

FPD content

Systemic Strategy

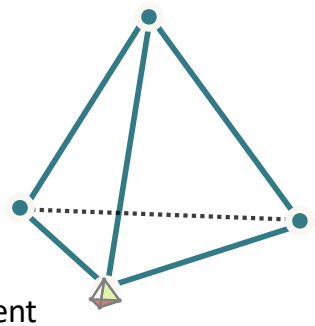
17+10+3+5+x facilitators

Personell Strategy

Teacher PD level

Material Strategy

PD recources



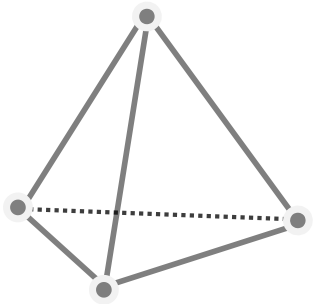
PD content

ca. 400 teachers

Personell Strategy

Classroom level

Curriculum resources



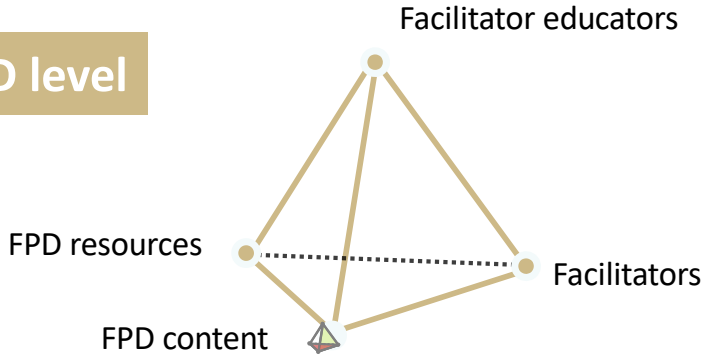
Mathematical content

Unexperienced facilitators
–> more explications about teachers‘ typical professional growth necessary

Empirical foundation?

What kind of empirical foundation do we need for professional development?

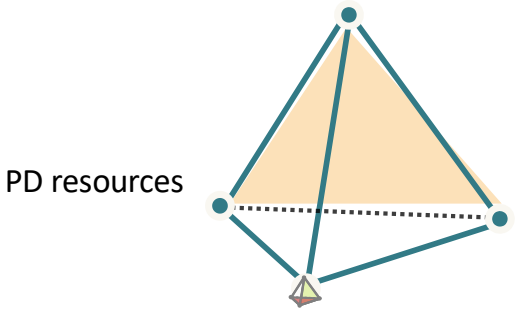
Facilitator PD level



So far, PD research has mainly concentrated on generic design principles,
without much explicit attention to the PD content

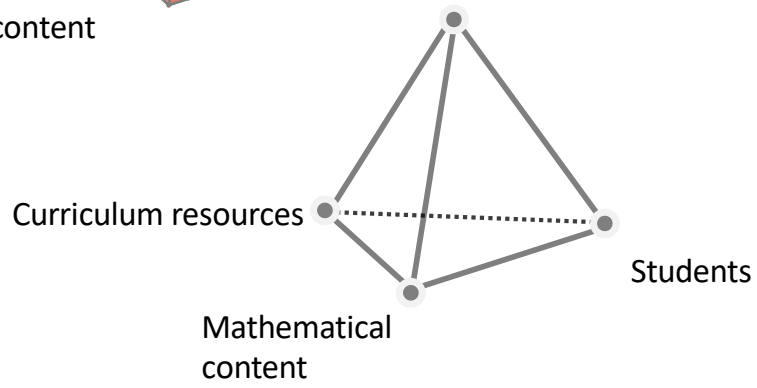
(Yoon et al. 2007, Lipowsky 2010, Timperley et al. 2007)

Teacher PD level



e.g.
long-term programs
initiate reflection
cooperation
case-based work

Classroom level

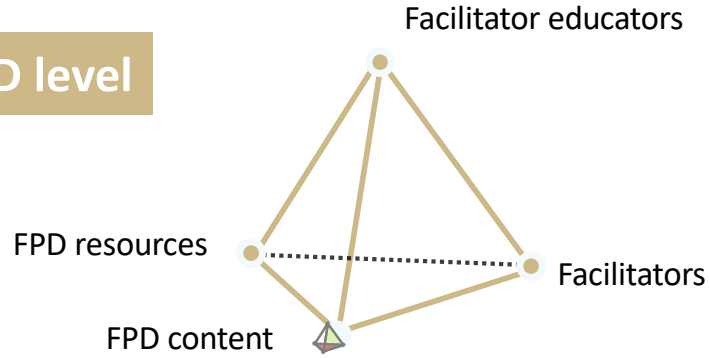


Empirical foundation?

What kind of empirical foundation do we need for professional development?

Why is content-related PD research so important?

Facilitator PD level



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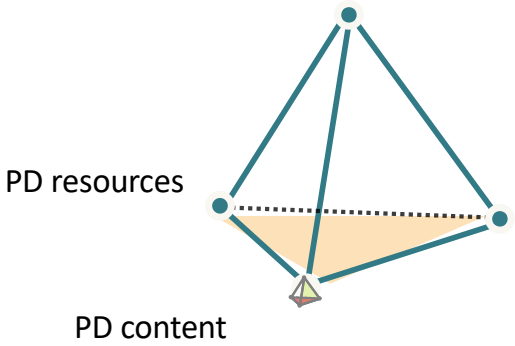
Teacher PD level

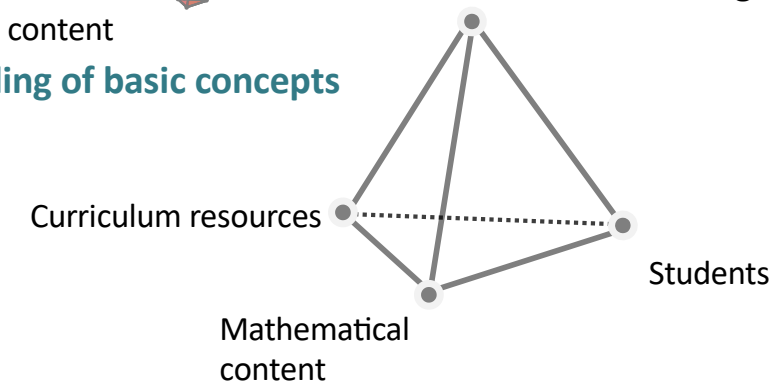


Main goal of content-related PD research:

Understanding teachers‘ content-related professional growth so that PD program can target core issues

