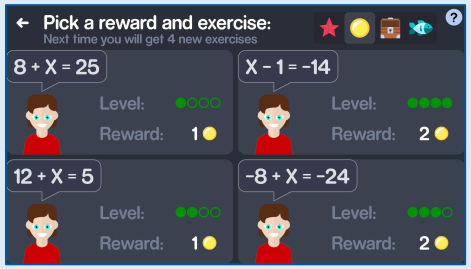
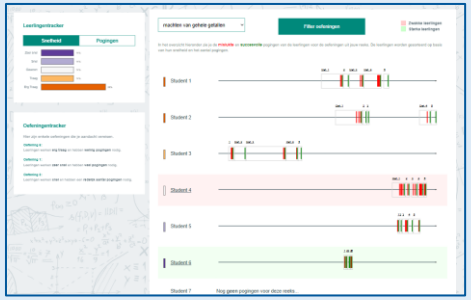
How can digital systems help with differentiation in education?

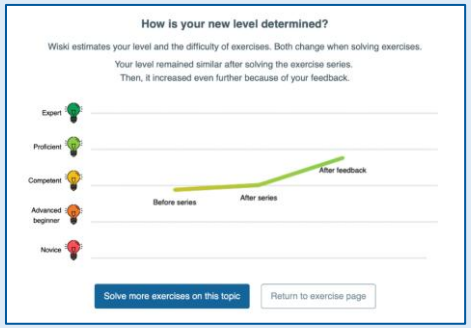
Jeroen Ooge

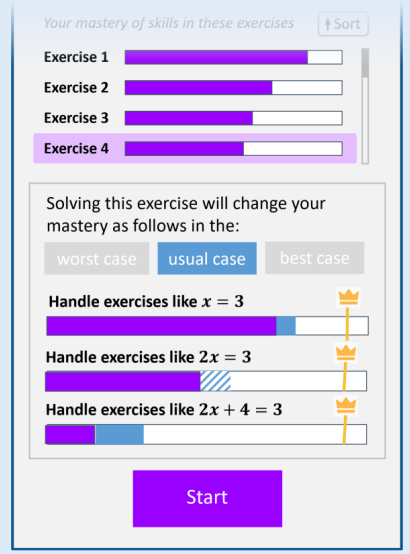
jeroenooge.be

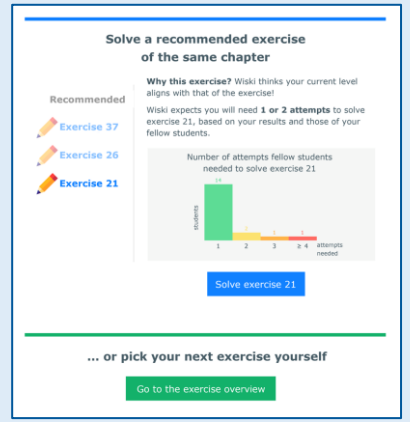
Universiteit Utrecht

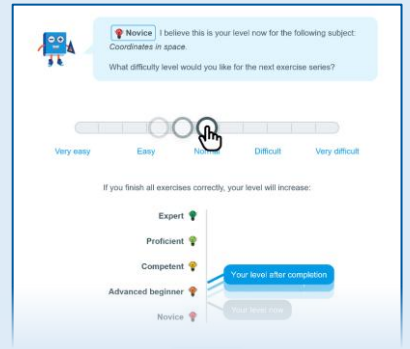












My (professional) life in 1 slide

Explainable and controllable AI systems to personalise education and motivate learners

MSc fundamental mathematics
MSc applied informatics
2012-2019

KU LEUVEN

PhD in computer science
2019-2023

Assistant professor
in computer science
Nov 2023-now

Universiteit Utrecht

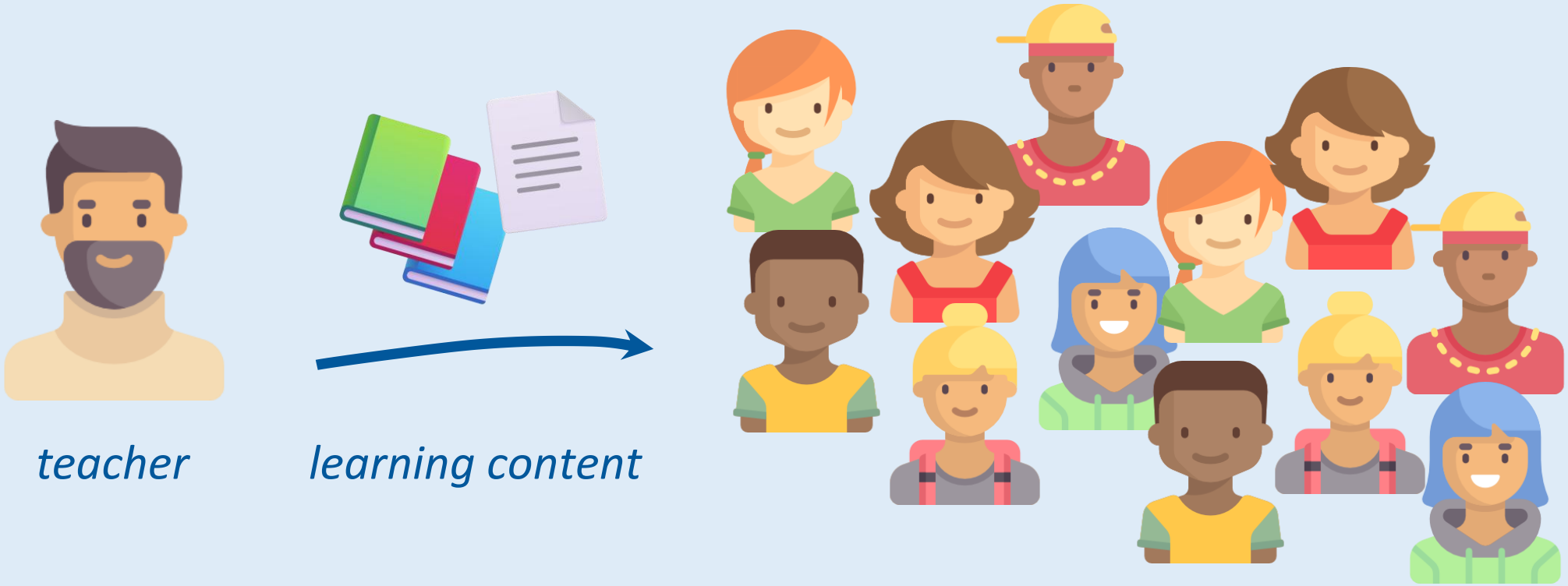
Jeroen Ooge
jeroenooge.be

How can digital systems help with differentiation in education?

WTF is dit?

