



CSCCL meets STEM: How and when collaborative learning with computer support may aid STEM learning

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Collaborative learning

“... a situation in which **two or more people** learn or attempt to **learn something together.**”

(Dillenbourg, 1999, p. 1)

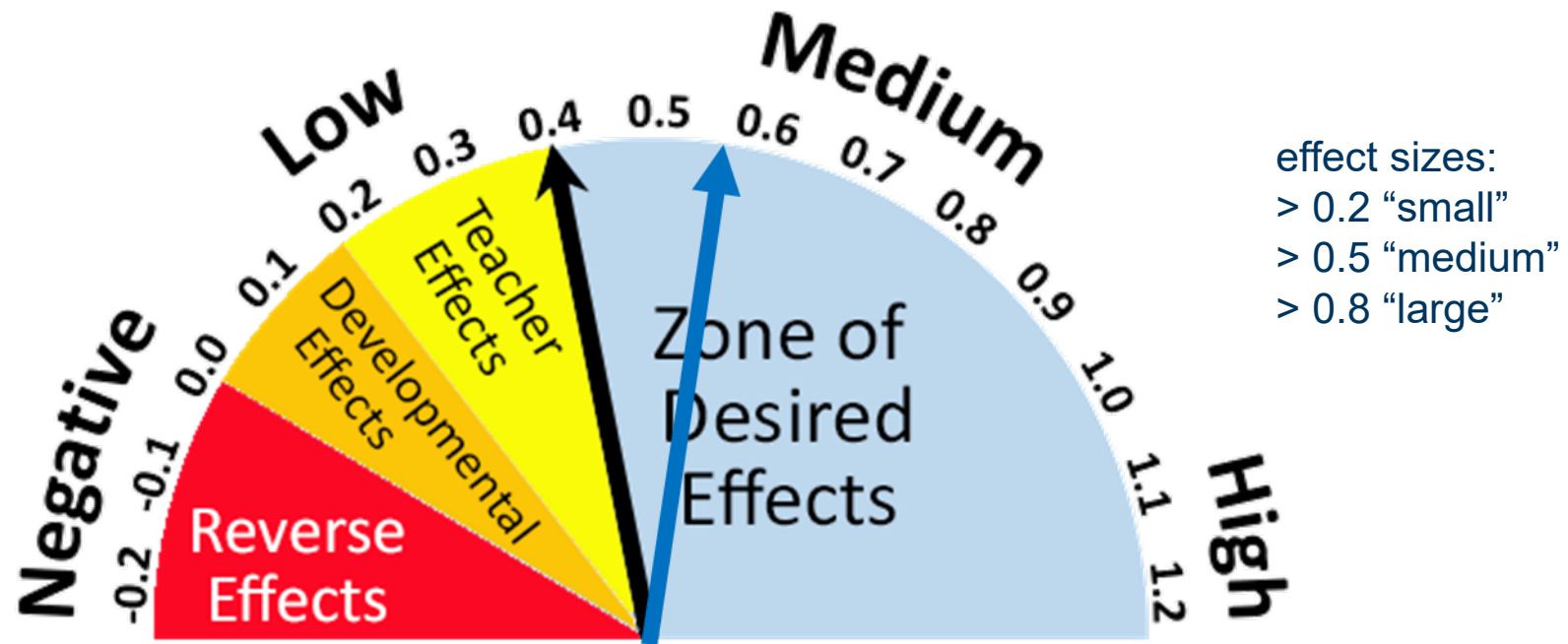
“... describes a variety of educational practices in which **interactions among peers** constitute the most important factor in learning, although without excluding other factors such as the learning materials and interactions with teachers.”

(Dillenbourg, Järvelä & Fischer, 2009, p. 3)

Why care?

“The Hattie Study” (Hattie 2009): 800+ meta-analyses, 50'000+ studies, 240'000+ students

Collaborative vs. individualistic learning: ($d = .59$)



Computer-supported collaborative learning



Context: Intelligent tutoring systems (ITS)

Feedback on errors

Hint on demand

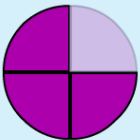
Comparing Fractions

A **Let's compare fractions**

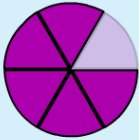
1 What is the least common denominator of the below fractions?

2

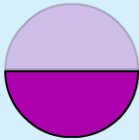
$$\frac{3}{4}$$



$$\frac{5}{6}$$



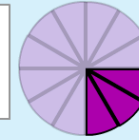
$$\frac{1}{2}$$



$$\frac{2}{3}$$



$$\frac{3}{12}$$



?

Hint

A common denominator for all the fractions is a number that can be divided by all the denominators.

← Previous

Next →

Three perspectives



Image from
<https://www.edweek.org/ew/articles/2017/03/29/curriculum-playlists-a-take-on-personalized-learning.html>



Student Learning in CSCL

1. Designing for collaborative STEM learning in digital environments
2. Are two heads always better than one?
3. Combining collaborative and individual learning

Rummel, 2018, *ijCSCL*;
Rummel, Mullins & Spada, 2012, *ijCSCL*;
Strauss & **Rummel**, 2020, *ILS*

Mullins, **Rummel**, & Spada, 2011, *ijCSCL*

Olsen, **Rummel**, & Alevan, 2019, *ijCSCL*



Designing for CSCL

Instructional design sets the stage for interactions that promote learning

Example: the group task

- Promoting positive interdependence by inserting a “split where interaction should happen” (SWISH, Dillenbourg & Jermann, 2007)
- A famous example: Jigsaw tasks (Aronson, 1978):





Designing for CSCL

Example from my research

Equivalent Fractions

A **Match the equivalent fractions.**

1 Match an equivalent fraction for each fraction shown below. Make sure the circles show the same amounts before hitting submit.
You and your partner can each move only half of the fractions. Discuss with your partner what the correct answers are.

Partner A

| | | |
|----------------|---------------|---------------|
| $\frac{8}{10}$ | $\frac{5}{9}$ | $\frac{2}{7}$ |
|----------------|---------------|---------------|

Partner B

| | | |
|---------------|-----------------|---------------|
| $\frac{6}{7}$ | $\frac{16}{24}$ | $\frac{1}{4}$ |
|---------------|-----------------|---------------|

3 $\frac{9}{12}$ | 3 $\frac{6}{14}$ | 4 $\frac{\quad}{6}$

Submit

Hint

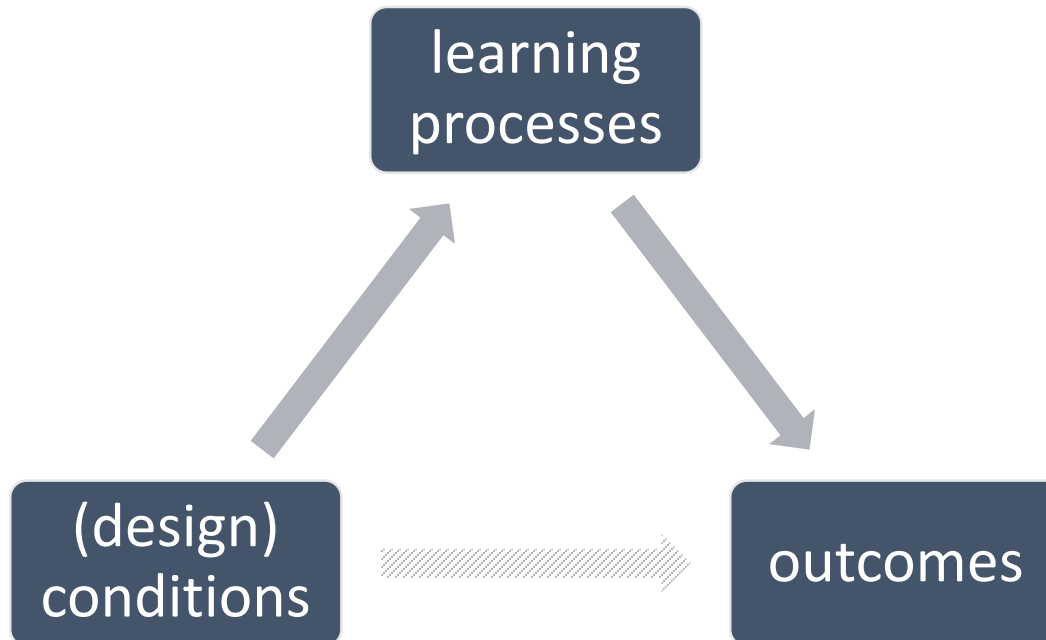
← Previous Next →

(Olsen, Rummel, & Alevan, 2016, ICLS)