Here: Foster understanding of basic concepts

Classroom level



Theoretical background: Model of content-related teacher expertise

(Prediger 2019 adapted from Bromme 1992 & Schoenfeld 2010)

	Prescriptive specification of intended expertise ⟷	**Identification of enacted practices of teachers and their backgrounds**
Jobs	• Which jobs do mathematics teachers have to master? • Which practices are productive for mastering the jobs?	• Which jobs do mathematics teachers really work on, which do they avoid? • By which practices do teachers manage the chosen jobs?
Pedagogical tools	• Which pedagogical tools can be used for the practices to manage the jobs productively?	• Which pedagogical tools do teachers use in their practices for managing the jobs?
Categories for noticing and thinking	• Which categories for noticing and thinking should underly the practices for mastering the jobs?	• Which categories for noticing and thinking do underly the enacted practices for managing the jobs?
Orientations	• Which orientations should guide the prioritization of the jobs and the choice of practices?	• Which orientations do guide the prioritization of the jobs and the enacted practices for managing them?

Theoretical background: Model of content-related teacher expertise

(Prediger et al., to appear in JRME)

Jobs

Monitor students' learning progress (in basic concepts)

Enhance students' understanding (of basic concepts)

Pedagogical tools

Diagnostic tasks

Tasks for enhancement

Visuals & Manipulatives

Teachers' moves

Categories for noticing and thinking

"Understanding of basic concept"

<- challenging PCK category!

Orientations

Diagnostic orientation

Communicative orientation

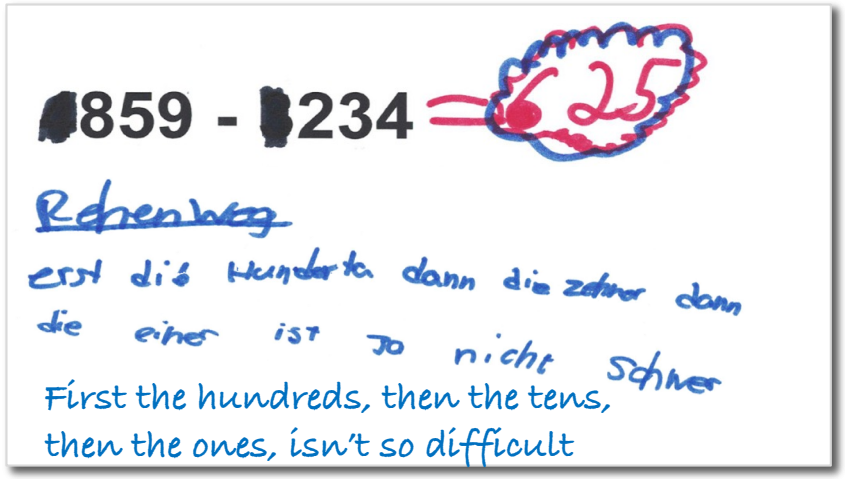
Conceptual orientation

Back to the case of Paul‘s practices

(Prediger 2020 ICMI study)

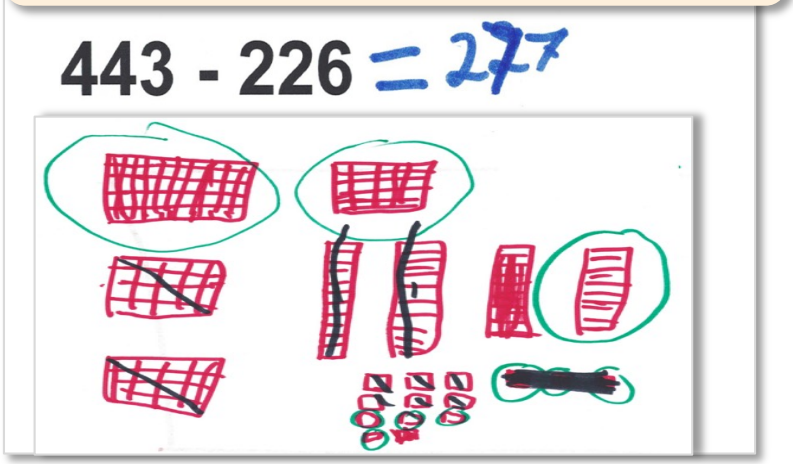
Paul‘s practice for monitoring Suleika‘s learning progress

Suleika can calculate the subtraction well, only the carries pose problems for her.



Paul‘s practice for supporting Suleika:

But we can handle this successfully by differentiated tasks: I only give her subtractions without carries.

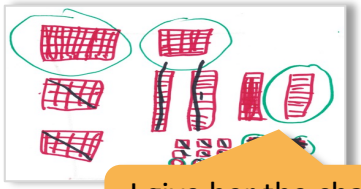


Categories for monitoring Suleika‘s learning needs

	Conceptual understanding	Procedural skills
Current content	Conceptual core, e.g. splitting numbers to understand the meaning of carries	New procedural skill: Multi-digit subtraction with carry
Basics	Underlying basic concept: Place value system	Basic skill: Digit-wise subtraction without carry

Identifying (un)productive practices of teachers and underlying orientations

Intended practices in the Mastering Math program

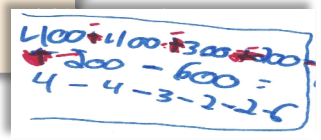


I give her the chance to wrap up what she missed some years ago

Teacher's enacted practices

as identified e.g. in the case of Paul (and many others)

Differentiated tasks: I only give her subtractions without carries.



Enhancement practices for understanding of basic concepts

Compensation practices for circumventing difficulties

Distinction known from other contexts (Corno 2008, Wember 2013)

Identifying (un)productive practices of teachers and underlying orientations

Intended practices for fostering at-risk students'mathematics learning

Teacher's enacted practices with at-risk students

Enhancement practices for understanding of basic concepts ⟷ Compensation practices for circumventing difficulties

2015-2019

Distinction known from other contexts (Corno 2008, Wember 2013)

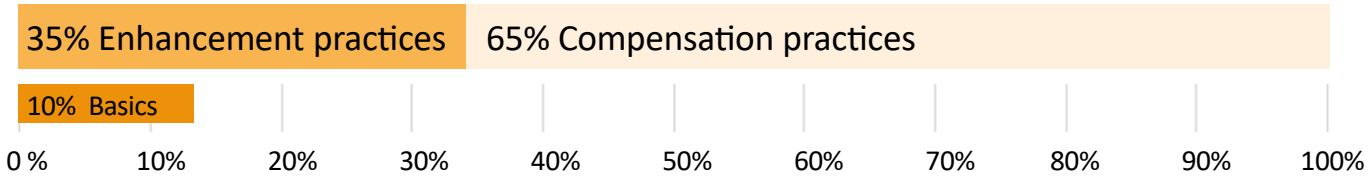
Distinction repeatedly identified in several case studies

(Watson & Geest 2005; Prediger, Schnell & Rösike 2016, Prediger & Buró 2021, Büscher 2019)

2021

Prevalence shown in MATILDA video study: (Prediger & Buró 2022IJIE)

Total: 1821 Practices coded in videos from 25 lessons in inclusive math classrooms



Key question for qualitative PD research:
What does underly these compensation practices?