Jeroen Ooge
jeroenooge.be
Universiteit Utrecht

The non-differentiated (usual?) way

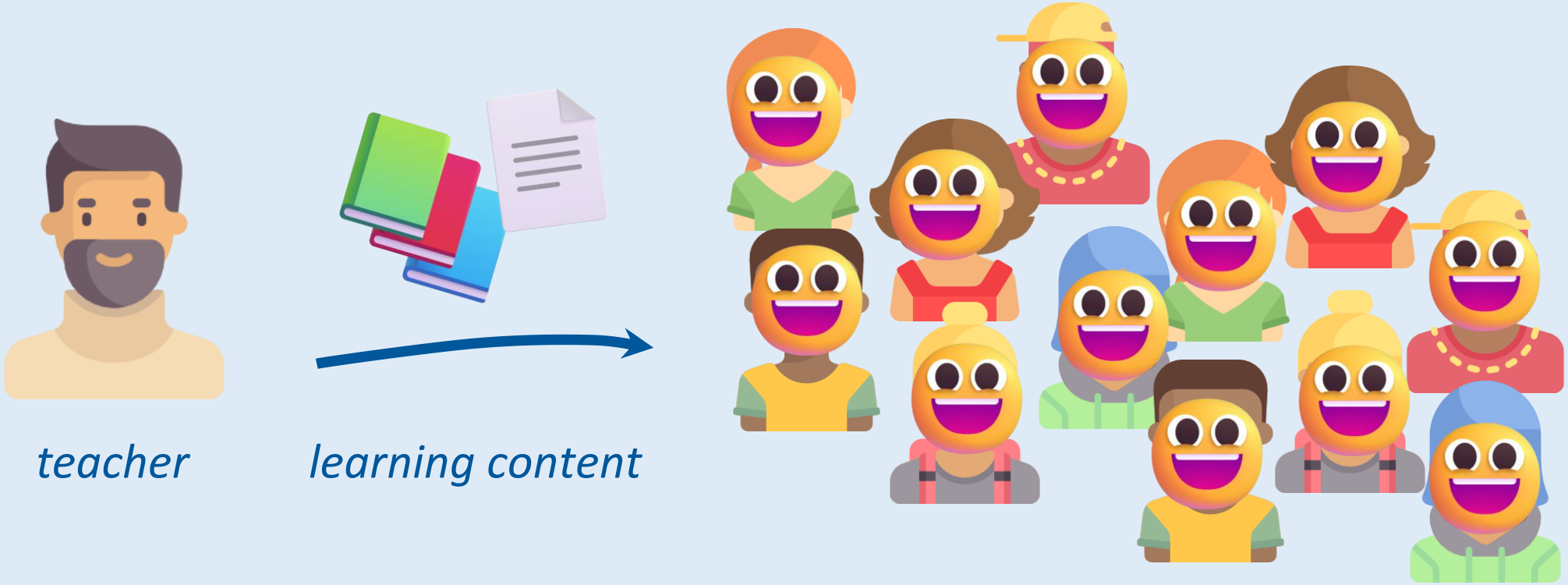


teacher

learning content

learners

What teachers might expect

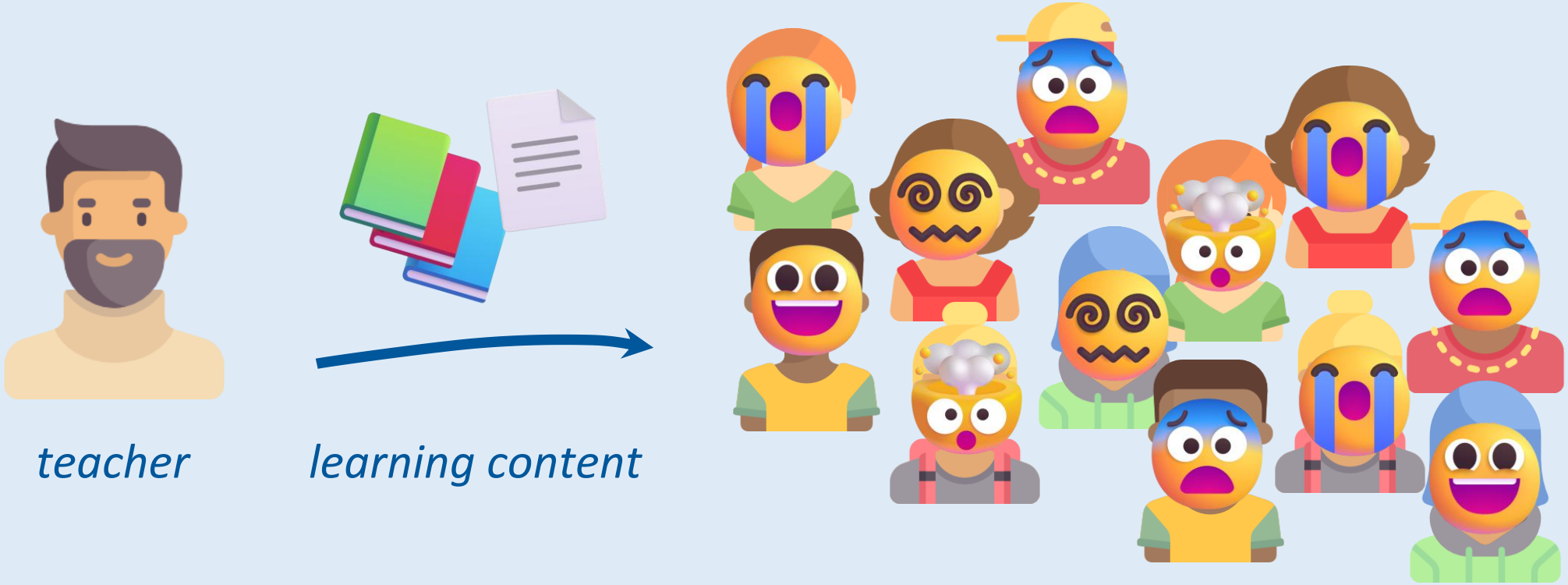


teacher

learning content

one-size-fits-all approach works for everyone

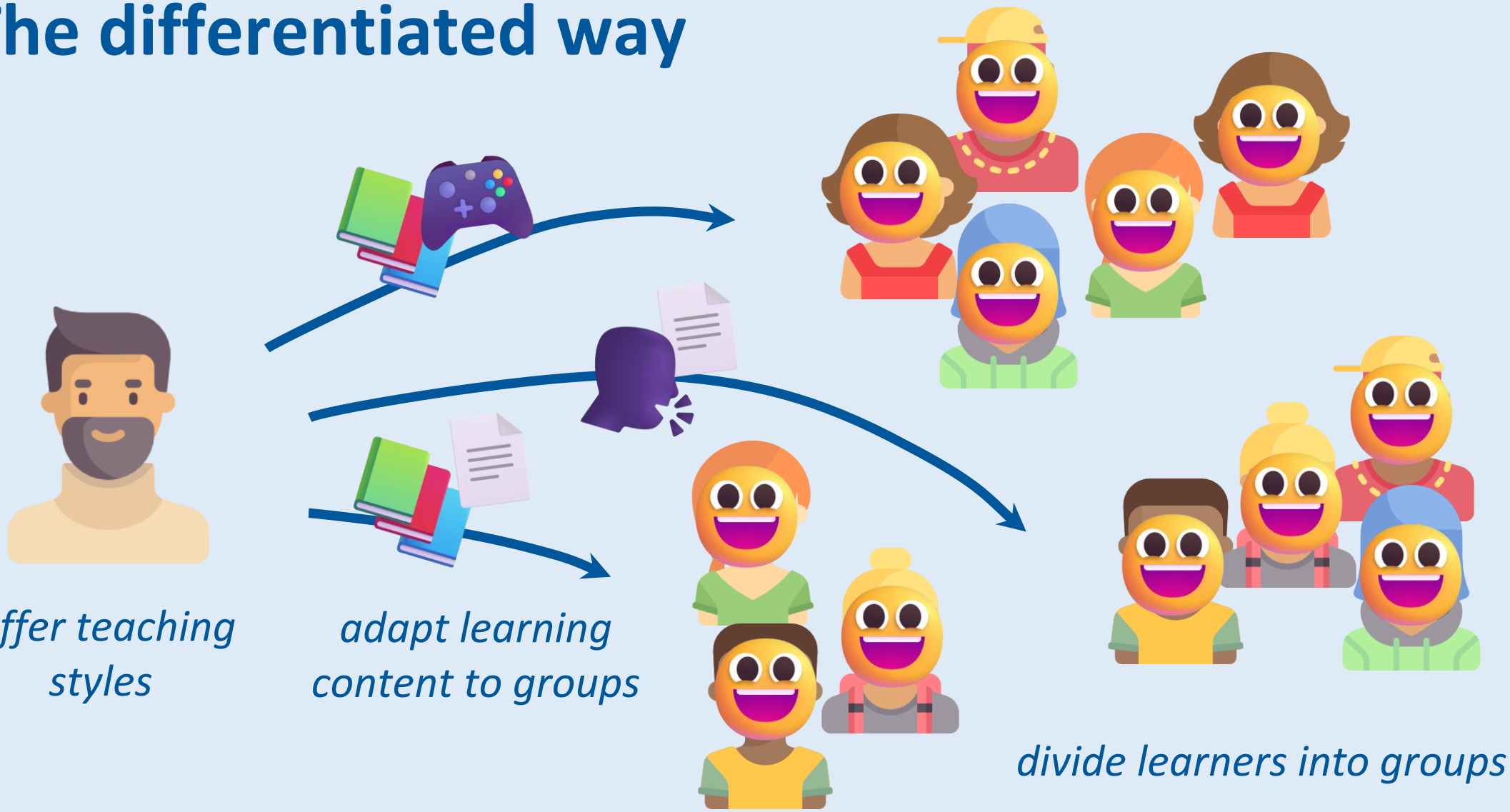
Reality



teacher *learning content*

effectiveness depends on abilities, interests, background…

The differentiated way



differ teaching styles

adapt learning content to groups

divide learners into groups

What is differentiation (formally)?

“dividing students into groups or classes based on their assessed abilities and aptitudes … is assumed to increase the teacher’s opportunities to adapt the teaching to the students”

differentiate teachers

differentiate content

differentiate students

Ingunn Eikeland and Stein Erik Ohna. 2022. Differentiation in education: a configurative review. *Nordic Journal of Studies in Educational Policy* 8, 3: 157–170. https://doi.org/10.1080/20020317.2022.2039351

What is differentiation (formally)?

Differentiation as individualisation

Differentiation as adaptation to specific groups

Differentiation as adaptations within diverse classrooms

Differentiation in a system perspective

Ingunn Eikeland and Stein Erik Ohna. 2022. Differentiation in education: a configurative review. *Nordic Journal of Studies in Educational Policy* 8, 3: 157–170. https://doi.org/10.1080/20020317.2022.2039351

What is differentiation (formally)?

Differentiation as individualisation

= “adapt the curriculum, tasks, and teaching to students’ individual abilities”

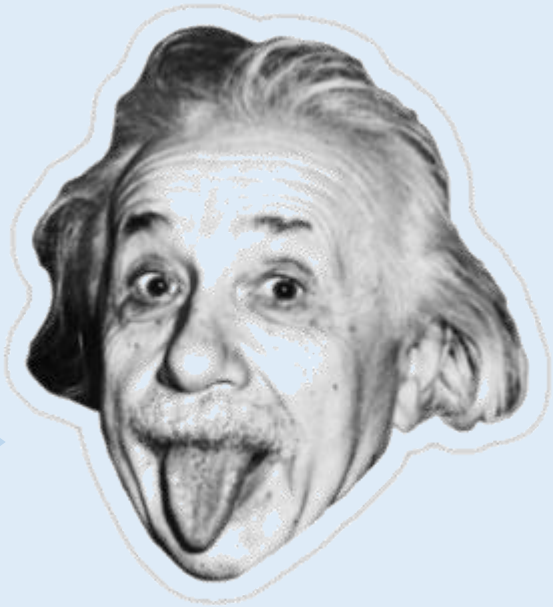
= personalisation

Differentiation as adaptation to sp

Differentiation as adaptations with

Differentiation in a system perspec

“enable all students to meet high standards and … provide optimal conditions for learning and progress”



Ingunn Eikeland and Stein Erik Ohna. 2022. Differentiation in education: a configurative review. *Nordic Journal of Studies in Educational Policy* 8, 3: 157–170. https://doi.org/10.1080/20020317.2022.2039351

How can digital systems help with differentiation* in education?

*in the sense of individualisation/personalisation

Make learning experiences more
1 adaptive, 2 transparent, and 3 motivating

How can digital systems help with differentiation?

1 Adaptation

2 Transparency

3 Motivation

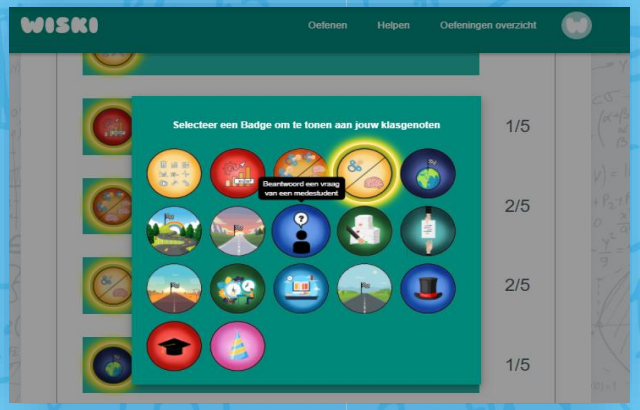
How can digital systems help with differentiation?

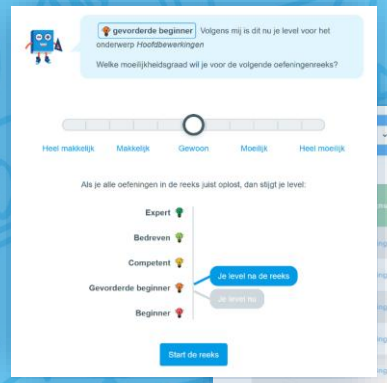
1 Adaptation

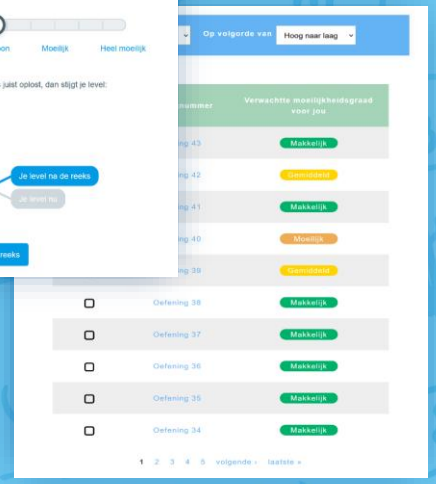
2 Transparency

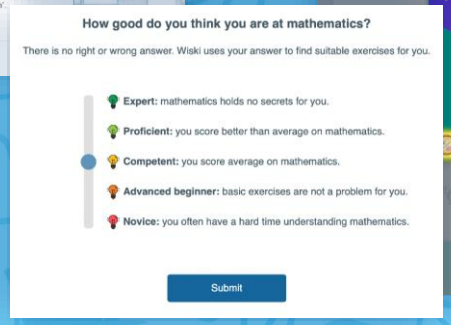
3 Motiva

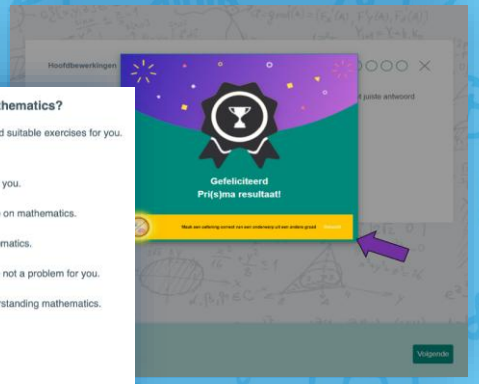
About fake whiskey, Elo ratings, and spying dashboards

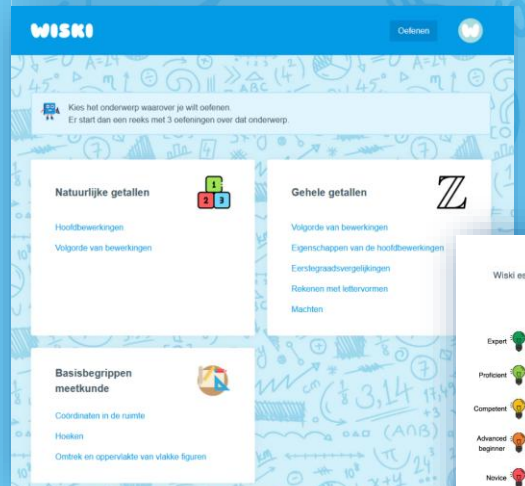


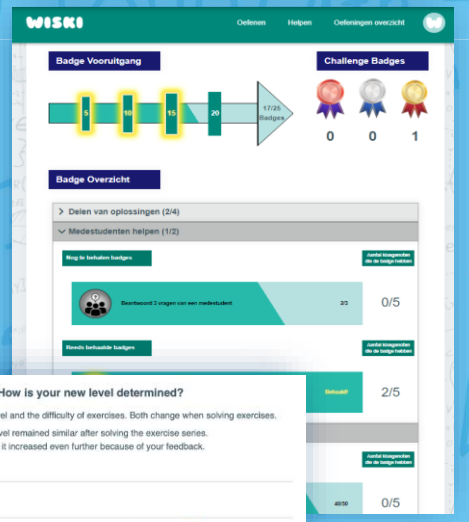


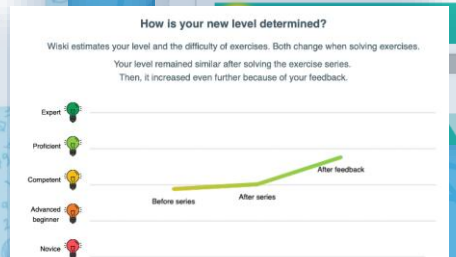












WISKI

personalised maths practice with AI

Volgorde van bewerkingen

$6 \cdot (-12) + 36 \cdot 2 = \ldots$ Bereken en tik de juiste oplossing aan.

- (•) 0
- ( ) -144
- ( ) 72
- ( ) 144

Correct

Top-π!

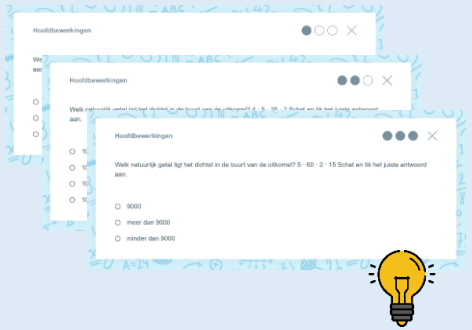
Overslaan Volgende

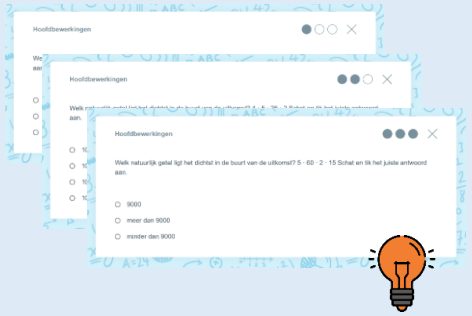
expert

competent

beginner

Recommender system





Estimating mastery and difficulty with Elo ratings

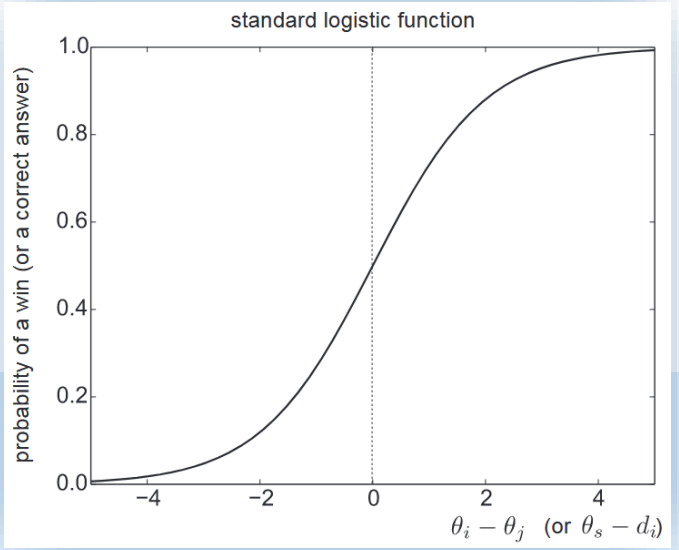
2.2. The Elo rating system in an educational setting