Designing for CSCL

The collaborative learning triangle



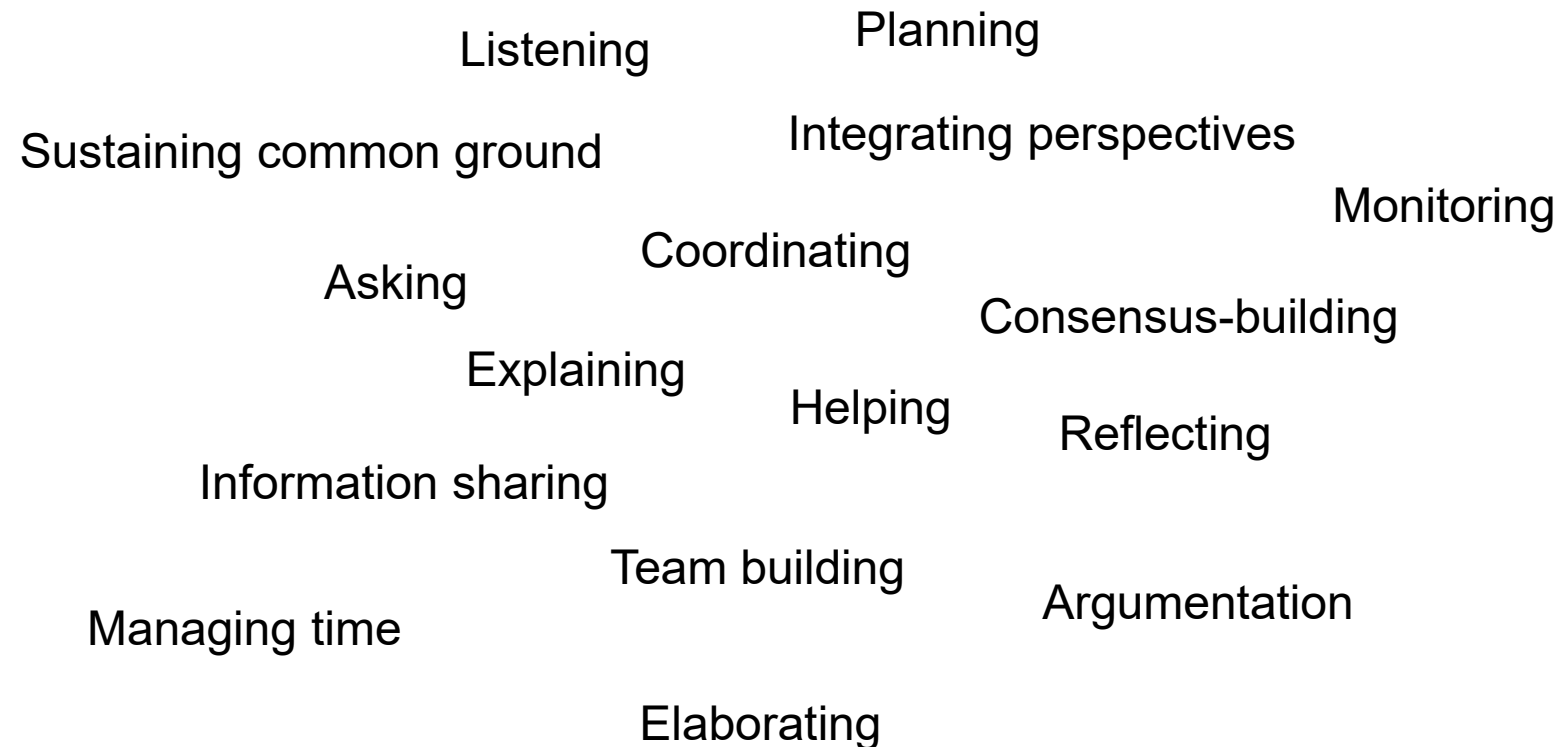
Dillenbourg, Baker, Blaye, & O'Malley, 1995;

Deiglmayr, Loibl, & Rummel, 2015;



Designing for CSCL

Processes during collaborative learning





Designing for CSCL

Central learning mechanisms

- Explaining and elaborating
- Asking questions and receiving explanations
- Joint knowledge construction

Hausmann, et al., 2004;
Teasley, 1995

Webb & Mastergeorge, 2003;
Webb, 1989

Barron, 2000; Berg, 1993

Rummel, Mullins & Spada,
2012, *ijCSCL*



Designing for CSCL

Collaboration scripts: cognitive and social scaffolding of student interactions

“Restaurant Script”

- scenes
- roles
- activities

(adapted from Schank & Abelson, 1977)

1. Entering

Customer goes into restaurant.
Customer looks around.
Customer decides where to sit.
Customer goes to the table and sits down.

2. Ordering

Customer picks up menus.
Customer decides on food.
Customer orders food from waiter.
Waiter tells cook the order.
Cook prepares food.

3. Eating

Cook gives food to waiter.
Waiter gives food to customer.
Customer eat food.

4. Exiting

Waiter writes out check.
Waiter brings check to customer.
Customer gives tip to waiter.
Customer goes to cash register.
Customer gives money to cashier.
Customer leaves restaurant.

Rummel & Spada, 2007;
Rummel, Spada, &
Hauser, 2009, ijCSCL;
Rummel, Mullins, &
Spada, 2012, ijCSCL



Designing for CSCL

Collaboration scripts: cognitive and social scaffolding of student interactions



Rummel & Spada, 2007;
Rummel, Spada, &
Hauser, 2009, ijCSCL;
Rummel, Mullins, &
Spada, 2012, ijCSCL



Collaboration scripts

Phases of the collaboration

Phase 1:

Bisherige Arbeitszeit: 0 von 55 Minuten (vor dieser Phase)

Klärt kurz (**5 Minuten**) erste Verständnisfragen:
Was habt ihr beim Durchlesen der Fallbeschreibung nicht verstanden?
Gab es Fachbegriffe, die euch nicht klar waren und nach denen ihr euren Partner fragen wollt?

Achtet dabei darauf,

- einander zuzuhören und den Partner aussprechen zu lassen
- verständliche Erklärungen zu geben
- nachzufragen, wenn ihr etwas nicht verstanden habt.

Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Phase 6
Phase 7

Verbleibende Zeit:
1

Working individually

Working collaboratively

Instructions for the phase, including timing

Rummel, Spada, & Hauser (2009), ijCSCL



Do collaboration scripts work?

Effects of CSCL scripts: Meta-analyses show positive effects on domain learning, social skills and motivation

- Domain learning: Hedges' $g=0.24$
- Collaboration skills: Hedges' $g=0.72$
- Motivation: Hedges' $g=0.13$ (n.s.)

Vogel, Wecker, Kollar, & Fischer, 2017, EPR;

Radkowitz, Vogel & Fischer, 2020, ijCSCL



Do collaboration scripts work?

Drawback:

- Do not take into account already existing internal collaboration scripts
- Danger of underscripting or overscripting

→ Adaptive support for CSCL

Dillenbourg & Jermann, 2007

Kollar et al., 2005

Rummel, Mullins & Spada, 2012, ijCSCL;
Walker, **Rummel** & Koedinger, 2009a, 2009b, 2011, 2014



Adaptive support for CSCL

Prerequisite:

- (Automatic) analysis of collaborative learning activities in real-time
 - Compare to model of good collaboration and/or domain model
- Build upon work on Intelligent Tutoring Systems
→ Learning Analytics

Example from my own research:

- Adaptive support for peer tutoring with the Cognitive Tutor Algebra

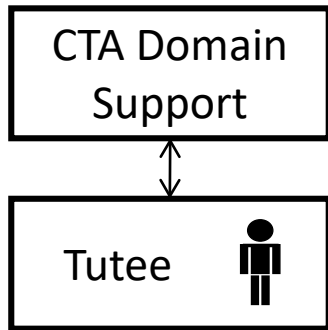
Soller, Martinez, Jermann
& Muehlenbrock, 2005