Identification of orientations and categories underlying productive practices in the model of expertise

(Prediger 2020 ICMI Study, Prediger & Buró 2021))

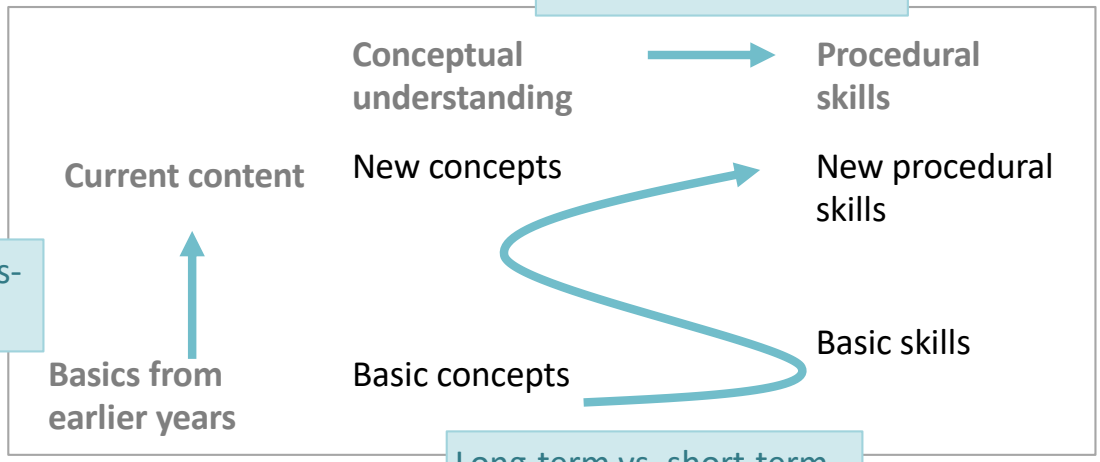
Intended practices in the Mastering Math program

Enhancement practices for understanding of basic concepts

Communicative pedagogy

Categories for monitoring Suleika's learning needs

Conceptual vs. procedural orientation



Diagnostic vs. syllabus-bound orientation

Long-term vs. short-term orientation

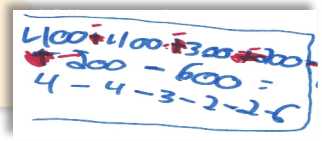
Orientations

Empirical identification of a guiding unproductive category – Task completion

Intended practices and their backgrounds

Teacher's guiding categories
identified in several case studies

Differentiated tasks: I only give her subtractions without carries.



Enhancement practices for students' progress in understanding of basic concepts

Compensation practices for circumventing difficulties

Intended categories for noticing and thinking

Learning progress along a learning trajectory

	Conceptual understanding →	Procedural skills
Current content	New concepts	New procedural skills
Basics from earlier years	Basic concepts	Basic skills