To apply the Elo rating system in the context of educational systems, we interpret a student's answer to an item as a match between the student and the item. In this context it is natural to slightly change the notation while keeping the basic principle the same. We denote skill of a student s as θ_s, difficulty of an item i as d_i, and the correctness of an answer of a student s on an item i as $\text{correct}_{si} \in \{0,1\}$. The probability of a correct answer is given by the logistic function with respect to the difference between skill and difficulty (Fig. 1 left):

$$P(\text{correct}_{si} = 1) = 1 \Big/ \left(1 + e^{-(\theta_s - d_i)}\right)$$

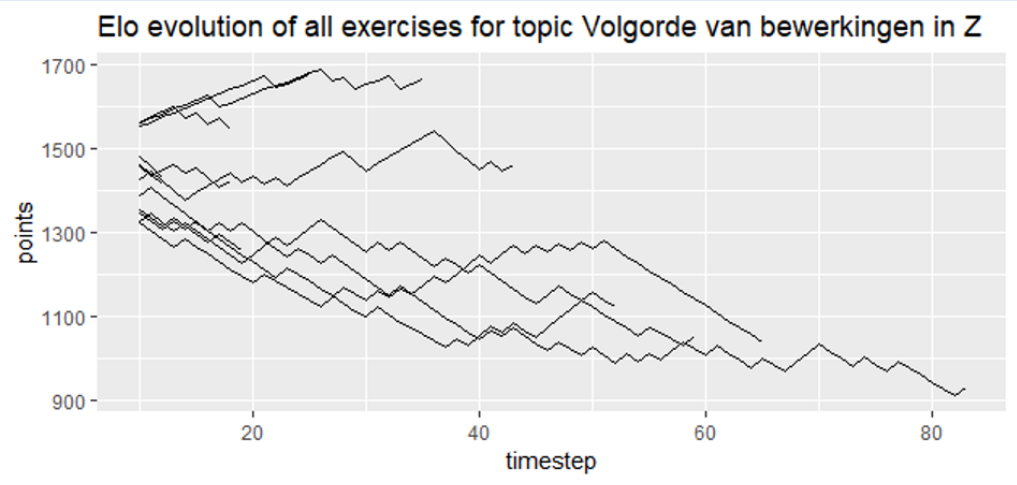
The skill and difficulty estimates are updated as follows:

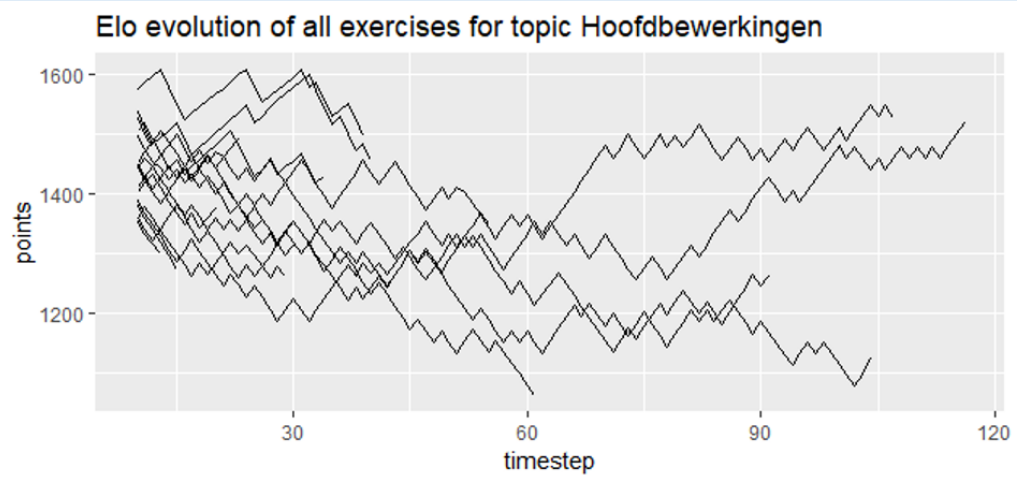
$$\begin{aligned} \theta_s &:= \theta_s + K \cdot (\text{correct}_{si} - P(\text{correct}_{si} = 1)) \\ d_i &:= d_i + K \cdot (P(\text{correct}_{si} = 1) - \text{correct}_{si}) \end{aligned}$$

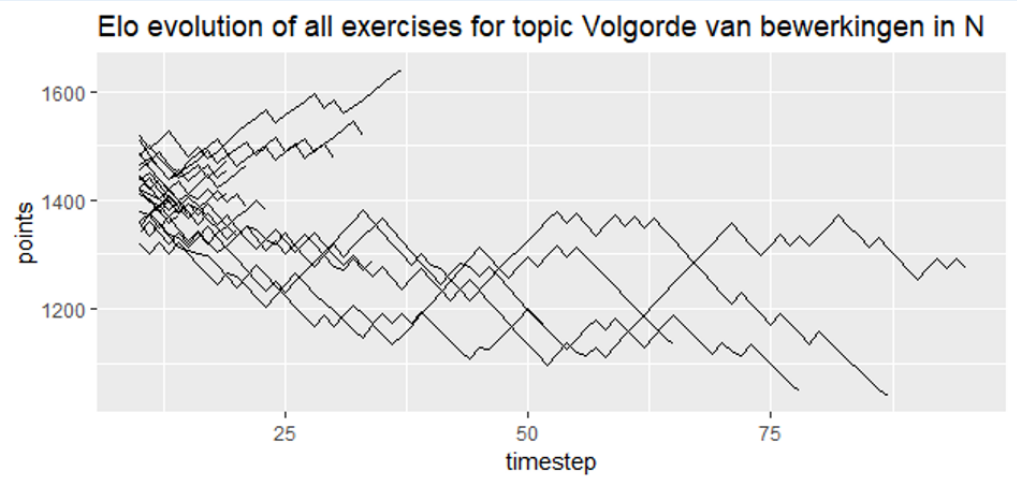


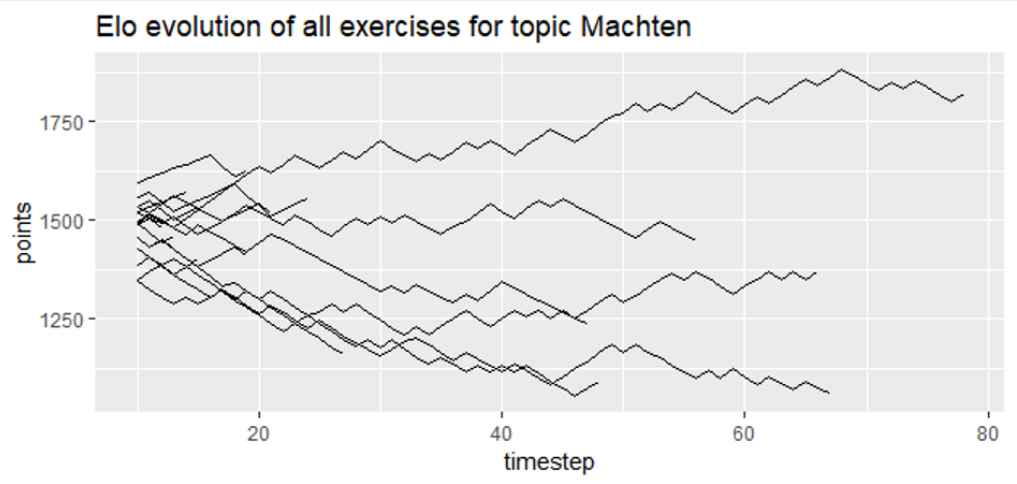
Radek Pelánek. 2016. Applications of the Elo rating system in adaptive educational systems. *Computers & Education* 98: 169–179.
https://doi.org/10.1016/j.compedu.2016.03.017