Walker, **Rummel** &
Koedinger, 2009a, 2009b,
2011, 2014

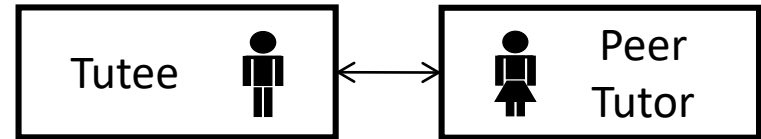


Adaptive support for CSCL

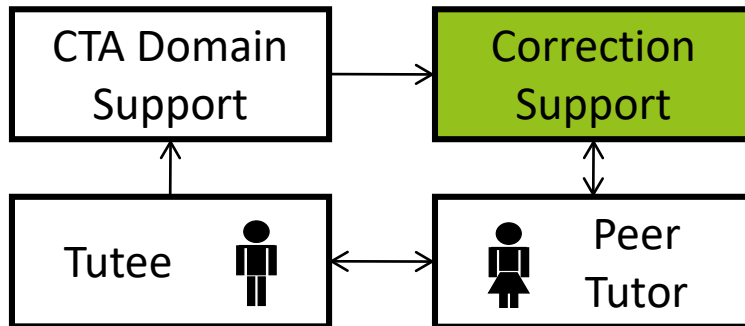
Original Algebra Tutor



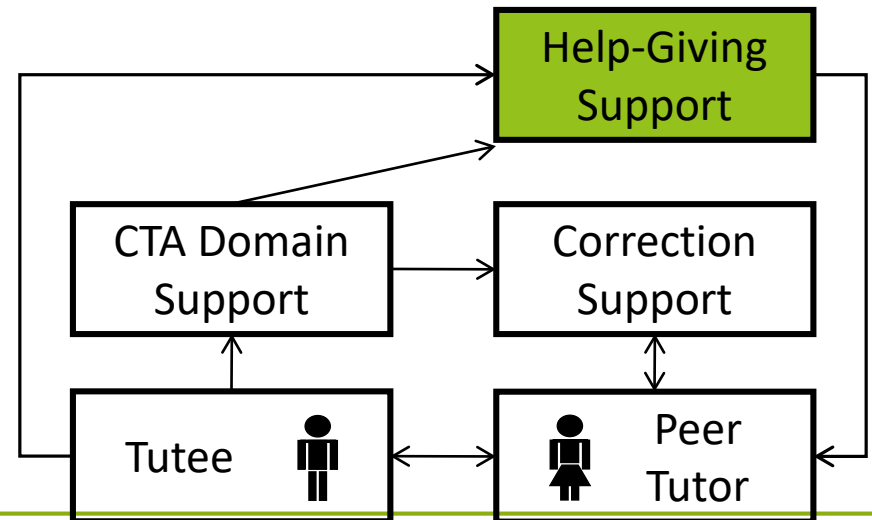
Peer Tutoring



Extended Algebra Tutor




Algebra and Peer-tutoring Tutor





Original Algebra Tutor

CTA Domain Support

Tutee 

Carnegie Learning's Algebra I - [] X

File Tutor Go To View Help

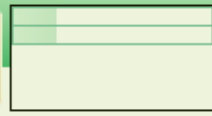
12 - Solving Literal Equations _A1 Unit17

1 - Section 1 lit47

Look Ahead Problems Look Back Glossary Hint Done

Solver Transformation Simplification

Skillometer



Solve for y

$$ay + by + m = n$$

$$ay + by + m - m = n - m$$

$$ay + by + m - m = n - m$$

$$ay + by = n - m$$

$$\frac{ay + by}{b} = \frac{n - m}{b}$$

$$\frac{ay + by}{b} = \frac{n - m}{b}$$

Problem solving

Hint X


In $\frac{ay + by}{b}$, $ay + by$ is divided by b . How do you undo division?

Close << Previous Hint Next Hint >>

Hints

Subtract m from both sides

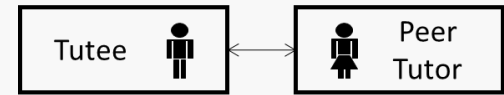
Add/subtract terms in $ay + by + m - m$

Divide both sides by b 

Error feedback



Peer tutoring



Carnegie Learning's Peer Tutoring: Algebra I

37 Tutoring Literal Equations -- Independent Phase
Solving Literal Equations

PEER TUTEE

arkansas 1 rabbit
lit47

Done

Chat

rabbit says: is that right so far?
turtle says: so far, now how do you get the m on the side?
rabbit says: i think i just messed up
turtle comments: ii am a lil confused... i would have thought that you would have started at the beginning by subtracting the m, but u did the n which took me off guard

Support by peer tutor

Solver Transformation Simplification

Solve for y

$$ay + by + m = n$$

$$ay + by + m - n = n - n$$

$$ay + by + m - n = 0$$

$$\frac{ay + by + m - n}{y} = \frac{0}{y}$$

$$\frac{ay + by + m - n}{y} = 0$$

Problem solving

Subtract n from both sides ✓

Divide both sides by y !

Peer error feedback

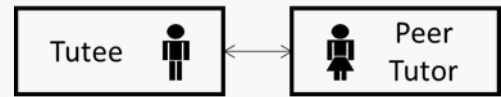
Skillometer

- Multiply or divide
- Remove coefficient
- Combine like terms by factoring
- Add or subtract
- Remove constant
- Combine like terms by adding/subtracting

Peer assessment



Peer tutoring



Carnegie Learning's Peer Tutoring: Algebra I

37 Tutoring Literal Equations -- Independent Phase
Solving Literal Equations

PEER TUTOR

arkansas 1 turtle
lit47

Chat

rabbit says: is that right so far?
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rabbit says: i think i just messed up
turtle comments: ii am a lil confused... i would have thought that you would have started at the beginning by subtracting the m, but u did the n which took me off guard

Provide support/ explanations to tutee

Your Partner's Solution

Solve for y

$$ay + by + m = n$$

$$ay + by + m - n = n - n$$

$$ay + by + m - n = 0$$

$$\frac{ay + by + m - n}{y} = \frac{0}{y}$$

$$\frac{ay + by + m - n}{y} = 0$$

Problem solving of Tutee

Problem Solution

Subtract n from both sides ✓ ✕

Divide both sides by y ✓ ✕

Provide error feedback to tutee

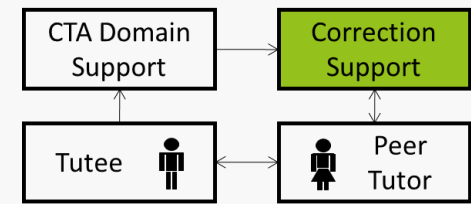
Skillometer

- Multiply or divide
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Provide peer assessment



Extended Algebra Tutor



Carnegie Learning's Peer Tutoring: Algebra I

37 Tutoring Literal Equations -- Independent Phase
Solving Literal Equations

PEER TUTOR

arkansas 1 owl
lit47

Tutor Hint

Skillometer

- Multiply or divide
- Remove coefficient
- Combine like terms by factoring
- Add or subtract
- Remove constant
- Combine like terms by adding/subtracting
- Distribute
- Get rid of parentheses

ResourceTool

Click on the buttons underneath the chat window, and information will pop up here to help you to tutor.

Solver

Solve for y

$$ay + by + m = n$$
$$y(a + b) + m = n$$

Factor out y ✓ ✕

Error feedback to peer tutor

Chat

Hint

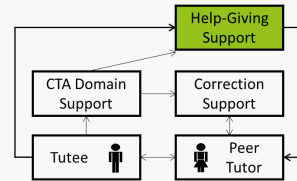
Your partner has the right idea. Ask them why they took that step.

Close << Previous Hint Next Hint >>

Hint to peer tutor



Algebra and peer-tutoring tutor



Carnegie Learning's Peer Tutoring: Algebra I
arkansas 1 owl lit47

PEER TUTOR

Skillometer

- Multiply or divide
- Remove coefficient
- Combine like terms by factoring
- Add or subtract
- Remove constant
- Combine like terms by adding/subtracting
- Distribute
- Get rid of parentheses

ResourceTool

Problem Explanation

Sometimes, you will need to tell your partner what to do and why they should be doing it. Below is a problem solution that you can use to help you.