Individual categories for noticing and thinking

Task Completion

Functioning of totally individualized pedagogy

Orientations

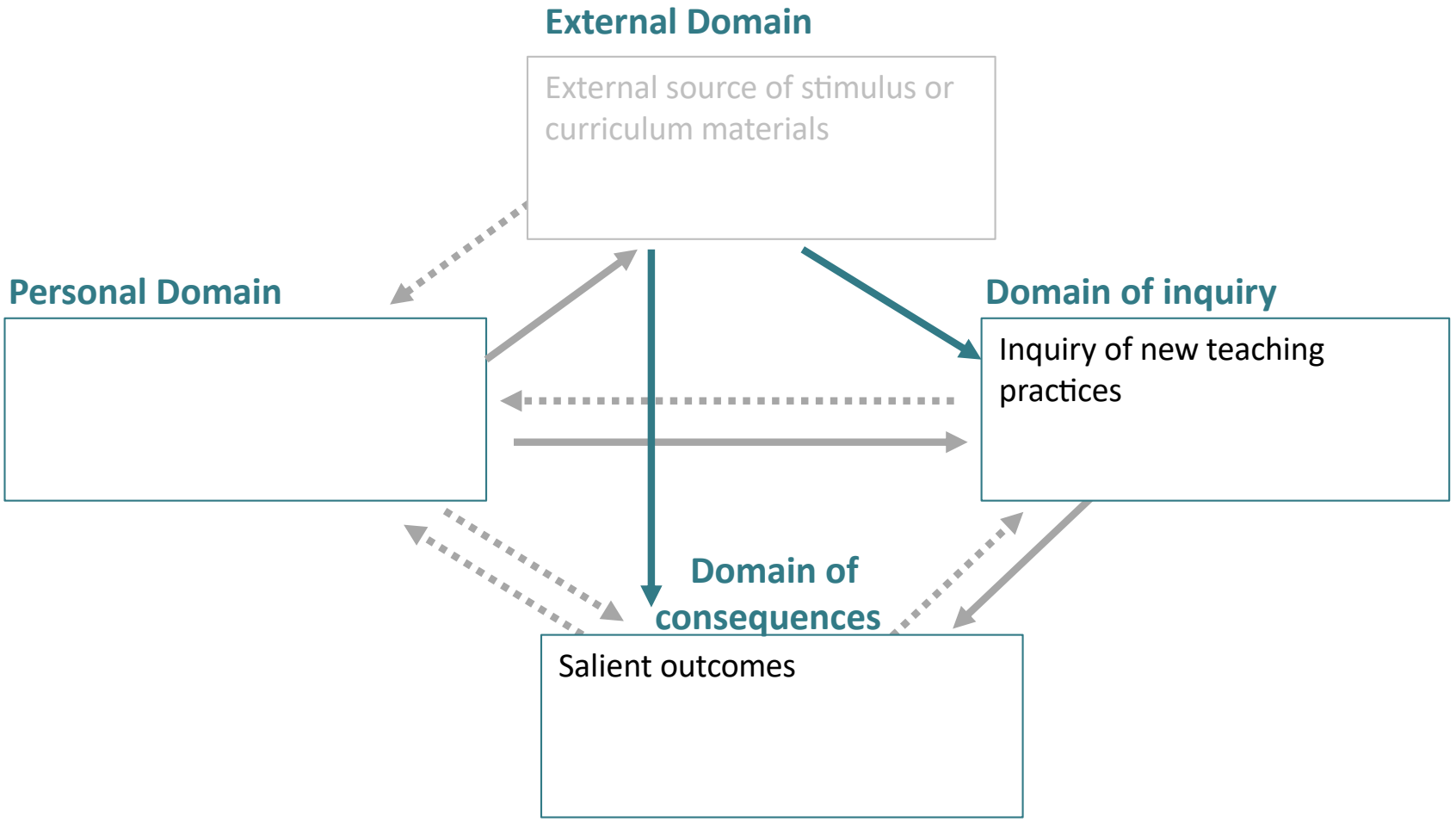
Long-term orientation

Short-term orientation

Explaining mechanisms of teachers' professional growth

Model of Professional Growth

(Clarke & Hollingsworth 2002)



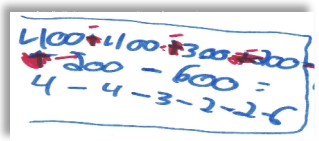
Explaining mechanisms of teachers' professional growth

Model of Professional Growth

(adapted from Clarke & Hollingsworth 2002 in Prediger 2022ICMI)

Maria

I tried to teach them subtraction with carries several times, but they always forget it.



External Domain

External source of stimulus or curriculum materials, e.g., materials for assessing and fostering basic conceptual needs

not yet in play before facilitator-researcher joined

Collective Domain

Shared practices, orientations and categories: established compensation practices with underlying evaluation categories

Domain of inquiry

Collaborative inquiry of new teaching practices: differentiation by compensation practices for at-risk students

forgetting not related?

simplified tasks with lowered expectation

Domain of consequences

Salient outcomes, evaluated by ||learning progress|| in ||understanding basic concepts|| vs. ||task completion||

Both evaluation categories could not push teachers' professional growth for 3 months

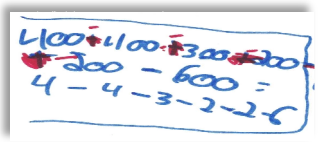
Paul: ||task completion||

Maria || forgetting ||, first aspect of ||learning progress||

Explaining mechanisms of teachers' professional growth

Model of Professional Growth

(adapted from Clarke & Hollingsworth 2002 in Prediger 2022ICMI)



External Domain

External source of stimulus or curriculum materials, e.g., materials for monitoring & enhancing understanding in basic concepts

Collective Domain

Shared practices, orientations and categories: established compensation practices with underlying evaluation categories

Domain of inquiry

Collaborative inquiry of new teaching practices:

new enhancement practices for at-risk students

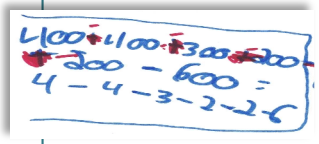
Offer other evaluation criteria

Domain of consequences

Salient outcomes, evaluated by

||learning progress|| in || basic conceptual needs ||

vs. || task completion ||



PD trajectory for evaluation categories for practices

1. || Work intensity ||
2. || Task completion ||
3. || Procedural learning progress||
4. || Conceptual learning progress||

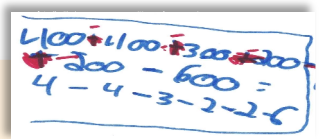
Prediger, S. (2022, in press). Content-specific theory elements for explaining and enhancing teachers' professional growth in collaborative groups. In H. Borko & D. Potari (Eds.), ICMI Study 25. Teachers of mathematics working and learning in collaborative groups. Springer.

Systematic relation of intended and enacted practices and orientations

Intended practices and underlying orientations

Enacted practices and underlying orientations

Differentiated tasks: I only give her subtractions without carries.

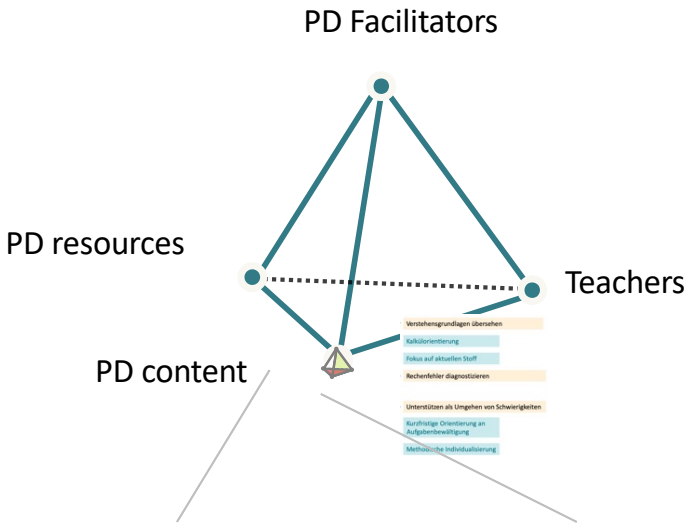


Identify relevant basic concepts	⟷	Overlook unaccomplished understanding in basic c.
Conceptual orientation		Procedural orientation
Long-term focus on basics		Short-term focus on current content
Monitor students‘ progress in basic concepts	⟷	Monitor students‘ procedural performance
Diagnostic orientation		Syllabus-bound orientation
Enhance understanding of basic concepts	⟷	Compensate to circumvent difficulties
Long-term orientation		Short-term orientation for repair
Communicative pedagogy		Solely individualized pedagogy