Elo ratings going crazy

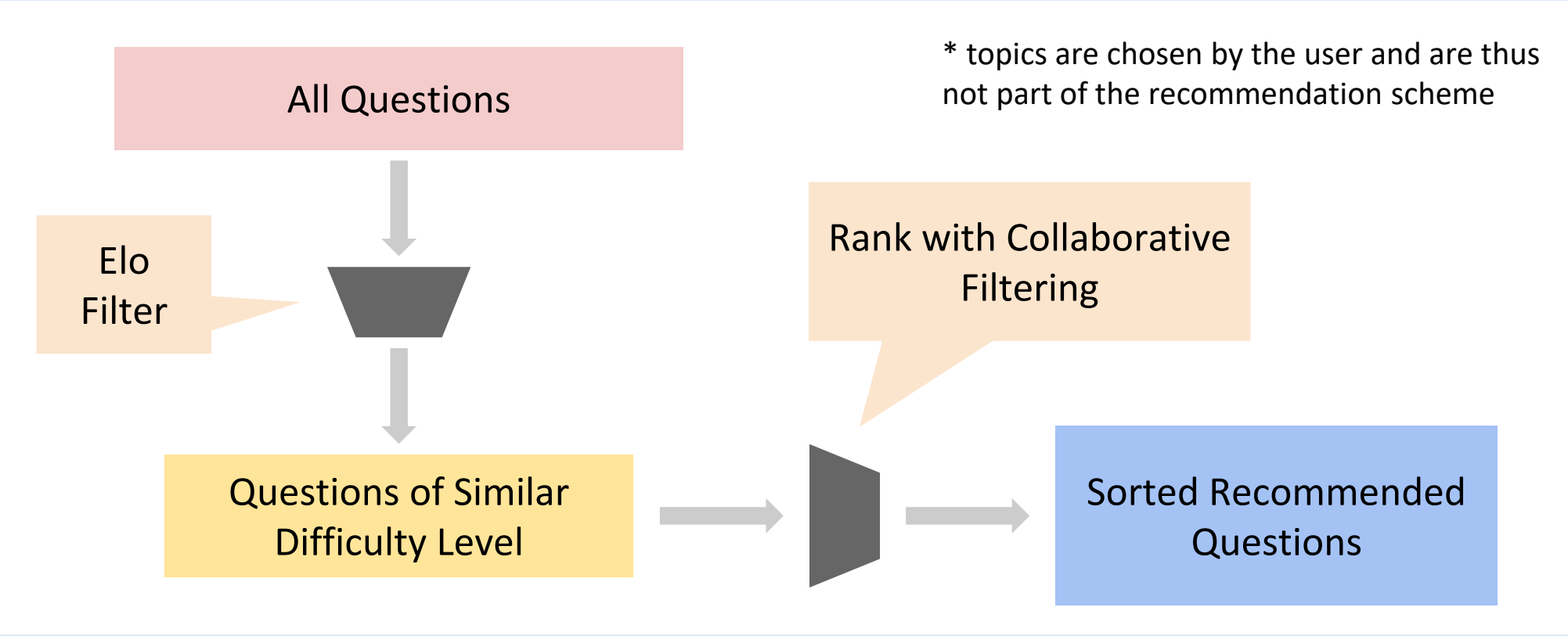






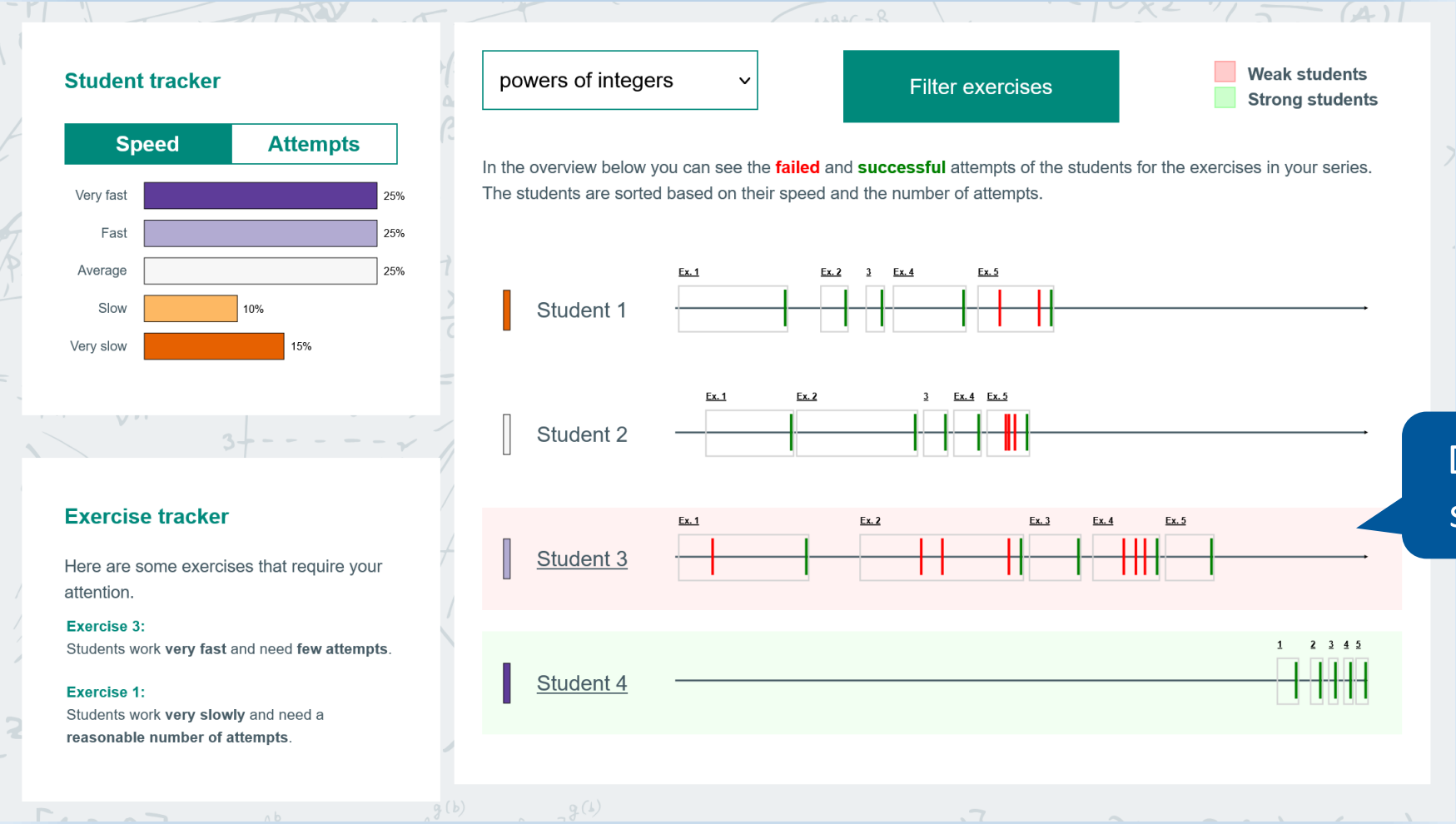


Recommending with Elo and collaborative filtering



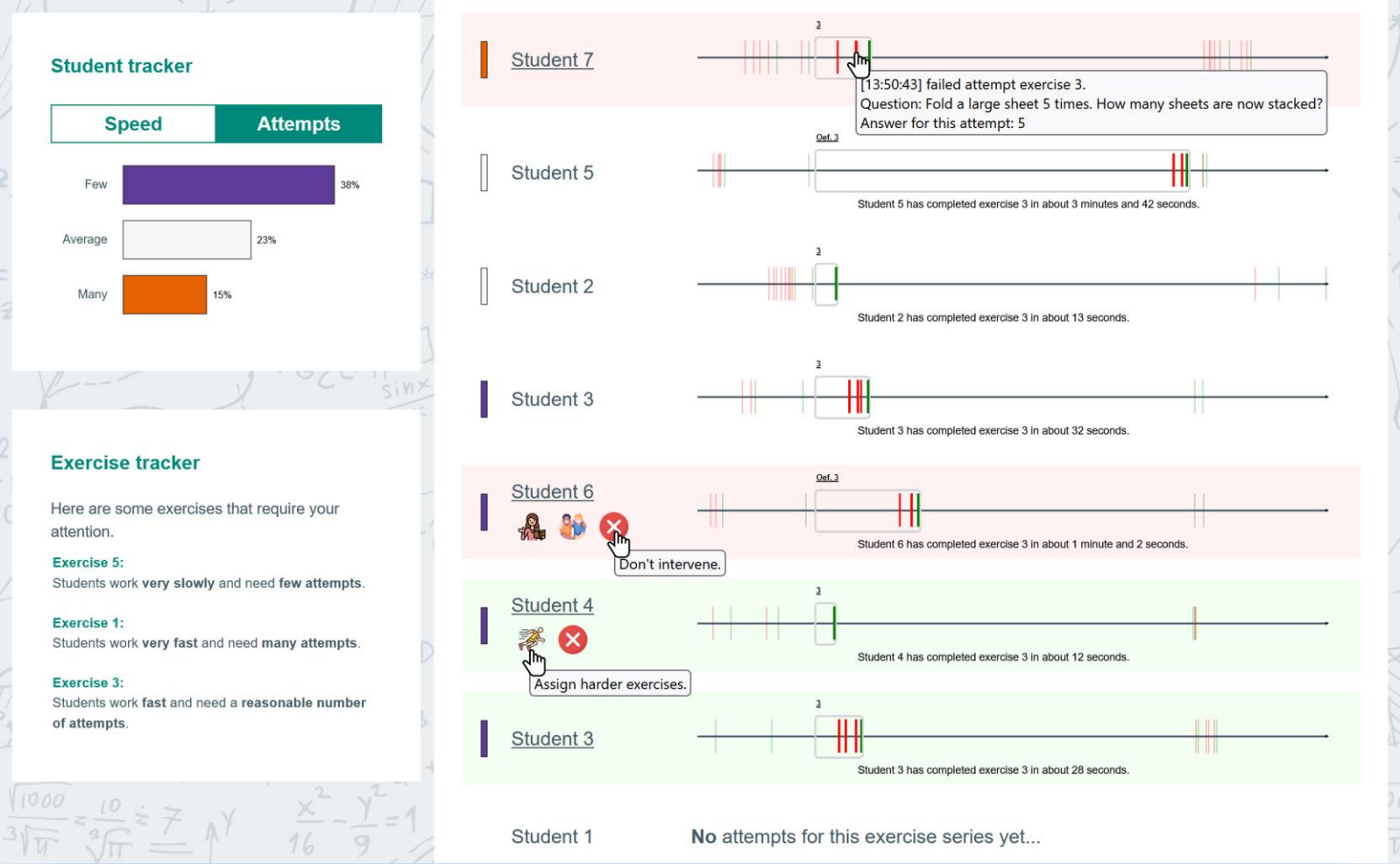
Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

Monitoring dashboard for teachers



Jeroen Ooge*, Anissa Faik* & Katrien Verbert. Detect, Explain, Act: How Teachers Trust and Use an Explainable Real-Time Monitoring Dashboard to Detect Student Outliers in Class. In *Proceedings of the 16th Learning Analytics and Knowledge Conference*, April 2026, https://doi.org/10.1145/3785022.3785087

Monitoring dashboard for teachers



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TIME FOR
QUESTIONS

How can digital systems differentiate with **adaptation** in universities?

How can digital systems help with differentiation?

1 Adaptation

2 Transparency

3 Motiva

About fake whiskey, Elo ratings, and spying dashboards

How can digital systems help with differentiation?

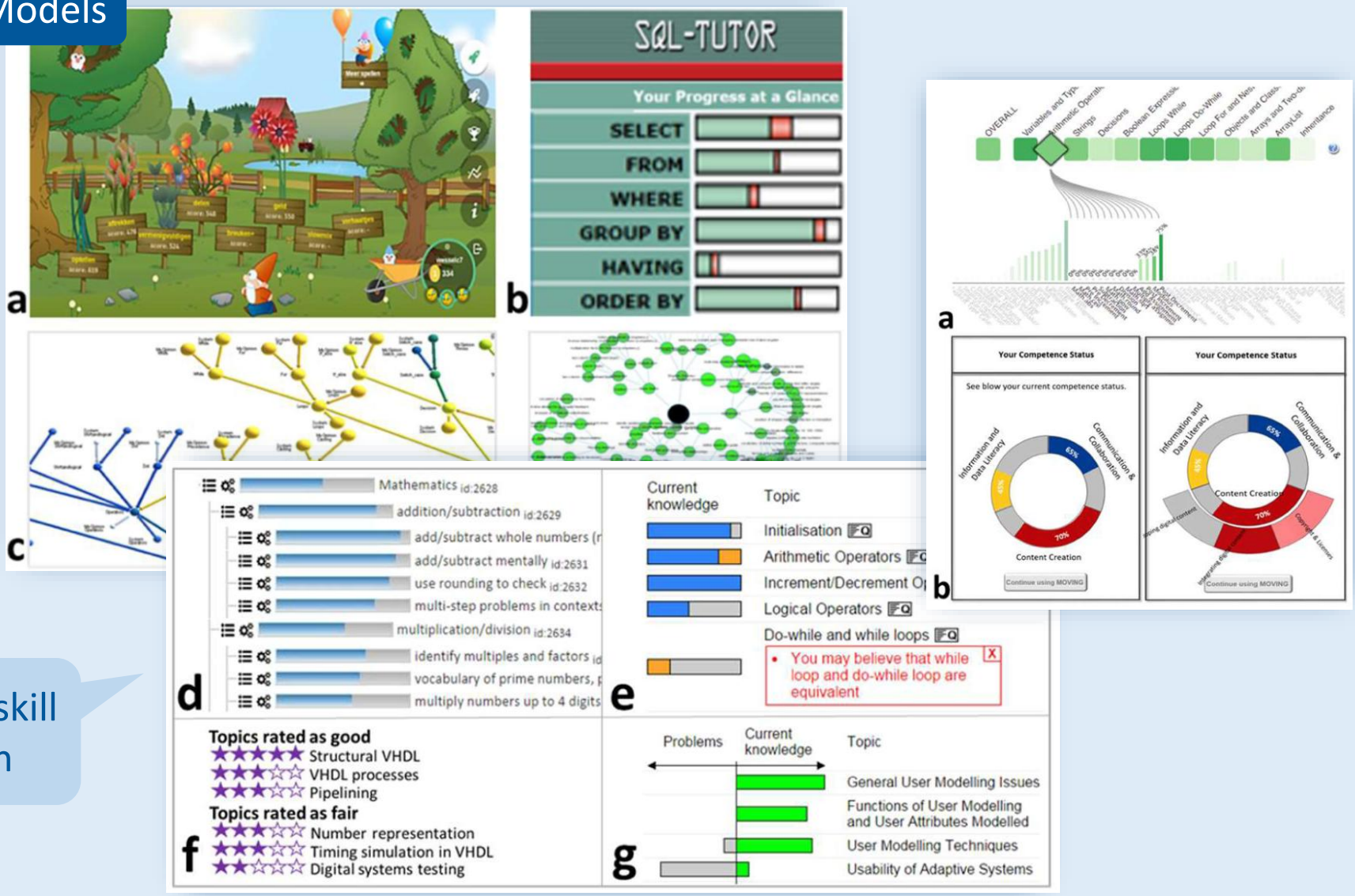
1 Adaptation

2 Transparency

3 Motivation

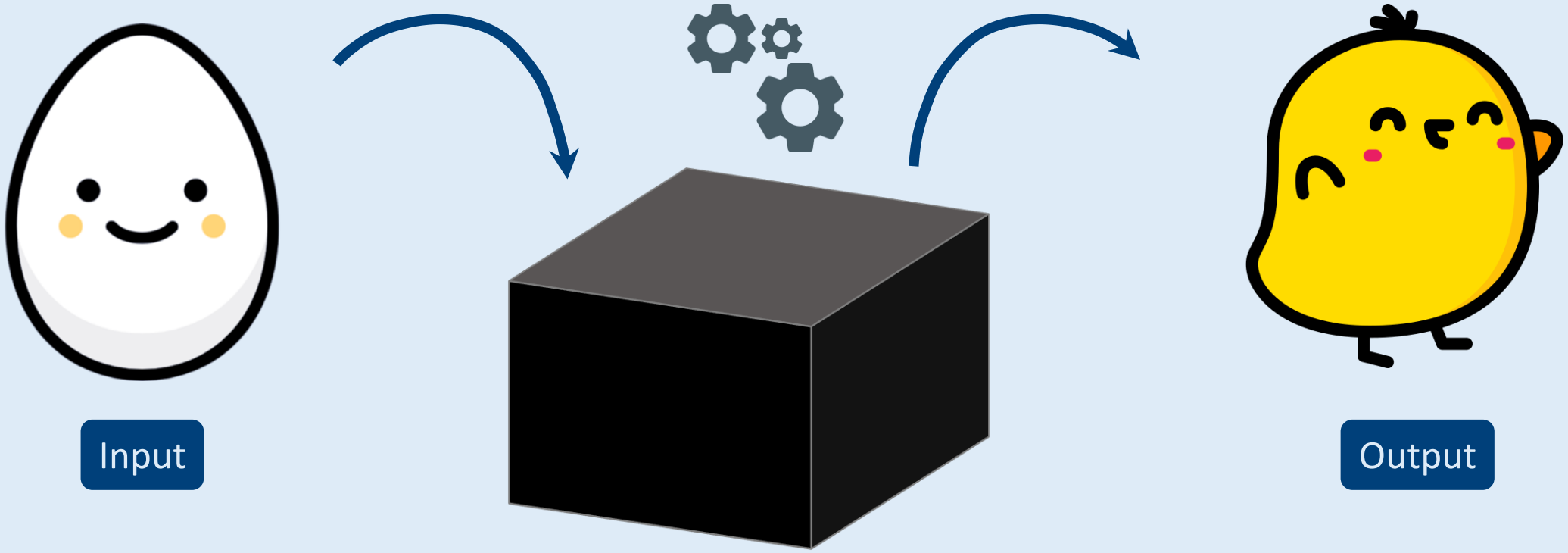
About seeing what you master and explaining AI decisions