Solve for x
 $dy - cz = ax + bx$

- Find the variable you want to isolate.
 $dy - cz = ax + bx$
- Combine like terms by factoring x
 $dy - cz = x(a + b)$
- Move the coefficient to the other side of the equation using the inverse operation

$$\frac{dy - cz}{a + b} = \frac{x(a + b)}{a + b}$$

$$\frac{dy - cz}{a + b} = x$$

Solver

Solve for y

$ay + by + m = n$

Factor out y

$y(a + b) + m = n$

$y(a + b) + m + m = n + m$ Add m to both sides

$y(a + b) + 2m = n + m$

Chat

owl asks for explanation: why did you take that step?

eagle explains: to get the "y" by itself

subtract

Ask Why
Explain Why Wrong

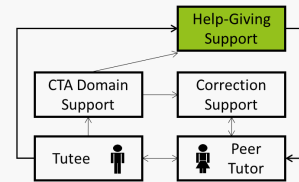
Give Hint
Explain What Next

Other

Get tutor hint from computer



Algebra and peer-tutoring tutor



Chat ?

owl asks for explanation: why did you take that step?
eagle explains: to get the "y" by itself

subtract|

Ask Why Explain Why Wrong
Give Hint **Explain What Next**
Other

? Get tutor hint from computer

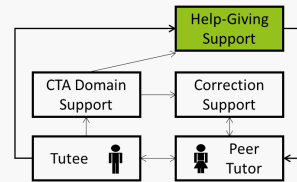
2. Combine
 $dy - cz$

3. Move the equation

$$\begin{array}{r} (dy - c) \\ dy - cz \\ \hline a + b \\ dy - cz \\ \hline a + b \end{array}$$



Algebra and peer-tutoring tutor



Chat

owl asks for explanation: why did you take that step?
eagle explains: to get the "y" by itself
owl explains next step: subtract
computer comments: owl, can you explain your partner's mistake?

Hint to peer tutor

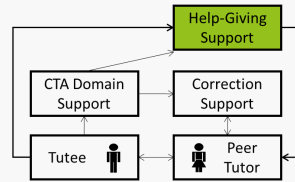
2. Combine li
 $dy - cz =$

3. Move the c equation u

$$\frac{(dy - cz)}{a + b} =$$
$$\frac{dy - cz}{a + b} =$$

Buttons: Ask Why, Explain Why Wrong, Give Hint, Explain What Next, Other, Get tutor hint from computer

Algebra and peer-tutoring tutor



Carnegie Learning's Peer Tutoring: Algebra I
arkansas 1 owl lit47

PEER TUTOR

Skillometer

- Multiply or divide
- Remove coefficient
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$$\frac{dy - cz}{a + b} = \frac{x(a + b)}{a + b}$$

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Solver

Solve for y

$$ay + by + m = n$$

Factor out y

$$y(a + b) + m = n$$

Add m to both sides

$$y(a + b) + 2m = n + m$$

Chat

owl asks for explanation: why did you take that step?

eagle explains: to get the "y" by itself

owl explains next step: subtract

computer comments: owl, can you explain your partner's mistake?

Machine classification

Self-classification

Get tutor hint from computer



Is it worth the effort?

Comparison of fixed script support vs. adaptive support.
Positive effects on:

- Domain learning
- Collaborative skill
- Knowledge about good collaboration

- Not a psychological effect: Real adaptive better than told adaptive

Walker, **Rummel** & Koedinger, 2009a, UMUAI; 2011, ijCSCL

Walker, **Rummel** & Koedinger, 2014, IJAIED



Designing for CSCL

A taxonomy of CSCL support dimensions

- Taxonomy was developed bottom-up from existing research
- Not a perfect, definite set of dimensions
- Proposes a shared language to address different aspects of support;
- advocates testing the effects of different configurations
- For designers of CSCL environments it is useful to organize the various dimensions along lead questions they ask

Rummel, 2018, ijCSCL



Designing for CSCL

Table 1 Taxonomy of CSCL support dimensions

| | |
|-------------------|--|
| 1. Goal | <ul style="list-style-type: none"> – interaction/group processes – outcome/result of the collaboration (i.e. an artifact) – individual domain knowledge – social skill (i.e. collaborative competence) – affective outcomes (e.g. satisfaction with the collaboration) – motivational outcomes (e.g. learning motivation, attitude towards future collaboration) |
| 2. Timing | <ul style="list-style-type: none"> – prior to the collaboration (e.g. instruction, training, group formation) – during the collaboration (e.g. prompts, resources): immediate, delayed – after the collaboration (e.g. reflection) |
| 3. Implementation | <ul style="list-style-type: none"> – fixed (one size/time fits all) – adaptive (i.e. automated) – adaptable (i.e. user-based) |
| 4. Delivery agent | <ul style="list-style-type: none"> – human – digital persona (i.e. pedagogical agent) – digital system |
| 5. Target | <ul style="list-style-type: none"> – cognitive (i.e. domain help) – metacognitive (e.g. reflection, employment of learning strategies) – social (e.g. managing the interaction) – affective (e.g. coping with frustration) – motivational (e.g. participation) |
| 6. Granularity | <ul style="list-style-type: none"> – task level – step level – turn level |
| 7. Availability | <ul style="list-style-type: none"> – visible – on demand |
| 8. Directivity | <ul style="list-style-type: none"> – no advice – implicit (i.e. enabling conditions, resources) – explicit: general advice – explicit: specific guidance |
| 9. Foundation | <ul style="list-style-type: none"> – no information on state (i.e. just alert) – show state (i.e. raw data) – show aggregated data (i.e. mean or other indicators) – show interpretation of state (i.e. assessment good vs. bad) |
| 10. Addressee | <ul style="list-style-type: none"> – individual – group |
| 11. Mediation | <ul style="list-style-type: none"> – direct (provided to learner/group in need) – indirect (mediated; e.g. presented to peer, teacher, parent) |
| 12. Coercion | <ul style="list-style-type: none"> – no action required – some/any action is required – specific action is required |

Rummel, 2018, ijCSCL

ons

ons



Lead questions for CSCCL design

- 1. WHY:** Goals: Expected Outcomes
- 2. WHAT:** Targeted Aspects
Timing
Implementation
Granularity
- 3. WHO:** Sources
Addressee
- 4. HOW:** Delivery
Availability
Directivity
Foundation
Coercion



Lead questions for CSCL design

1. WHY: **Goals: Expected Outcomes**

2. WHAT: Targeted Aspects
Timing
Implementation
Granularity

3. WHO: Sources
Addressee

4. HOW: Delivery
Availability
Directivity
Foundation
Coercion

- cognitive outcomes
(e.g. individual domain knowledge)
- social skills
(i.e. collaborative competence)
- affective outcomes
(e.g. satisfaction with the collaboration)
- motivational outcomes
(e.g. learning motivation, attitude towards future collaboration)



Are two heads always better than one?

Investigating differential effects:

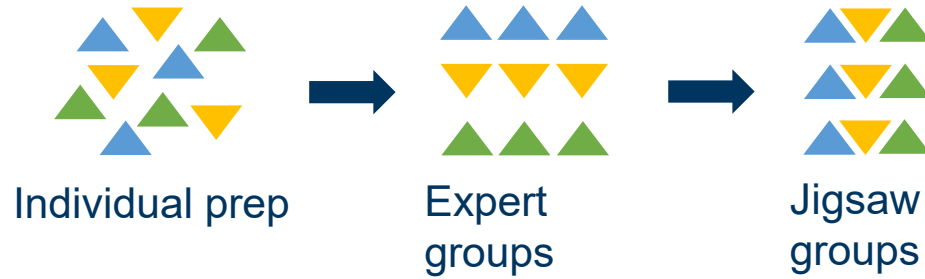
- Procedural skill
- Conceptual knowledge

→ collaboration best for conceptual knowledge acquisition

Mullins, **Rummel** & Spada,
2011, ijCSCL



Combining collaborative and individual learning



Phase 1:

Klärt kurz (**5 Minuten**) erste Verständnisfragen:
Was habt ihr beim Durchlesen der Fallbeschreibung nicht verstanden?
Gab es Fachbegriffe, die euch nicht klar waren und nach denen ihr euren Partner fragen wollt?

Achtet dabei darauf,

- einander zuzuhören und den Partner aussprechen zu lassen
- verständliche Erklärungen zu geben
- nachzufragen, wenn ihr etwas nicht verstanden habt.

Bisherige Arbeitszeit: 0 von 55 Minuten (vor dieser Phase)

Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Phase 6
Phase 7

Working individually

Working collaboratively

Verbleibende Zeit:
1



Combining collaborative and individual learning

- Leveraging the complementary strength of the different social learning modes

Olsen, Alevan, & **Rummel**, 2017, JEM;
Olsen, **Rummel**, & Alevan, 2019, ijCSCL;



Combining collaborative and individual learning

Hypothesis:

Combining learning activities is more effective than studying only collaboratively or only individually.