Task completion

Outcomes of the qualitative research on the teacher PD level

Teacher PD level



Design Research for specifying the PD content in detail

- Cocneptual orientation
- Diagnostic orientation
- Communicative pedagogy

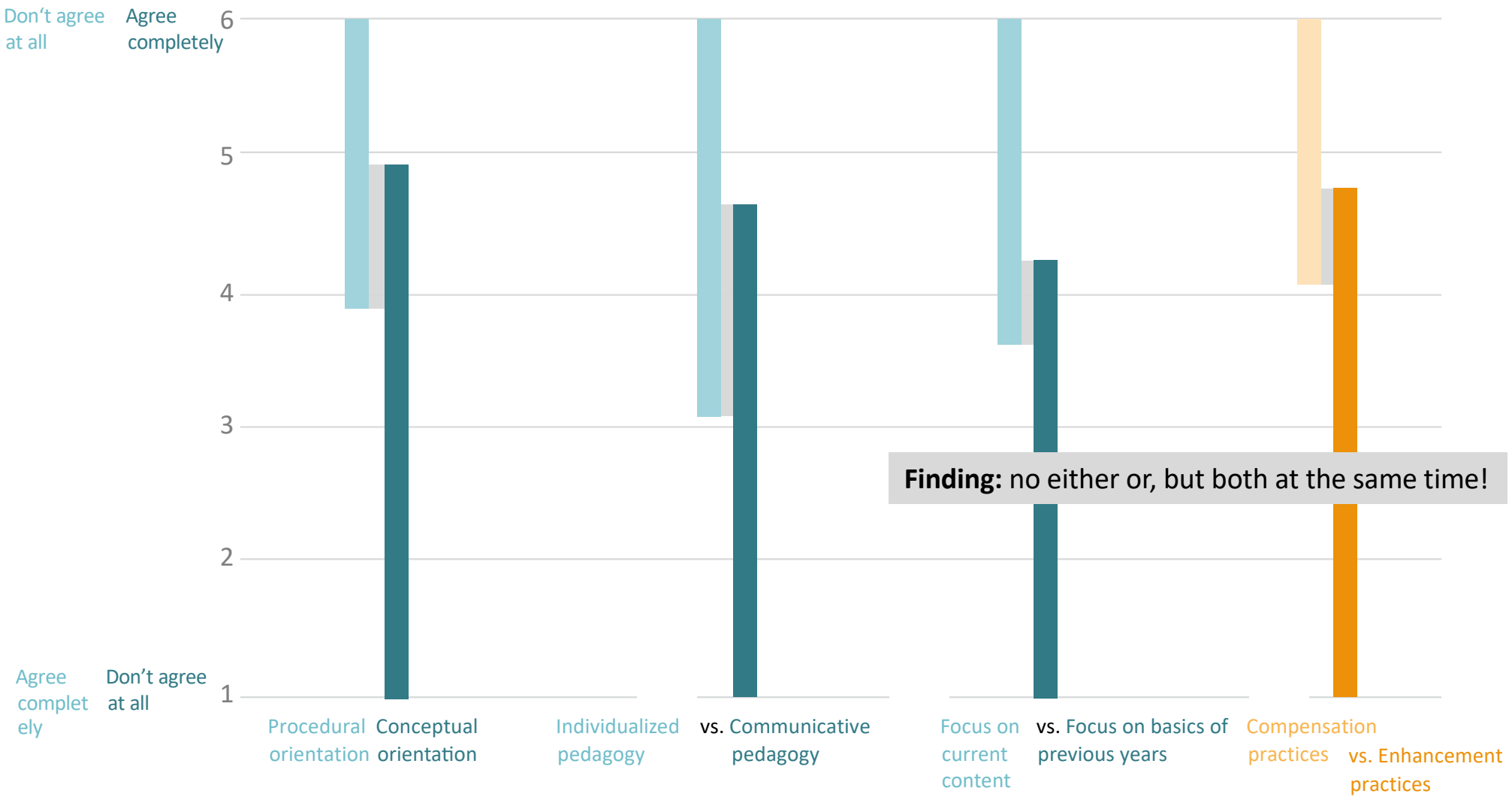
Jobs und produktiven Orientierungen	Unproduktive Praktiken und Orientierungen
Verstehensgrundlagen identifizieren	Verstehensgrundlagen übersehen
Verstehensorientierung	Kalkülorientierung
Fokus auf Grundlagen	Fokus auf aktuellen Stoff
Verstehensgrundlagen diagnostizieren	Rechenfehler diagnostizieren
Diagnosegeleitetheit	
Verstehensgrundlagen fördern	Unterstützen als Umgehen von Schwierigkeiten
Langfristige Orientierung an Verstehenszuwächsen	Kurzfristige Orientierung an Aufgabenbewältigung
Kommunikationsförderung	Methodische Individualisierung

-> Developing quantitative measures for capturing orientations

(Kattmann et al. 1996, Komorek et al. 2013)

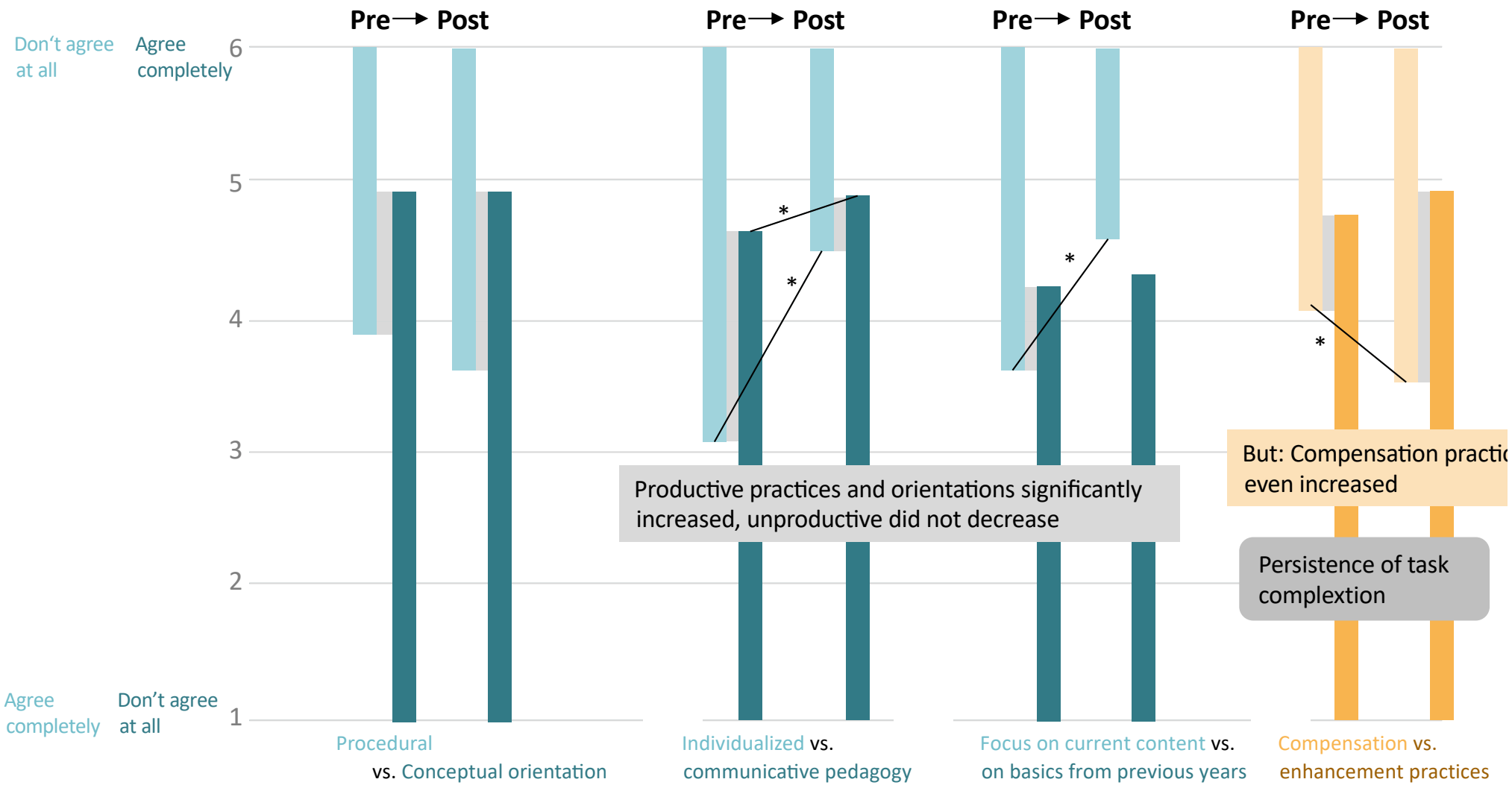
Quantitative measures on self-reported practices and orientations