Open Learner Models

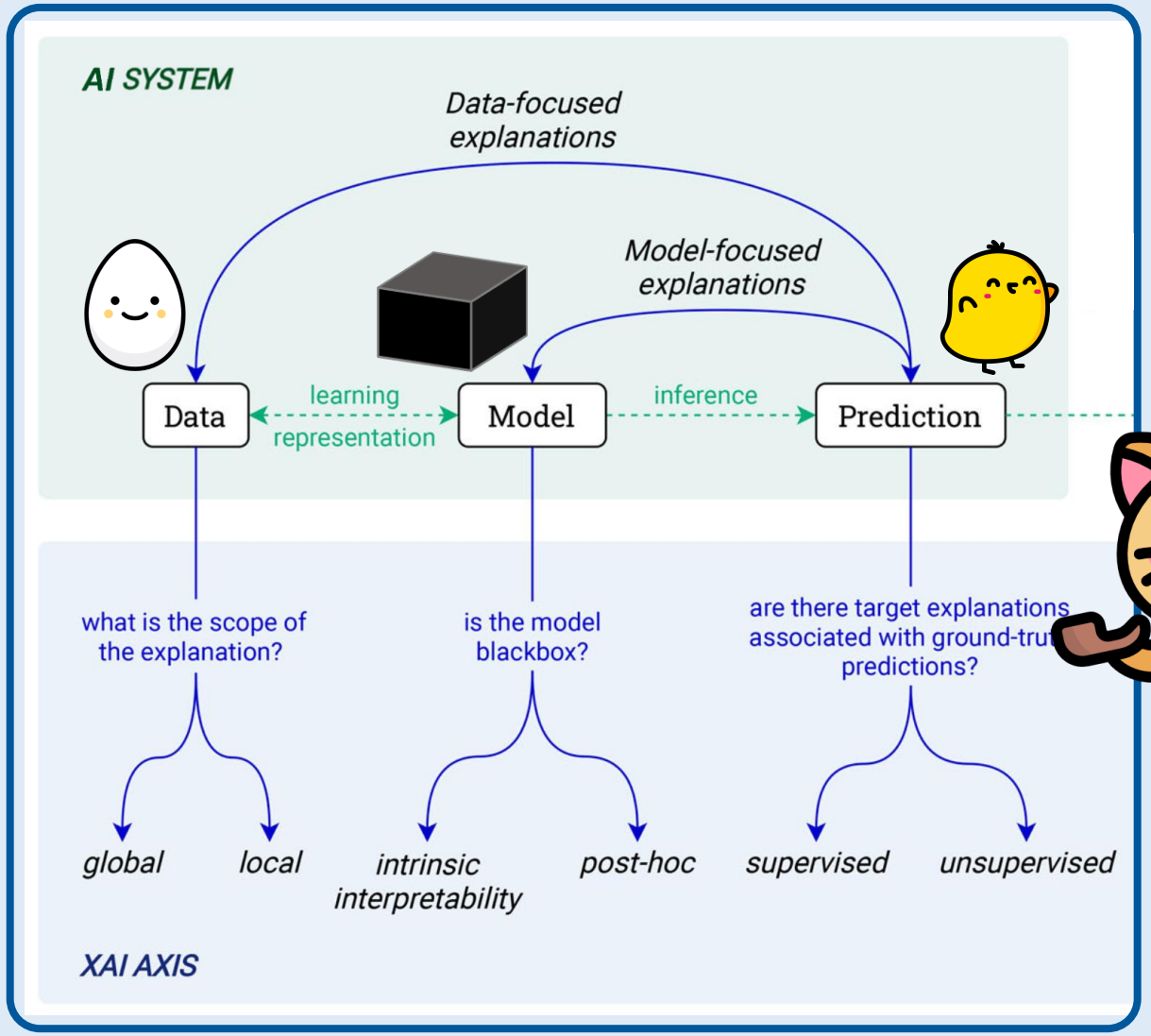


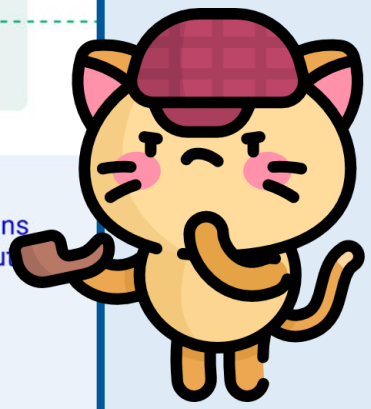
Algorithmic skill estimation

Susan Bull. 2020. There are Open Learner Models About! *IEEE Transactions on Learning Technologies* 13, 2: 425–448. https://doi.org/10.1109/TLT.2020.2978473


Input
AI model
Output

Algorithmic Explainability



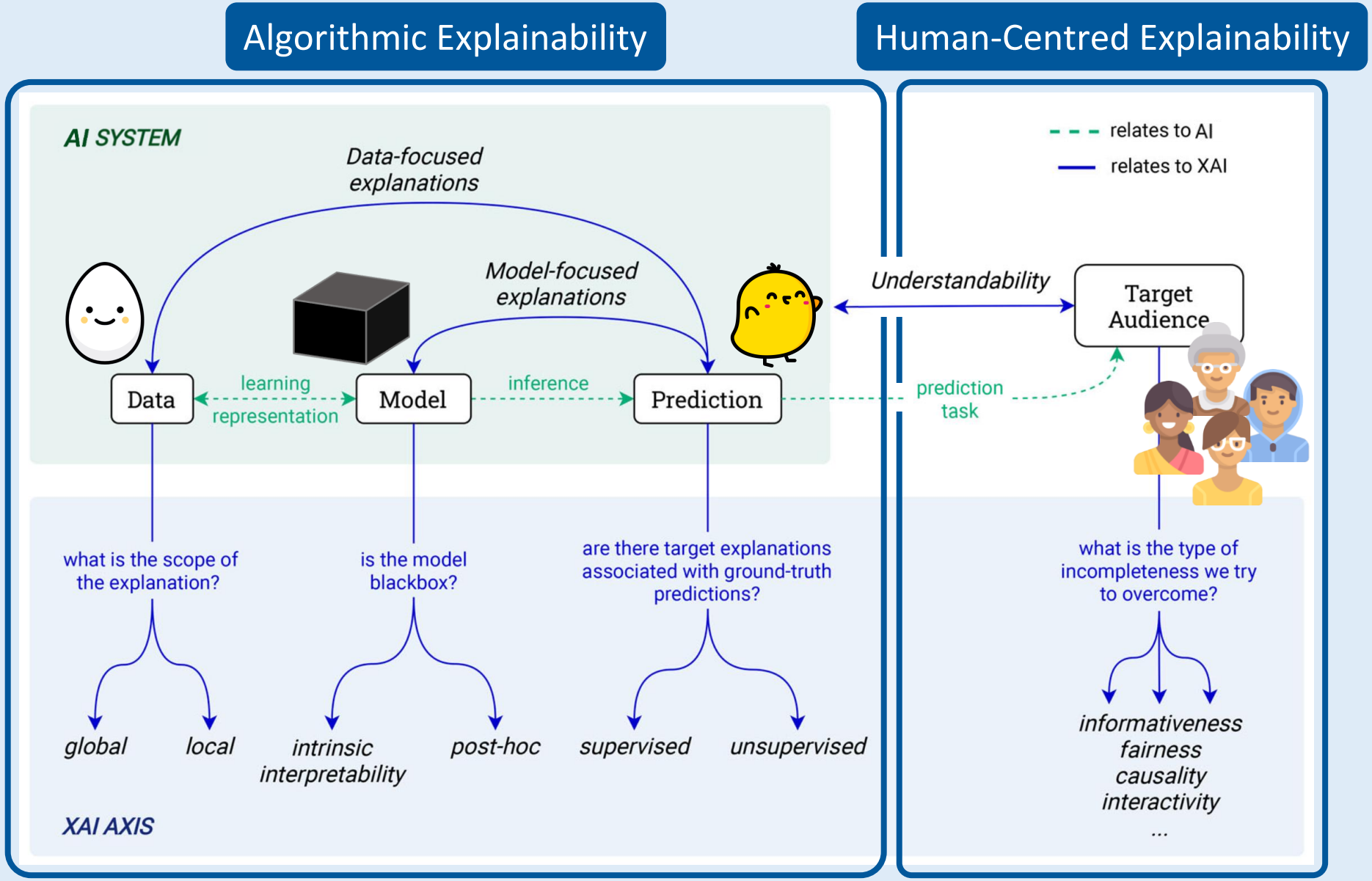


Which explanation do we use?

Who is the audience?

What is their context?

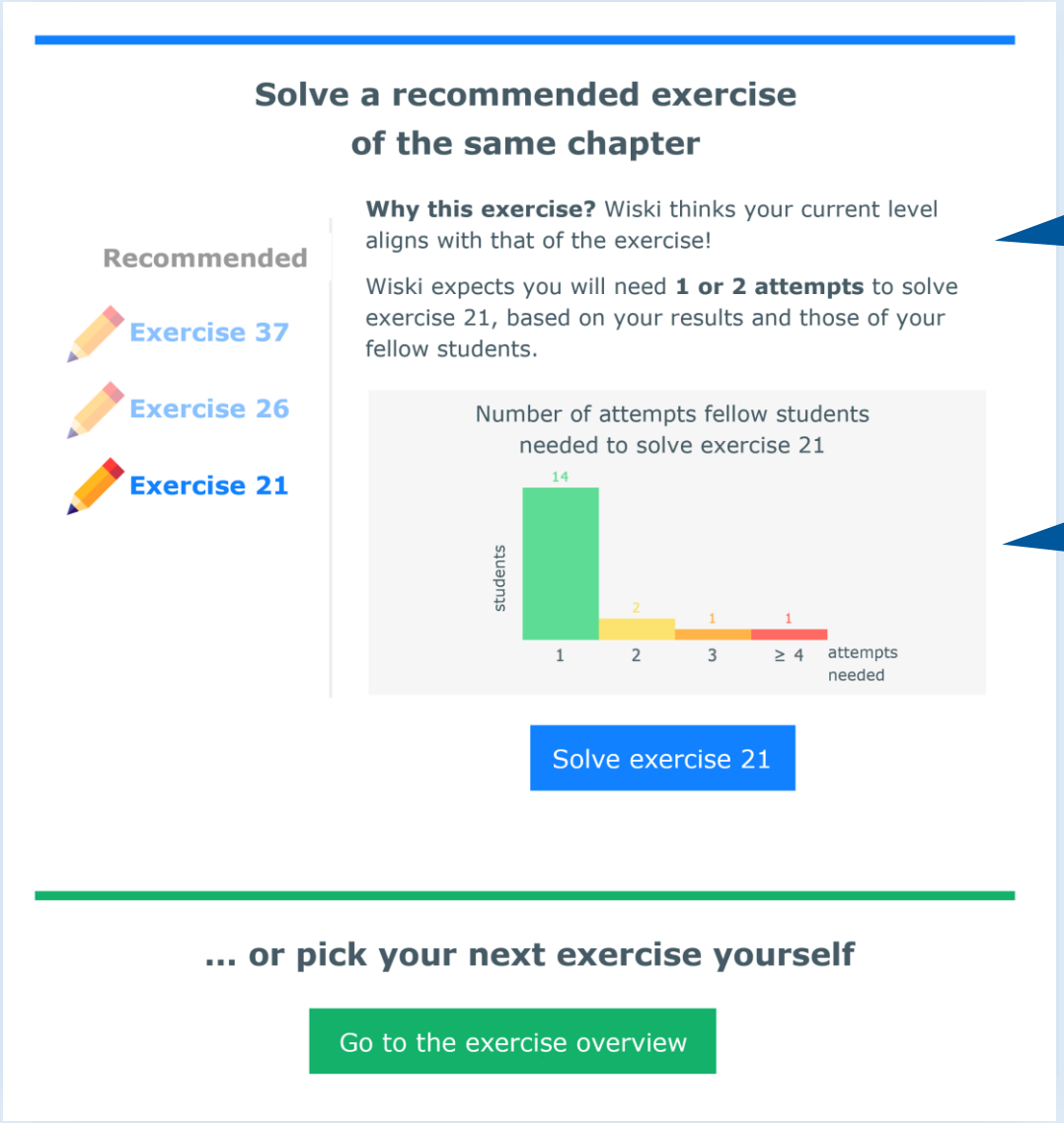
Darius Afchar, Alessandro Melchiorre, Markus Schedl, Romain Hennequin, Elena Epure, and Manuel Moussallam. 2022. Explainability in Music Recommender Systems. *AI Magazine* 43, 2: 190–208. https://doi.org/10.1002/aaai.12056



Darius Afchar, Alessandro Melchiorre, Markus Schedl, Romain Hennequin, Elena Epure, and Manuel Moussallam. 2022. Explainability in Music Recommender Systems. *AI Magazine* 43, 2: 190–208. https://doi.org/10.1002/aaai.12056

Human-Centred Explainability

Design explanations for a specific audience and **evaluate** how they affect behaviour
(e.g., trust, understanding, motivation, learning)