Sample:

307 students (4th and 5th grade)

Learning environment:
Intelligent tutoring system (ITS)

Domain: fractions

Design:

quasi-experiment

| | | |
|--|---|---|
| collaborative <i>conceptual</i> + individual <i>procedural</i> | collaborative <i>conceptual</i> + collaborative <i>procedural</i> | individual <i>conceptual</i> + individual <i>procedural</i> |
| <i>n</i> = 120 | <i>n</i> = 104 | <i>n</i> = 83 |

(Olsen, **Rummel**, & Alevan, 2019, ijCSCL)

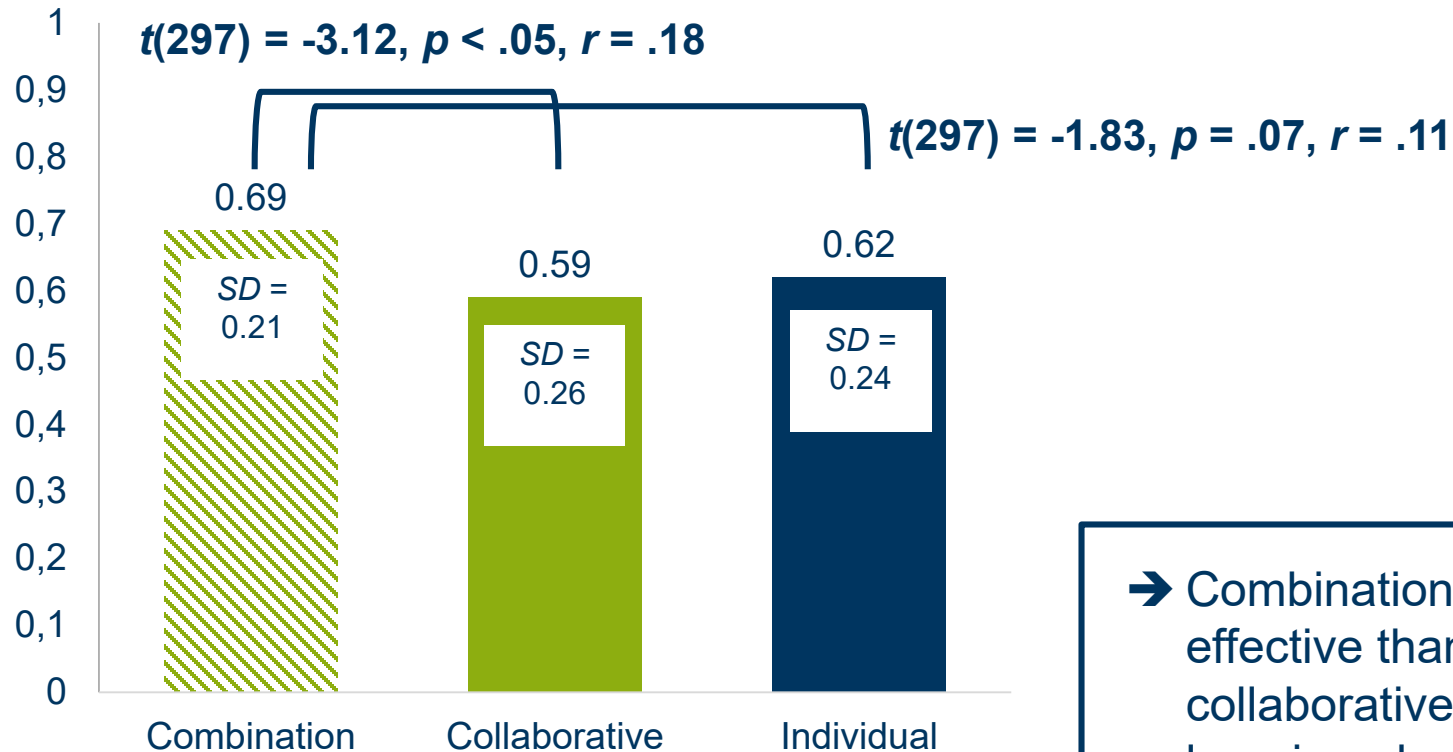


Combining collaborative and individual learning

Posttest

Hypothesis:

Combination > individual/
collaborative learning



→ Combination is more effective than collaborative or individual learning alone!

(Olsen, Rummel, & Alevan, 2019, ijCSCL)



Summary

1. Designing for collaborative STEM learning in digital environments
 - Set up conditions (e.g. group task)
 - Promote productive interactions (e.g. by scripting; best adaptively)
 - Taxonomy of support dimensions
2. Are two heads always better than one?
 - Collaboration best for conceptual knowledge
3. Combining collaborative and individual learning
 - A combination that leverages complementary strengths is best

Rummel, 2018, ijCSCL;
Rummel, Mullins & Spada, 2012, ijCSCL;
Strauss & **Rummel**, 2020, ILS

Mullins, **Rummel**, & Spada, 2011, ijCSCL

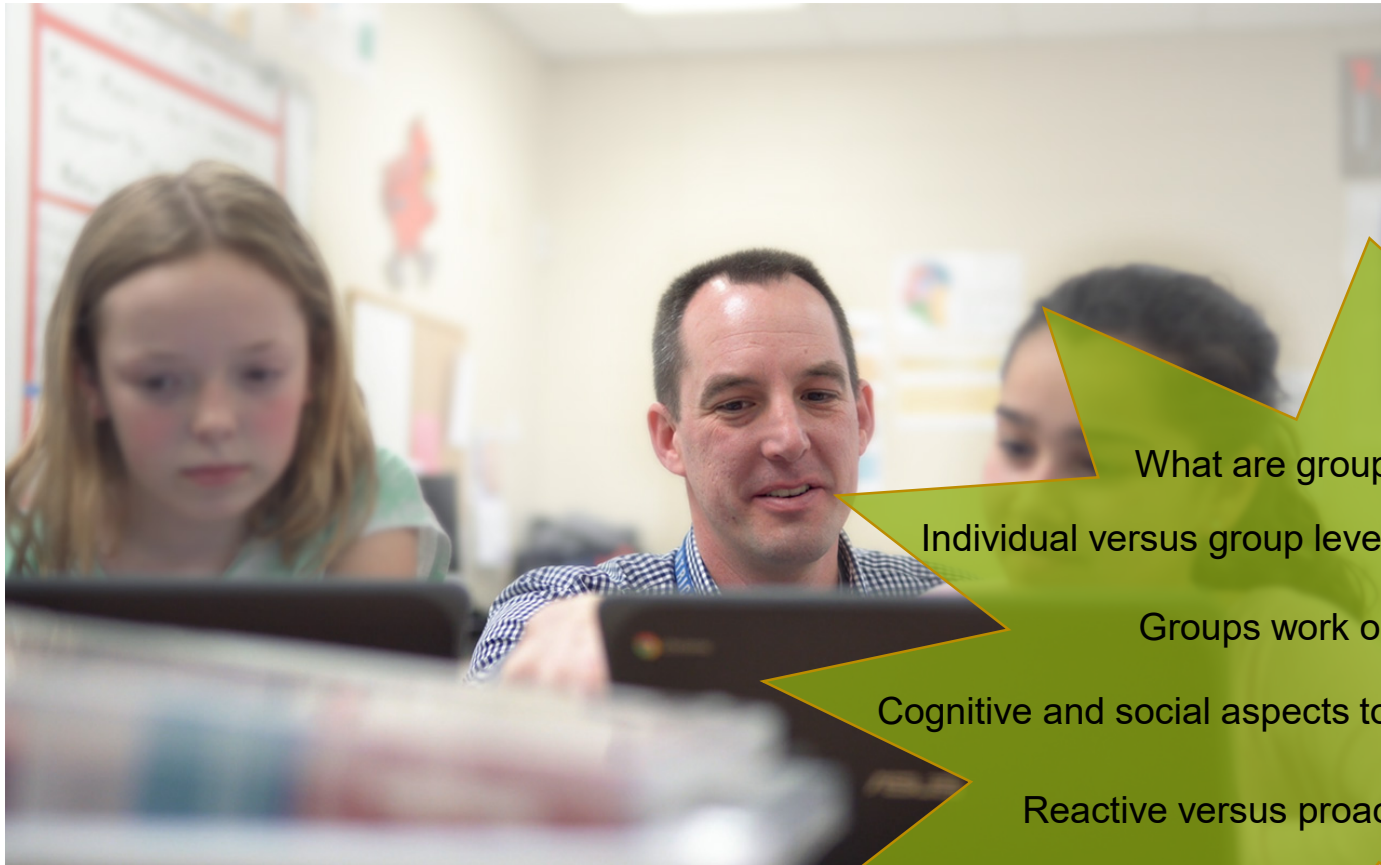
Olsen, **Rummel**, & Alevan, 2019, ijCSCL

Three perspectives



Image from
<https://www.edweek.org/ew/articles/2017/03/29/curriculum-playlists-a-take-on-personalized-learning.html>

Teacher support for orchestrating CSCL



Limited time

What are groups really doing?