Questionnaire at beginning of PD on Mastering Math
(n = 95 teachers)



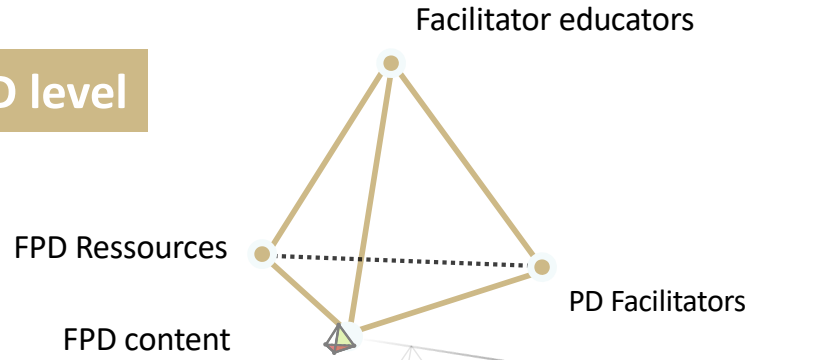
Measurable change of self-reported practices and orientations

Questionnaire at beginning of PD and after one year of PD on Mastering Math
(n = 95 teachers)

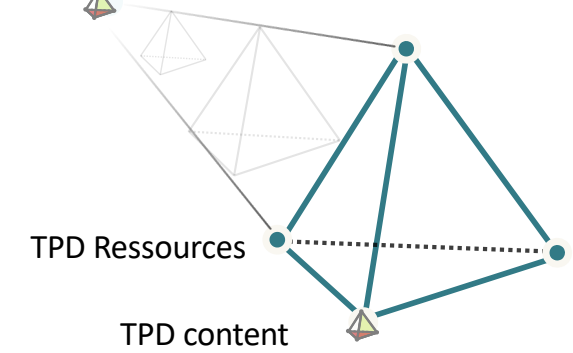


Empirical foundation by research on PD level

Facilitator PD level

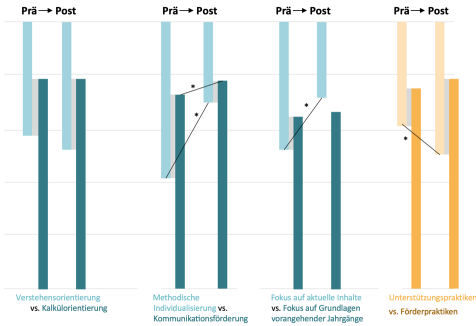


Teacher PD level

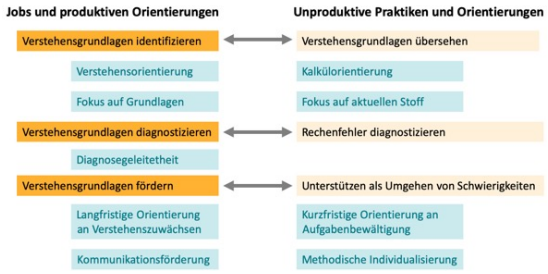


Mathematics teachers

First empiciral evidence for effectiveness



Design Research for specifying the PD content in detail



Substantiated model of teacher expertise for fostering at-risk students‘ understanding of basic concepts

(Prediger 2020, Prediger et al., to appear in JMTE)

Jobs

- Identify relevant basic concepts
- Monitor students‘ progress in basic concepts
- Enhance understanding of basic concepts
- Compensate by circum-venting difficulties

Pedagogical tools

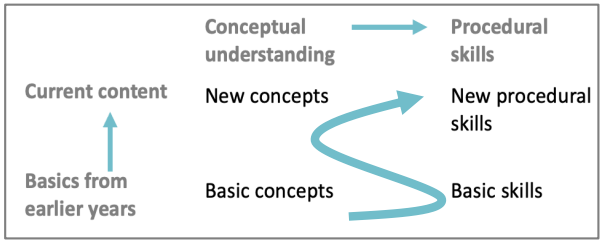
- Manual with didactical background on all basic concepts
- Diagnostic tasks

- Tasks for enhancement

- Visuals & Manipulatives

- Teacher moves

Categories for noticing & thinking



Learning progress on a leanring trajectory

Most heavy challenge!!