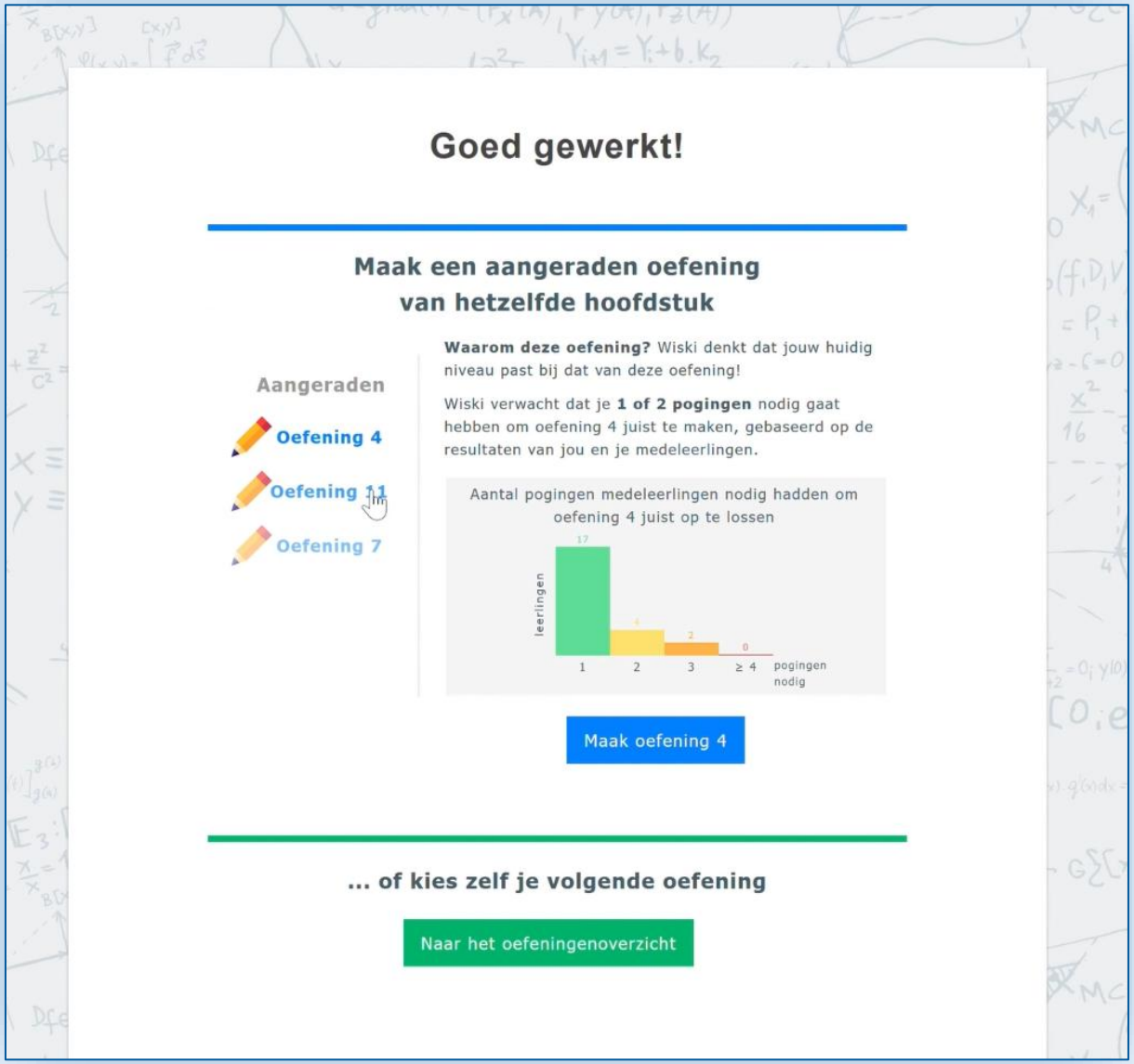


Textual explanation

Visual explanation

Justify *why* a specific exercise was recommended by the algorithm

Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140



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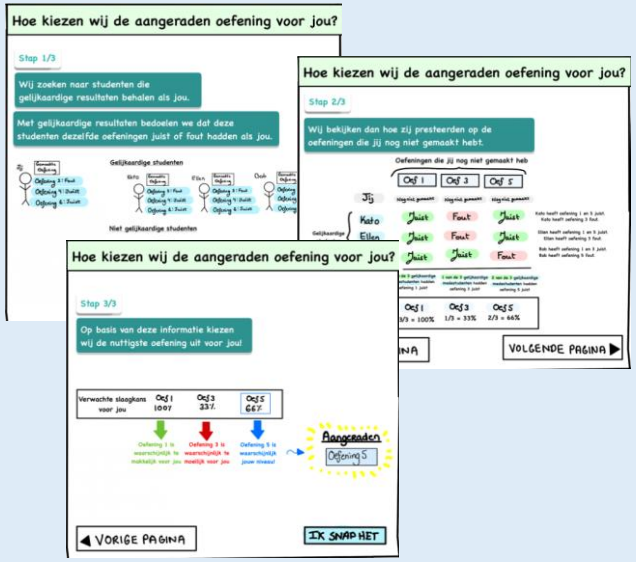
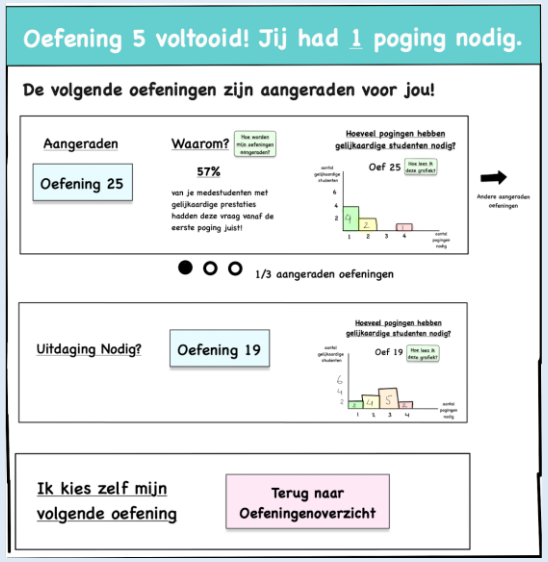
Designing explanations requires iterating



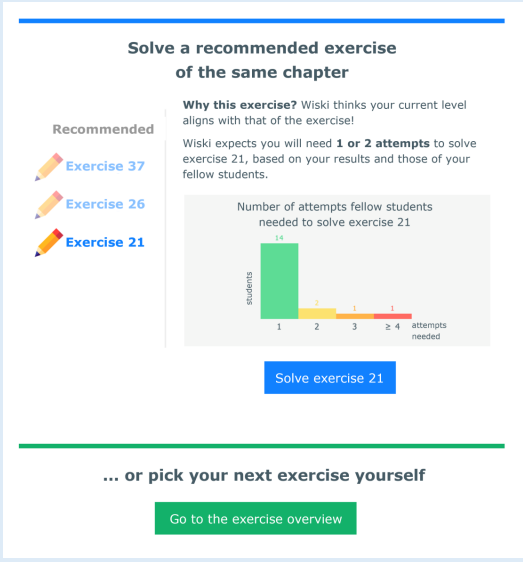
Tutorial for full transparency

9 think-aloud studies



Single-screen explanation

7 think-aloud studies

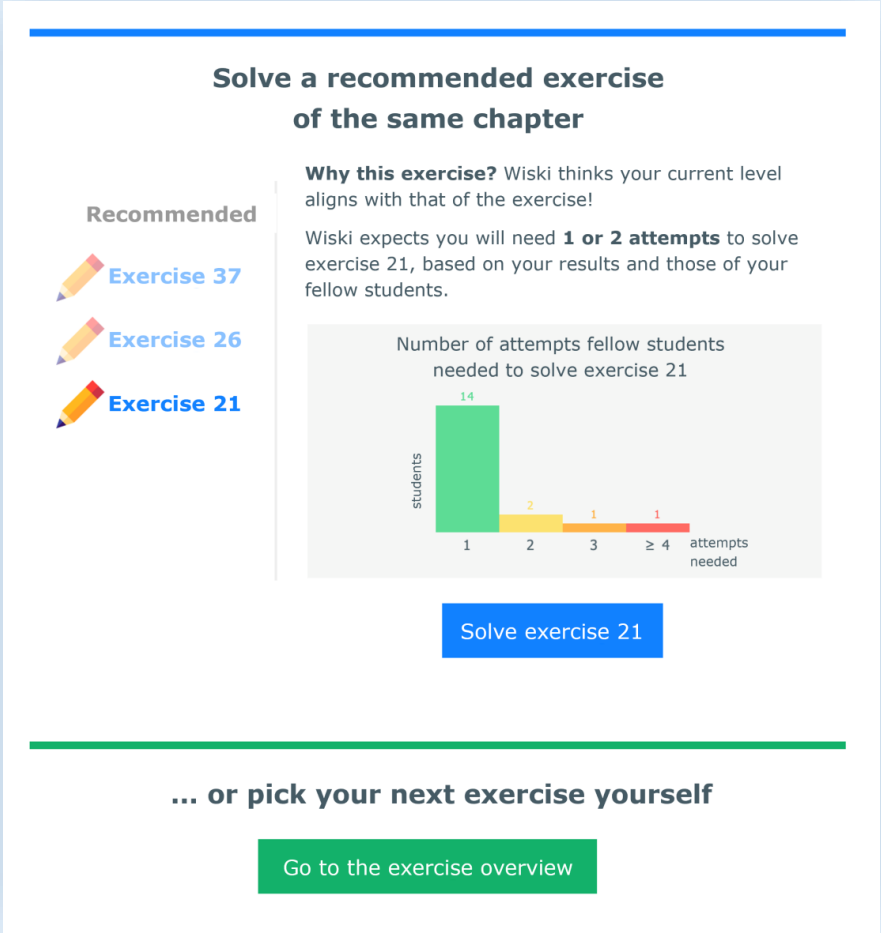


Final explanation interface

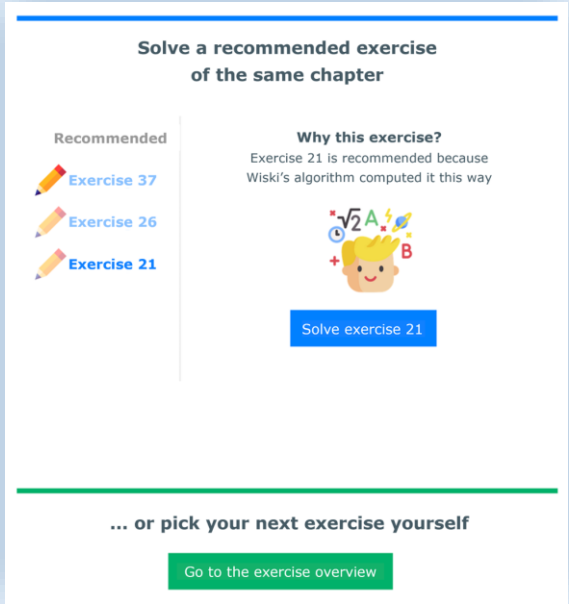
4 think-aloud studies

Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

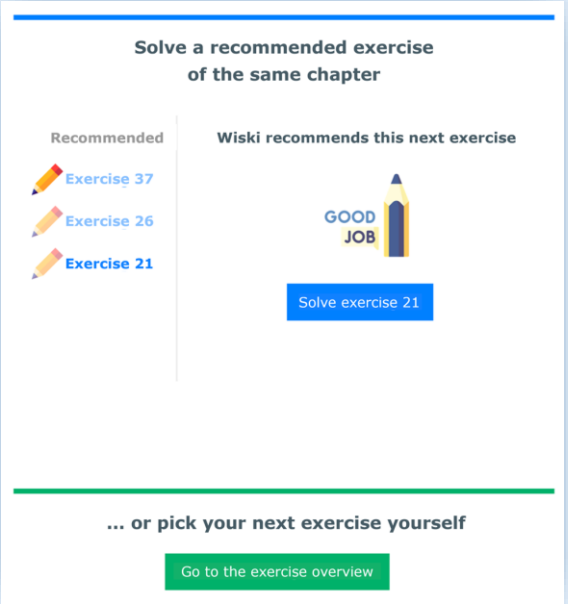
How was trust in the platform affected?



Real explanation



Placebo explanation



No explanation

Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

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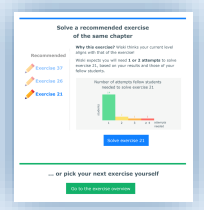
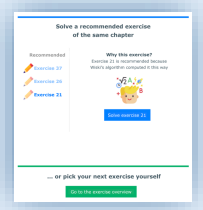