Individual versus group level

Groups work on different tasks

Cognitive and social aspects to monitor

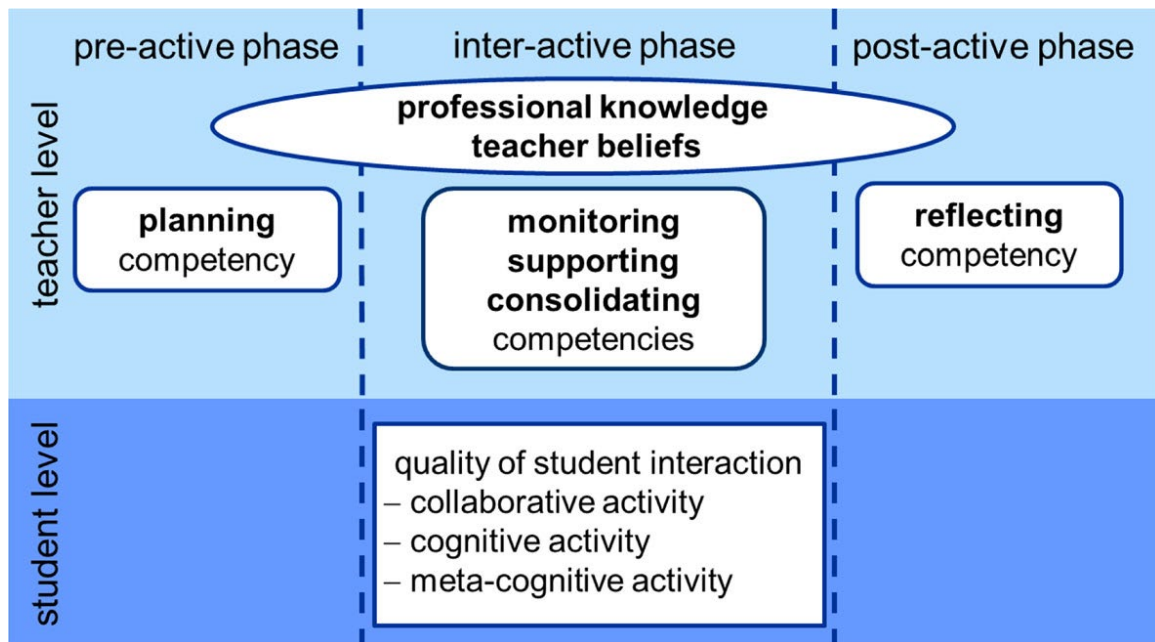
Reactive versus proactive?



The important role of the teacher

Teachers are central for supporting CSCL, but also under a lot of pressure

- The implementing collaborative learning in the classroom (ICLC) framework



Kaendler, Wiedmann,
Rummel & Spada, 2015,
EPR



Teacher training

A training to promote teacher competency

- Focus on noticing behavioral indicators of collaborative, cognitive, meta-cognitive activity
- Video-based training: 3 vignettes, 1-2 minutes



- Pre-posttest with validated assessment tool

Kaendler, Wiedmann,
Leuders, **Rummel** &
Spada, 2016, PLAT

(Wiedmann, 2015)



Teacher training

- N=107 pre-service teachers (university):
 - N=33 control condition,
 - N=74 training condition
- Additional cohorts for testing robustness of the findings: N=41 pre-service teachers (PH); N=42 in-service teachers (Referendariat)

Results

- The training helped pre-service teachers notice more behavioral indicators during collaborative learning
- Initial evidence that training is also effective for other pre-service teachers and in-service teachers

Kaendler, Wiedmann,
Leuders, **Rummel** &
Spada, 2016, PLAT



Teacher dashboards

Class overview

Tasks

Attempts

Trial-error

Talking

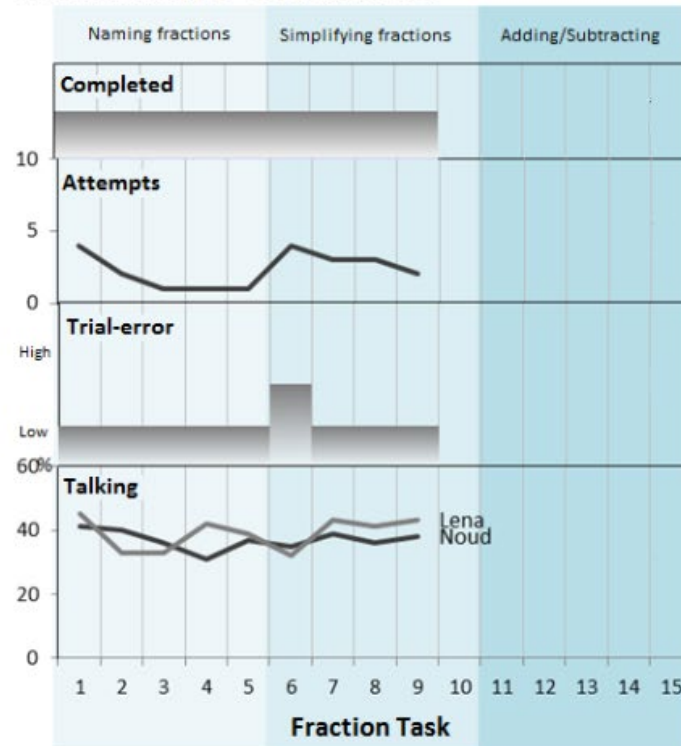
Skills

Activity

Group

- 1
- 2
- 3
- 4
- 5

Overview Group 1 - Lena and Noud

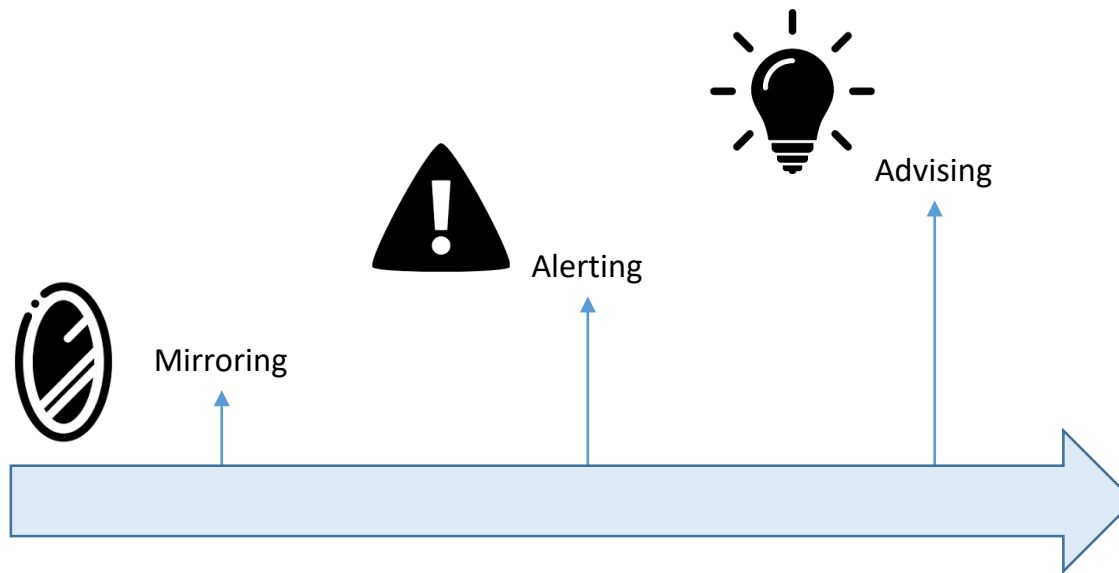


Van Leeuwen, Van Wermeskerken, Erkens, & Rummel, 2017; LRP



Teacher dashboards

Level of interpretational aid



Van Leeuwen, Rummel, & Van Gog, 2019, ijCSCL;