↔ Task completion

Orientations

- Conceptual rather than procedural orientation
- Diagnostic rather than syllabus-bound orientation
- Communicative, not individualized pedagogy
- Long-term, not short-term orientation

More detailed evaluation in a more complex matrix

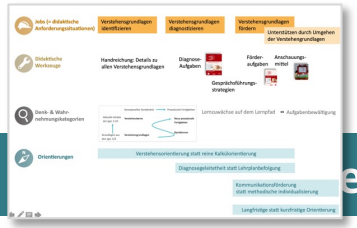
Changes in captured practices
with effect size *d*

Orientations	Specify learning content	Monitor students' learning progress	Enhance students' understanding
Compass: Diagnostic orientation OR Syllabus-bound orientation	Adaptive goal-setting practices -0.11 *Syllabus-bound goal-setting practices 0.73*		
Content: Conceptual orientation OR Procedural orientation	Conceptual goa-setting practices 0.05 Procedural goal-setting practices -0.27	Conceptual diagnostic practices-in-action 0.33 Procedural diagnostic practices-in-action -0.33	Conceptual enhancement practices 0.00 Procedural enhancement practices -0.09
Goal: Long-term orientation OR Short-term orientation	Long-term foundation practices 0.02 Short-term repair practices -0.64	Long-term diagnostic practices-in-action 0.03 Short-term diagnostic practices-in-action -0.03	Enhancement practices aim-ing at learning progress 0.13 *Compensation practices aim-ing at task completion 0.34*
Pedagogy: Communicative orientation OR Individualized orientation			Communicative pedagogies 0.26 Individualized pedagogies -0.82
Categories Categories for adequate mathematical focus	Unpacking practices-in-action 0.38	Targeted diagnostic practices-in-action 0.12	

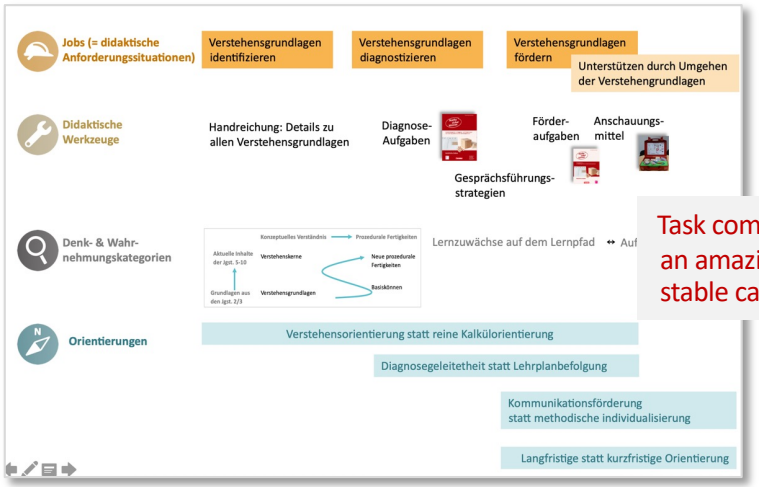
(Prediger et al., to appear in JMTE)

Implications for the facilitator preparation programs

Facilitator PD level

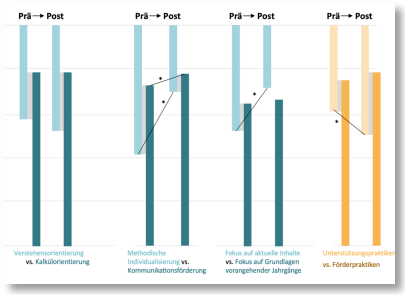


Design research for further specification of PD content



Task completion as an amazingly stable category

Effectiveness study shows effects and limitations of the PD

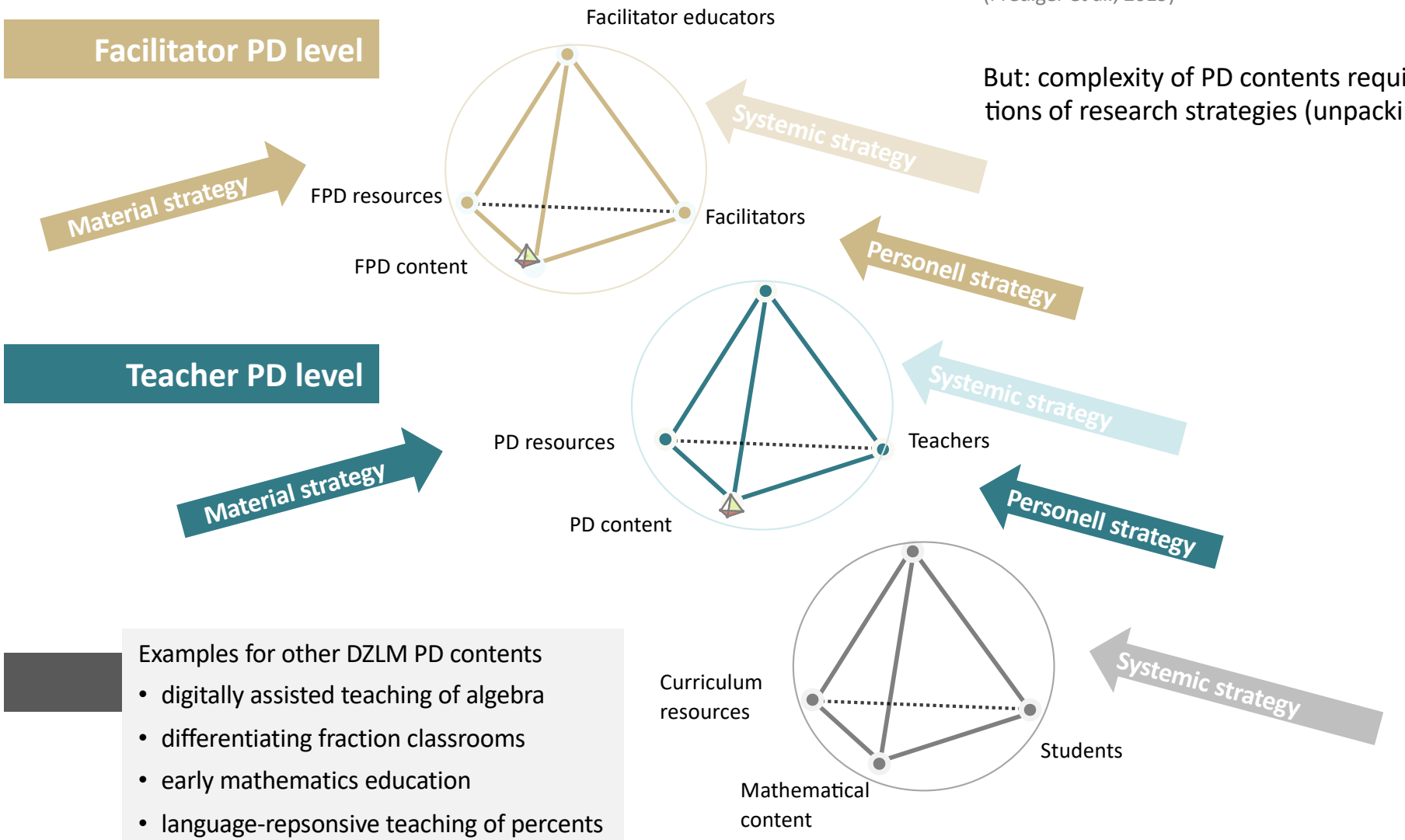


DZLM PD research program: Strive of content.related empirical foundation of all implementation strategies