Real vs no explanation

trust increased

trust unchanged

trust decreased

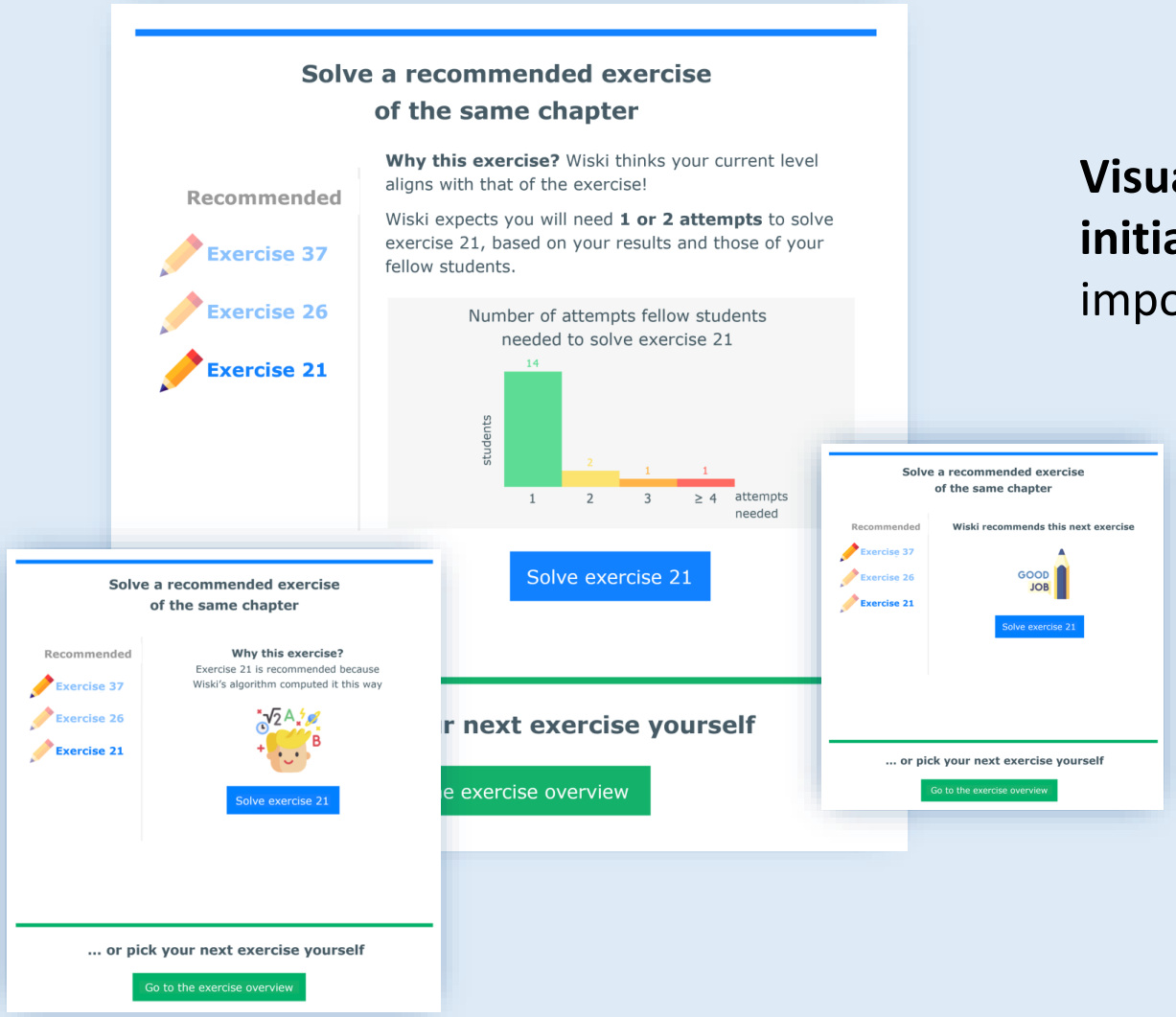
Placebo vs no explanation

trust increased

trust unchanged

trust decreased

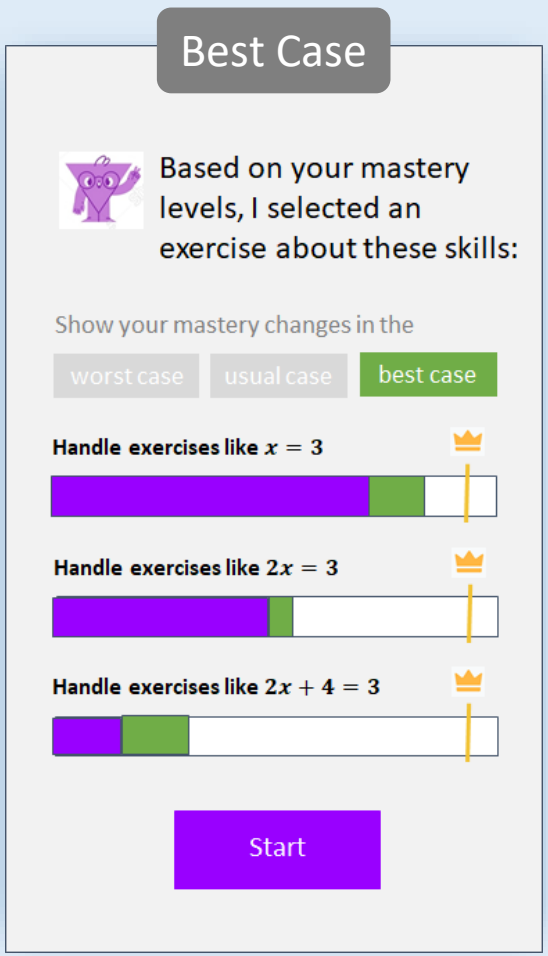
Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

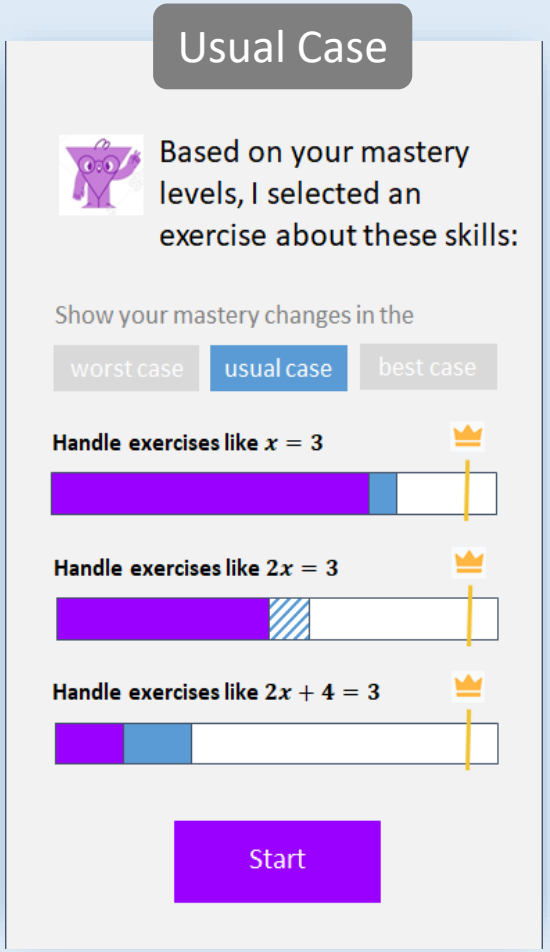


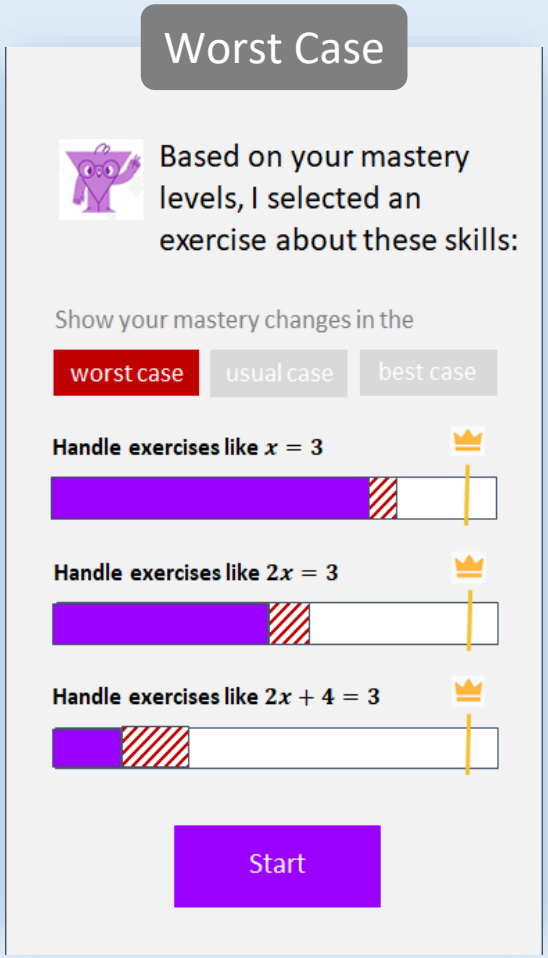
Visual explanations can increase initial trust but may not be the most important factor for building it

Jeroen Ooge*, Shotallo Kato*, and Katrien Verbert. 2022. Explaining Recommendations in E-Learning: Effects on Adolescents' Trust. In *27th International Conference on Intelligent User Interfaces* (IUI '22), 93–105. https://doi.org/10.1145/3490099.3511140

What-if explanations

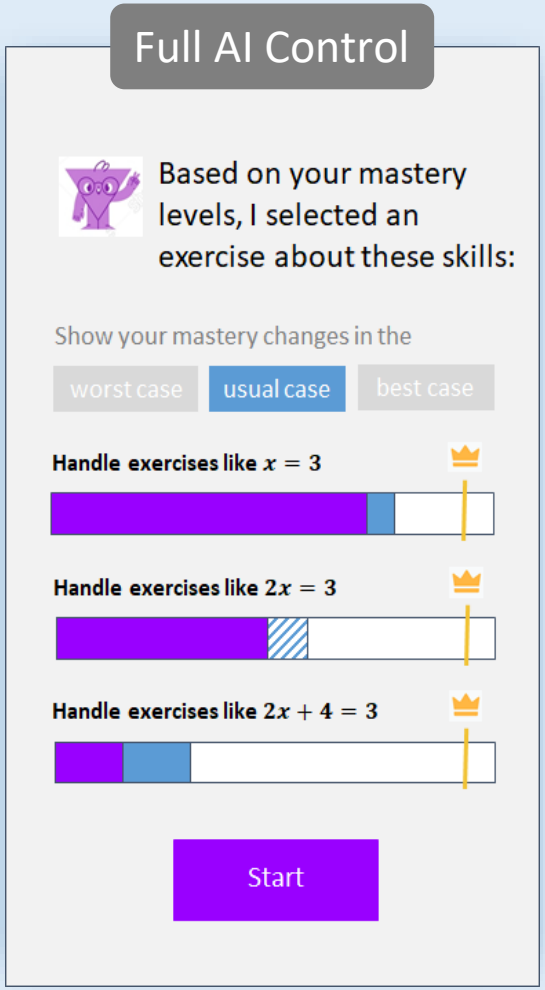


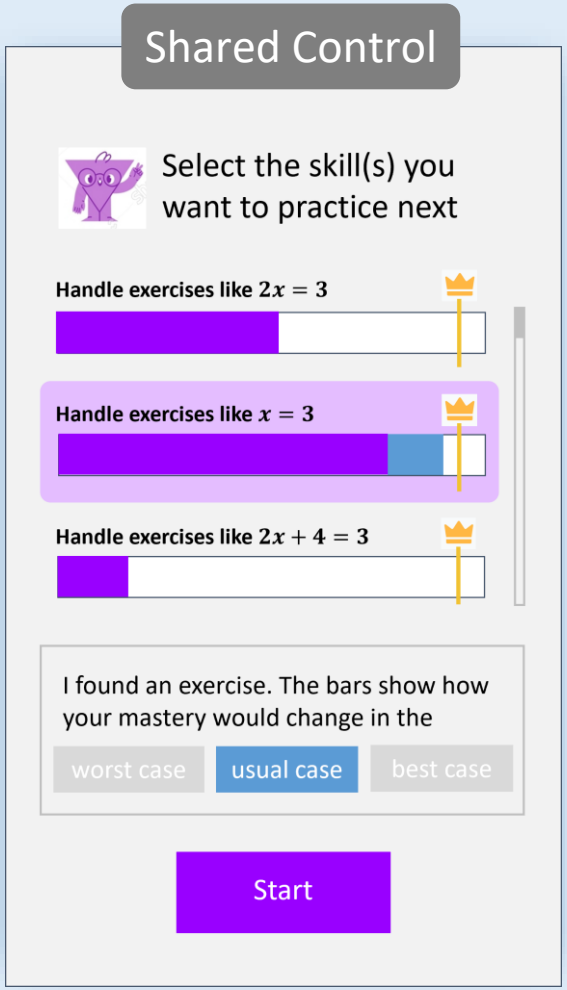


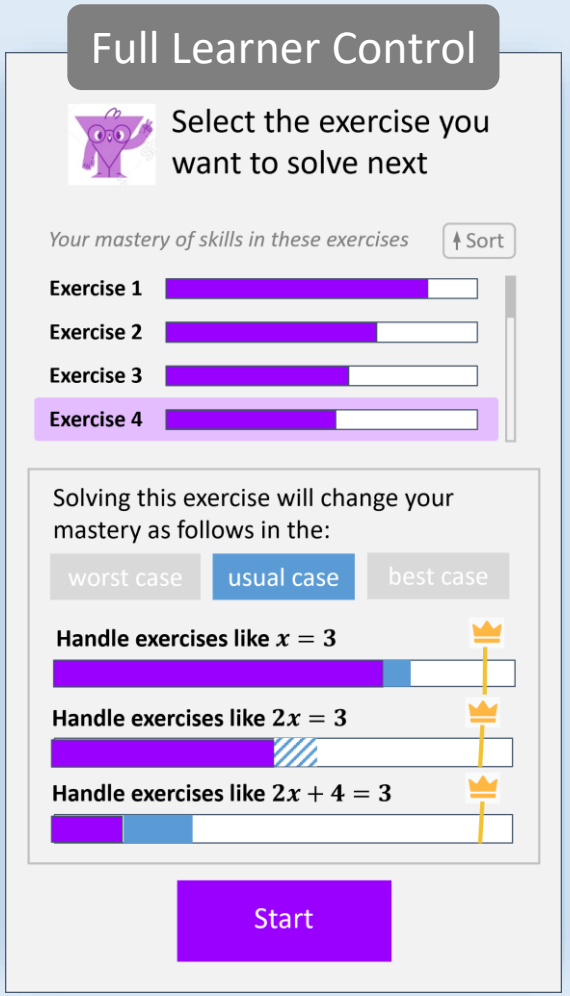


Conrad Borchers*, Jeroen Ooge*, Cindy Peng, and Vincent Aleven. 2025. How Learner Control and Explainable Learning Analytics About Skill Mastery Shape Student Desires to Finish and Avoid Loss in Tutored Practice. In *Proceedings of LAK '25*, 810–816. https://arxiv.org/abs/2412.10568

Sharing control with recommender systems







Conrad Borchers*, Jeroen Ooge*, Cindy Peng, and Vincent Aleven. 2025. How Learner Control and Explainable Learning Analytics About Skill Mastery Shape Student Desires to Finish and Avoid Loss in Tutored Practice. In *Proceedings of LAK '25*, 810–816. https://arxiv.org/abs/2412.10568


TIME FOR
QUESTIONS

How can digital systems differentiate with **transparency** in universities?

How can digital systems help with differentiation?

1 Adaptation

2 Transparency

3 Motivation

About seeing what you master and explaining AI decisions

How can digital systems help with differentiation?