Van Leeuwen & Rummel, 2020, LAK

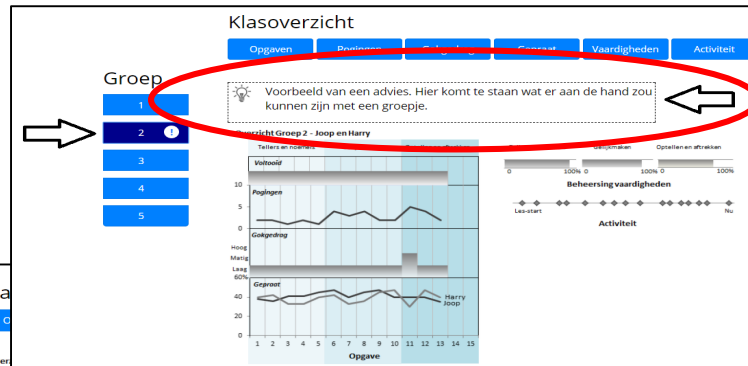


Teacher dashboards

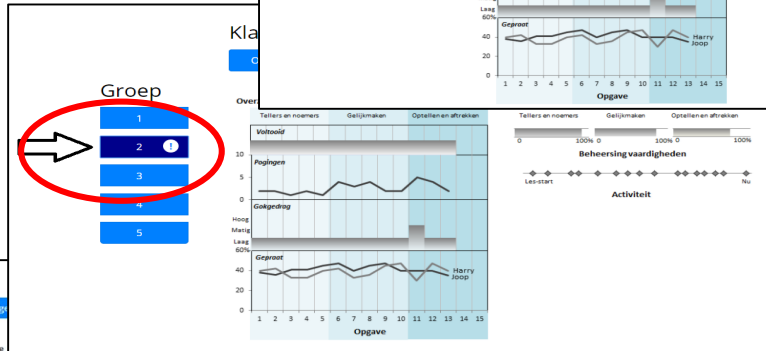
Study 1: Varying level of interpretational aid

Van Leeuwen, Rummel, & Van Gog, 2019, ijCSCL;

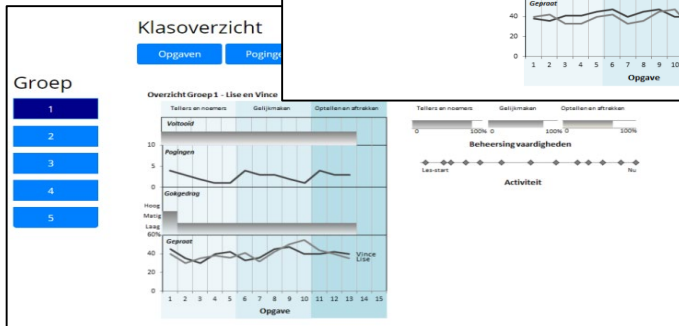
Advising



Alerting



Mirroring

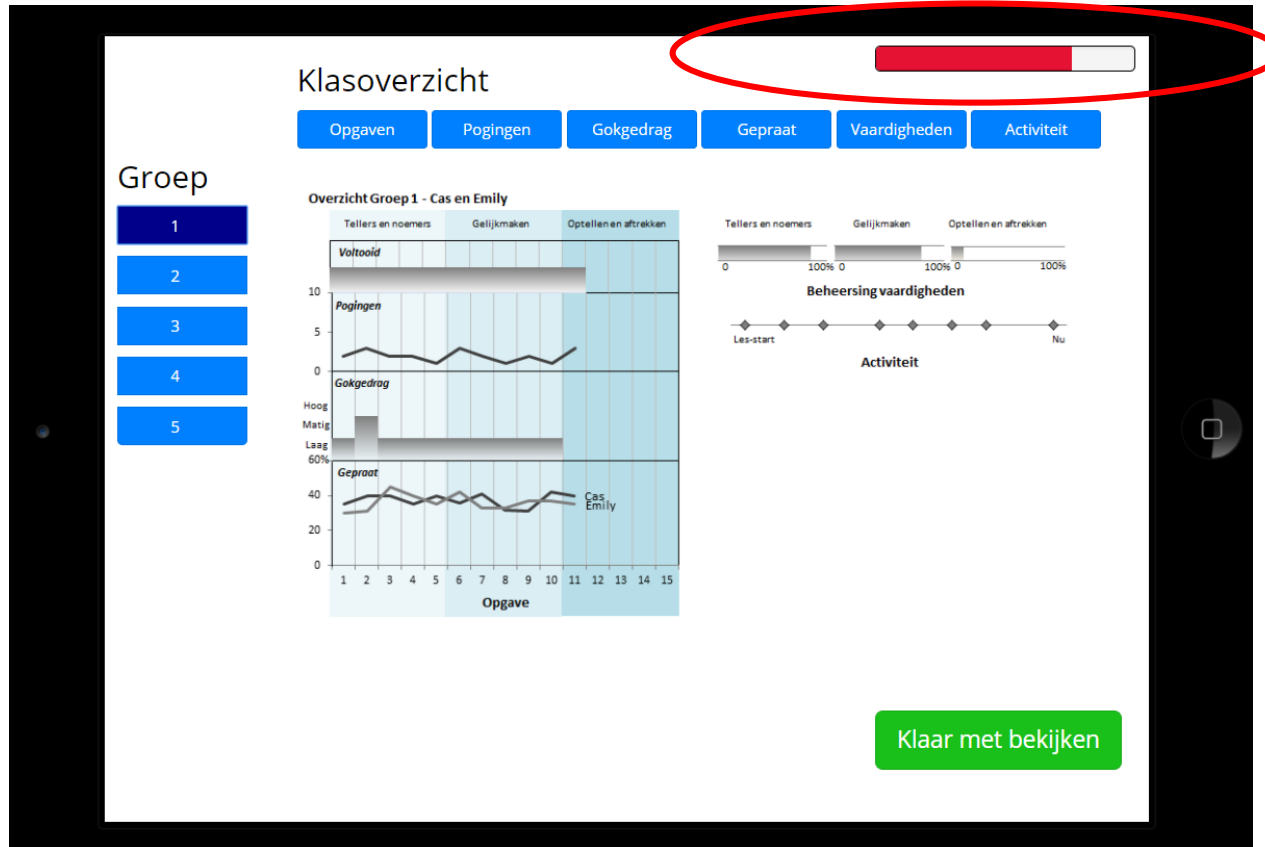




Teacher dashboards

Study 2: Introducing time pressure

Van Leeuwen & Rummel, 2020, LAK





Teacher dashboards

Study 2: Introducing time pressure

Van Leeuwen & Rummel,
2020, LAK

| | Mirroring (n=17) | Advising (n=18) |
|-----------------------------|---------------------|----------------------|
| Correctly identified groups | 6.65 (SD = 1.06) | 7.50* (SD = 0.62) |
| Cognitive load | 4.52 (SD = 0.97) | 2.77* (SD = 0.89) |
| Confidence | 6.74 (SD = 1.06) | 7.94* (SD = 1.20) |



Teacher support for CSCL

1. Important role of the teacher in implementing collaborative learning, but challenging
2. A training can promote teachers' competency for monitoring student interactions
3. Teacher dashboards: Advising dashboards best support teachers in monitoring student collaboration

Kaendler, Wiedmann, **Rummel** & Spada, 2015, EPR

Kaendler, Wiedmann, Leuders
Rummel & Spada, 2016, PLAT

Van Leeuwen & **Rummel**,
2019a,b, Unterrichtswissenschaft;
Van Leeuwen, **Rummel**, & Van
Gog, 2019, ijCSCL;
Van Leeuwen & **Rummel**, 2020,
LAK



Acknowledgements: Part 1

Project 1:

“Improving algebra learning and collaboration through collaborative extensions to the algebra cognitive tutor”

Funded by: NSF und Baden-Württemberg Stiftung



Project 2:

“Differential effects of collaboration on students’ computer-supported learning in mathematics”

Funded by: DFG (VGK)



Project 3:

“Combining advantages of collaborative and individual learning with an intelligent tutoring system for fractions”

Funded by: Institute of Educational Sciences (IES)





Acknowledgements: Part 2

Project 4:

“Was wissen Lehrkräfte über die Qualität von Kooperation und wie lässt sich ihr Wissen gezielt verbessern?”