Structural analogy of the tetrahedrons allows us to lift research approaches, questions, and methods

(Prediger et al., 2019)

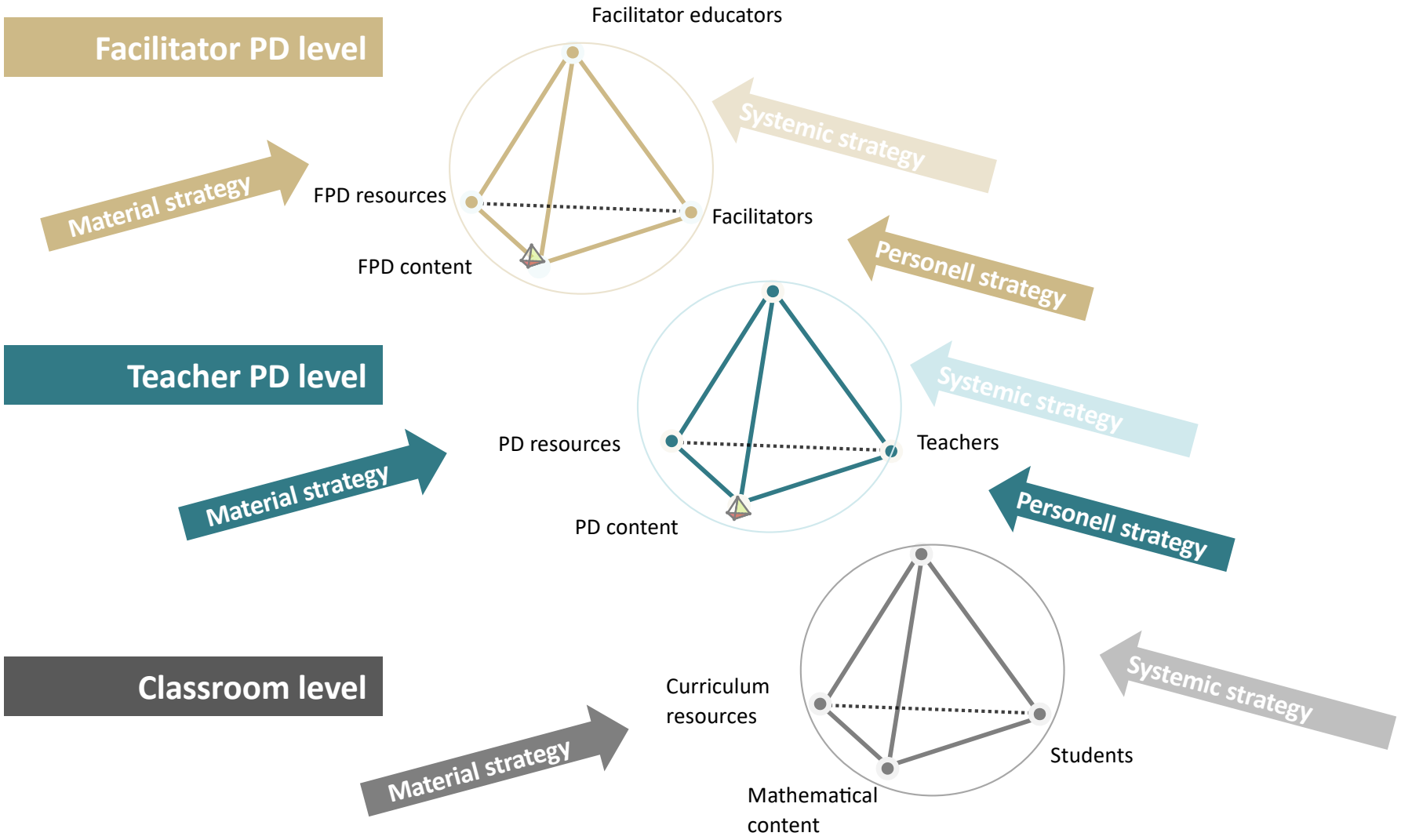
But: complexity of PD contents requires adaptations of research strategies (unpacking is needed!)



Examples for other DZLM PD contents

- digitally assisted teaching of algebra
- differentiating fraction classrooms
- early mathematics education
- language-repsonsive teaching of percents

DZLM PD research program: Strive of content-related empirical foundation of all implementation strategies



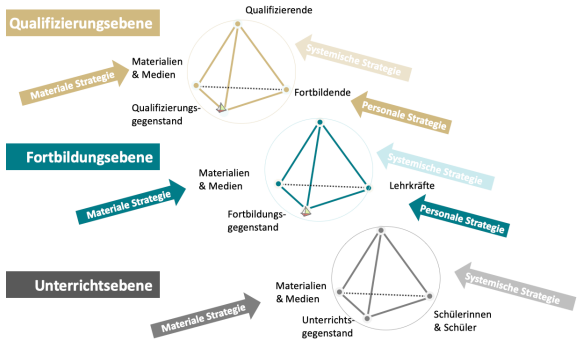
Roesken-Winter, B., Stahnke, R., Prediger, S., & Gasteiger, H. (2021). Towards a research base for implementation strategies addressing mathematics teachers and facilitators. *ZDM – Mathematics Education, 53*(5). doi:doi.org/10.1007/s11858-021-01220-x

Conclusion

What kind of empirical foundation do we need for professional development?

Why is content-related PD research so important?

How can we achieve an empirical foundation?



Because generic design principles are not sufficient,

we need to know more about teachers‘ learning pathways for particular PD contents

By multiple research approaches, in particular qualitative design research and quantitative effectiveness studies

Tests of (static) professional knowledge are not enough

Prediger, S., Roesken-Winter, B., & Leuders, T. (2019). Which research can support PD facilitators? Research strategies in the Three-Tetrahedron Model for content-related PD research. *Journal for Mathematics Teacher Education, 22*(4), 407-425. doi:10.1007/s10857-019-09434-3

Roesken-Winter, B., Stahnke, R., Prediger, S., & Gasteiger, H. (2021). Towards a research base for implementation strategies addressing mathematics teachers and facilitators. *ZDM – Mathematics Education, 53*(5). doi:10.1007/s11858-021-01220-x