Funded by: KeBU, State of Baden-Württemberg



Project 5:

“From Overload to Overview: Learning Analytics to Support Teachers”

Funded by: NWO Rubicon grant



References

- Aronson, E. (1978). *The jigsaw classroom*. Beverly Hills, CA: Sage.
- Barron, B. (2000). Achieving collaboration in collaborative problem-solving groups. *Journal of Learning Sciences*, 9 (4), 403 – 436.
- Berg, K. F. (1993). *Structured cooperative learning and achievement in a high school mathematics class*. Paper presented at the Annual Meeting of the American Educational Research Association, Atlanta, GA.
- Deiglmayr, A., Rummel, N. & Loibl, K. (2015). The mediating role of interactive learning activities in CSCL: An input-process-outcome model. In O. Lindwall, P. Häkkinen, T. Koschman, P. Tchounikine, & S. Ludvigsen (Eds.), *Exploring the Material Conditions of Learning. Proceedings of the 11th Conference on Computer Supported Collaborative Learning (CSCL 2015)*, Vol. 2 (pp. 518-522). Gothenburg, Sweden: International Society of the Learning Sciences, Inc.
- Dillenbourg P., Järvelä S., Fischer F. (2009). The Evolution of Research on Computer-Supported Collaborative Learning. In: Balacheff N., Ludvigsen S., de Jong T., Lazonder A., Barnes S. (eds) *Technology-Enhanced Learning*. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9827-7_1
- Dillenbourg, P., & Jermann, P. (2007). Designing Integrative Scripts. In F. Fischer, I. Kollar, H. Mandl, & J. M. Haake (Eds.), *Scripting Computer-Supported Collaborative Learning: Cognitive, Computational and Educational Perspectives* (Vol. 6, pp. 275–301). Boston, MA: Springer US.
- Dillenbourg, P., Baker, M. J., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (Eds.), *Learning in Humans and Machine: Towards an interdisciplinary learning science* (pp. 189–211). Oxford: Elsevier.
- Dillenbourg, P. (1999). What do you mean by 'collaborative learning'? In P. Dillenbourg (Ed.), *Collaborative learning. Cognitive and computational approaches* (pp. 1–19). Amsterdam: Pergamon.
- Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. London: Routledge.

References

- Hausmann, R. G. M., Chi, M. T. H. & Roy, M. (2004). Learning from collaborative problem solving: An analysis of three hypothesized mechanisms. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 26 (26), 547- 552.
- Kaendler, C., Wiedmann, M., Leuders, T., Rummel, N., & Spada, H. (2016). Monitoring student interaction during collaborative learning: Design and evaluation of a training program for pre-service teachers. *Psychology: Learning & Teaching*, 5(1) 44–64. doi: 10.1177/1475725716638010.
- Kaendler, C., Wiedmann, M., Rummel, N., & Spada, H. (2015). Teacher competencies for the implementation of collaborative learning in the classroom: A framework and research review. *Educational Psychology Review*, 27(3), 505-536. doi: 10.1007/s10648-014-9288-9.
- Kollar, I., Fischer, F., & Hesse, F. W. (2006). Collaboration scripts – A conceptual analysis. *Educational Psychology Review*, 18(2), 159–185. doi: 10.1007/s10648-006-9007-2
- Mullins, D., Rummel, N. & Spada, H. (2011). Are two heads always better than one? Differential effects of collaboration on students' computer-supported learning in mathematics. *International Journal of Computer Supported Collaborative Learning*, 6(3), 421-443. doi: 10.1007/s11412-011-9122-z.
- Olsen, J. K., Rummel, N., & Alevan, V. (2016). Investigating effects of embedding collaboration in an intelligent tutoring system for elementary school students. In C. K. Looi, J. Polman, U. Cress, & P. Reimann (Eds.), *Proceedings of the 12th International Conference of the Learning Sciences*, ICLS 2016 (Vol. I, pp. 338-345). Singapore: International Society of the Learning Sciences.
- Olsen, J.K., Alevan, V., & Rummel, N. (2017). Statistically modeling individual students' learning over successive collaborative practice opportunities. *Journal of Educational Measurement*, 54 (1), 123–138.
- Olsen, J.K., Rummel, N. & Alevan, V. (2019). It is not either or: An initial investigation into combining collaborative and individual learning using an ITS. *International Journal of Computer-Supported Collaborative Learning*, 14, 353–381. doi:10.1007/s11412-019-09307-0

References

- Radkowsch, A., Vogel, F., & Fischer, F. (2020). Good for learning, bad for motivation? A meta-analysis on the effects of computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, 15(1), 5–47.
- Rummel, N. (2018). One framework to rule them all? Carrying forward the conversation started by Wise and Schwarz. *International Journal of Computer-Supported Collaborative Learning*, 13(1), 123-129. doi: 10.1007/s11412-018-9273-2.
- Rummel, N., & Spada, H. (2007). Can people learn computer-mediated collaboration by following a script? In F. Fischer, I. Kollar, H. Mandl & J. Haake (Eds.), *Scripting computer-supported communication of knowledge. Cognitive, computational, and educational perspectives* (pp. 39-55). New York: Springer.
- Rummel, N., Mullins, D. & Spada, H. (2012). Scripted collaborative learning with the Cognitive Tutor Algebra. *International Journal of Computer Supported Collaborative Learning*, 7(2), 307-339. doi:10.1007/s11412-012-9146-z.
- Rummel, N., Spada, H., & Hauser, S. (2009). Learning to collaborate from being scripted or from observing a model. *International Journal of Computer-Supported Collaborative Learning*, 4(1), 69-92.
- Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures*. Lawrence Erlbaum.
- Soller, A., Martínez, A., Jermann, P., & Muehlenbrock, M. (2005). From mirroring to guiding: A review of state of the art technology for supporting collaborative learning. *International Journal of Artificial Intelligence in Education*, 15, 261–290.
- Strauß, S., & Rummel, N. (2020). Promoting interaction in online distance education: designing, implementing and supporting collaborative learning. *Information and Learning Sciences*, 121 (5/6), 251–260.
- Teasley, S.D. (1995). The role of talk in children’s peer collaborations. *Developmental Psychology*, 31 (2), 207 – 220.

References

- Van Leeuwen, A., & Rummel, N. (2019). Kooperative Unterrichtsettings: Technologische Tools zur Unterstützung von Lehrkräften. *Unterrichtswissenschaft*, 47(2), 137–141. doi:10.1007/s42010-019-00051-w
- Van Leeuwen, A., & Rummel, N. (2019). Orchestration tools to support the teacher during student collaboration: a review. *Unterrichtswissenschaft*, 47(2), 143-158. doi:10.1007/s42010-019-00052-9
- Van Leeuwen, A., & Rummel, N. (2020). Comparing teachers' use of mirroring and advising dashboards. In Rensing C., and Drachsler, H. (Eds.), LAK '20: Proceedings of the Tenth International Conference on Learning Analytics & Knowledge (pp. 26–34). Association for Computing Machinery, New York, NY, United States. <https://doi.org/10.1145/3375462.3375471>.
- Van Leeuwen, A., Rummel, N., & Van Gog, T. (2019). What information should CSCL teacher dashboards provide to help teachers interpret CSCL situations? *International Journal of Computer-Supported Collaborative Learning*, 14, 261–289. doi:10.1007/s11412-019-09299-x
- Van Leeuwen, A., Van Wermeskerken, M., Erkens, G., & Rummel, N. (2017). Measuring teacher sense making strategies of learning analytics: a case study. *To appear in Learning: research and practice*. DOI:10.1080/23735082.2017.1284252.
- Vogel, F., Wecker, C., Kollar, I., & Fischer, F. (2017). Socio-Cognitive Scaffolding with Computer-Supported Collaboration Scripts: A Meta-Analysis. *Educational Psychology Review*, 29(3), 477–511.
- Walker, E., Rummel, N. & Koedinger, K. (2014). Adaptive intelligent support to improve peer tutoring in Algebra. *International Journal of Artificial Intelligence in Education*, 24(1), 33-61. doi: 10.1007/s40593-013-0001-9.
- Walker, E., Rummel, N., & Koedinger, K. (2009a). CTRL: A research framework for providing adaptive collaborative learning support. *User Modeling and User-Adapted Interaction: The Journal of Personalization Research (UMUAI)*, 19(5), 387-431.
- Walker, E., Rummel, N., & Koedinger, K. (2009b). Integrating collaboration and intelligent tutoring data in evaluation of a reciprocal peer tutoring environment. *Research and Practice in Technology Enhanced Learning*, 4(3), 221-251.

References

- Walker, E., Rummel, N. & Koedinger, K. (2011). Designing automated adaptive support to improve student helping behaviors in a peer tutoring activity. *International Journal of Computer Supported Collaborative Learning*, 6(2), 279-306. doi: 10.1007/s11412-011-9111-2.
- Webb, N. M. & Mastergeorge, A. (2003). The development of students' helping behavior and learning in peer-directed small groups. *Cognition and Instruction*, 21(4), 361-428.
- Webb, N.M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, 13 (1), 21 – 39.