1 Adaptation

2 Transparency

3 Motivation

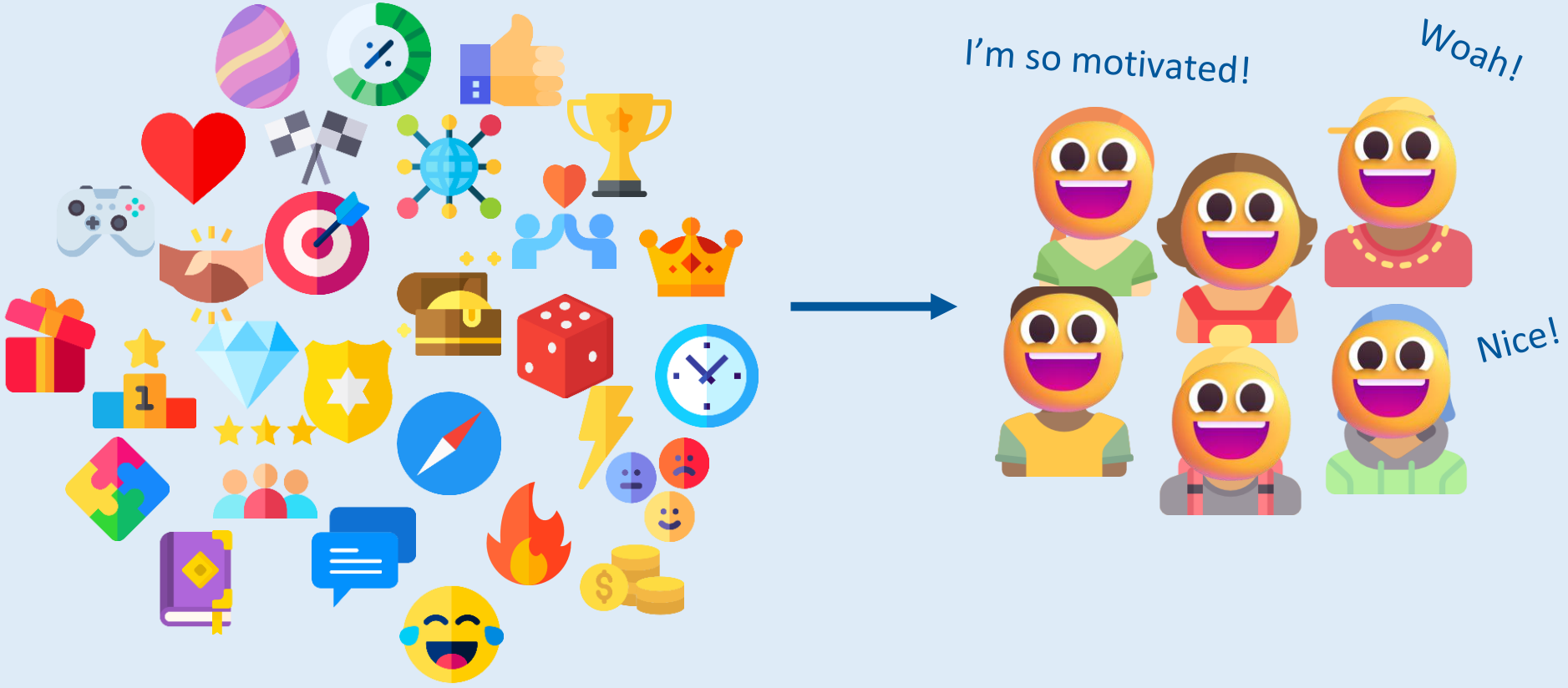
About cool gamification and comparing yourself to others

What is gamification?

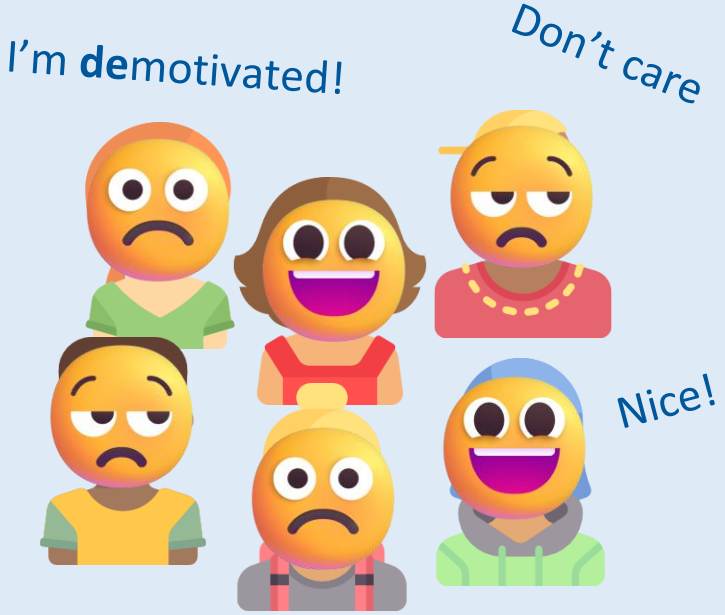
"Using game design elements in non-game contexts" to increase engagement and (extrinsic) motivation

Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke. 2011. From game design elements to gamefulness: defining "gamification." In *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments* (MindTrek '11), 9–15. https://doi.org/10.1145/2181037.2181040

How you might think gamification works

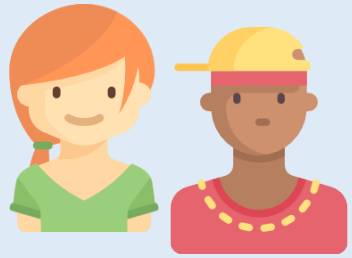


Reality



Not everyone likes
(the same) gamification

Gamification should be personalised

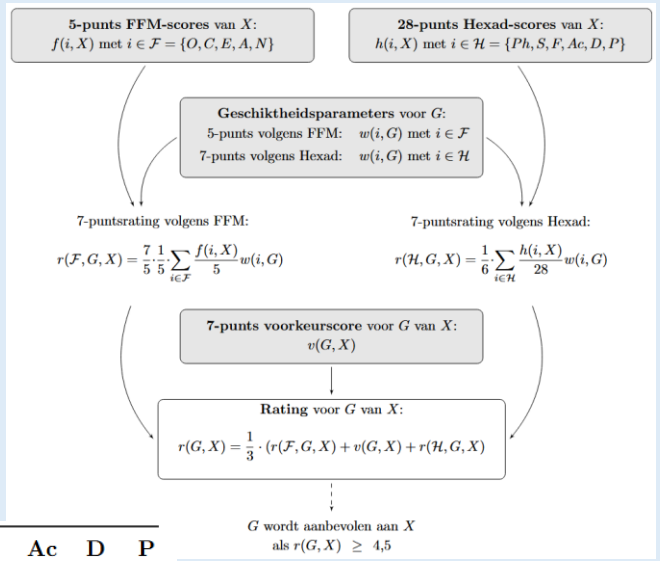


no gamification

Gamification needs to be personalised

Hexad gamification user types

Adapt gamification based on personality, Hexad profile, and preferences

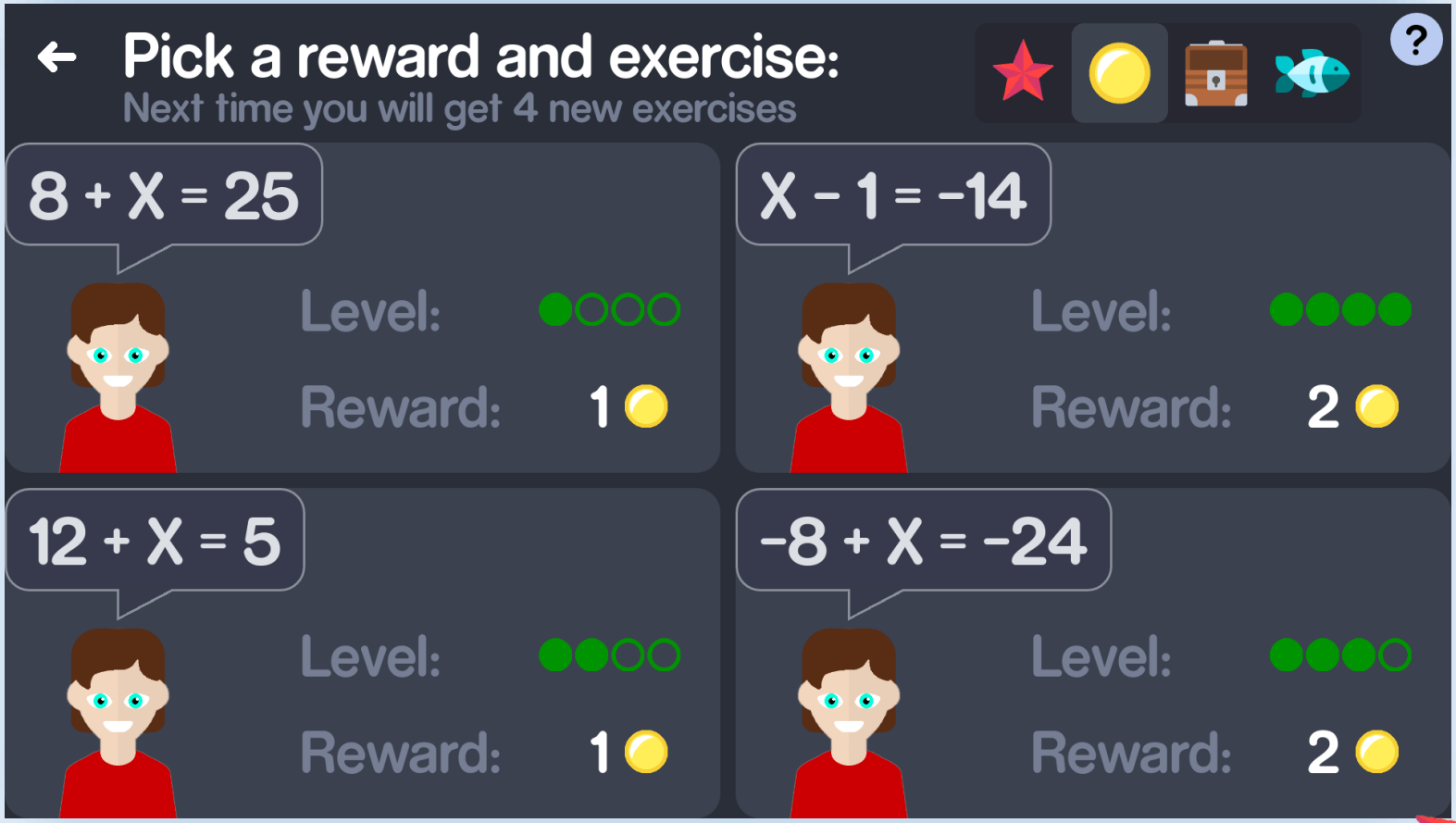


	O	C	E	A	N	Ph	S	F	Ac	D	P
Punten	5a	3	4c	3	4c	4	6c	5b	5b	5c	7a
Puntenklassement	3	4c	5a	4c	3	4	7a	5b	6a	6b	6a
Oefeningenklassement	3	4c	5a	4c	3	4	7a	5b	6a	6b	6a
Day streak	3	4c	3	3	5c	5a	5b	5b	5c	4	6b
Helpen	3	4c	4a	5c	3	7a	6a	5b	6a	5b	6b
Verrassingen	4c	4c	4c	3	5c	5a	5b	7a	7a	5a	7a
Uitdagingen	4c	4c	3	4c	2c	5b	4	7b	7a	5a	6a
Motiverende feedback	5a	3	4d	3	3	4	4	5b	4	5b	5b

Maximilian Altmeyer, Gustavo F. Tondello, Antonio Krüger, and Lennart E. Nacke. 2020. HexArcade: Predicting Hexad User Types By Using Gameful Applications. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play* (CHI PLAY '20), 219–230. https://doi.org/10.1145/3410404.3414232

Jeroen Ooge. 2019. Het personaliseren van motivationele strategieën en gamificationtechnieken m.b.v. recommendersystemen. Master's thesis, KU Leuven. https://jeroenooge.be/research/masters-thesis-personalising-motivational-strategies-and-gamification-techniques

Jeroen Ooge*, Joran De Braekeleer*, and Katrien Verbert. 2024. Nudging Adolescents Towards Recommended Maths Exercises with Gameful Rewards. In: Artificial Intelligence in Education. AIED 2024. Lecture Notes in Computer Science, vol 14830. Springer, Cham. https://jeroenooge.be/alchemath

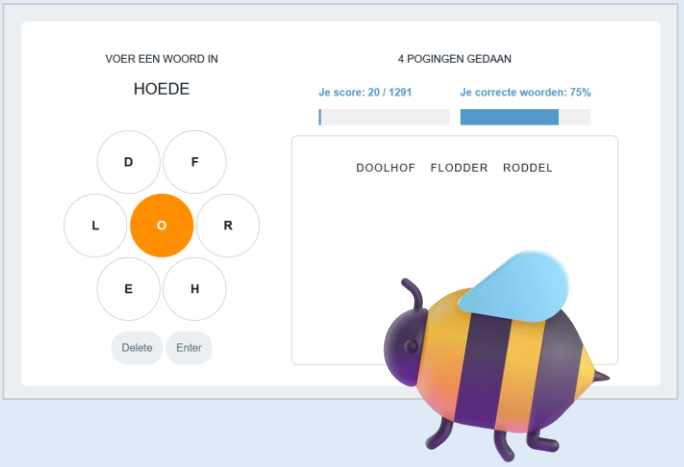


Difficulty for the learner

Reward for a correct answer

Jeroen Ooge*, Joran De Braekeleer*, and Katrien Verbert. 2024. Nudging Adolescents Towards Recommended Maths Exercises with Gameful Rewards. In: Artificial Intelligence in Education. AIED 2024. Lecture Notes in Computer Science, vol 14830. Springer, Cham. https://doi.org/10.1007/978-3-031-64299-9_28

Social comparison impacts emotions/motivation



People have many reasons to compare themselves

seeing yourself below average = 😟

seeing yourself above average = 🙂

Fleur Leenders. To compare or not to compare oneself? Studying the effect of motivation, affect, and comparison direction. Bachelor's thesis, Utrecht University, 2025. Paper under review. ☝️


TIME FOR
QUESTIONS

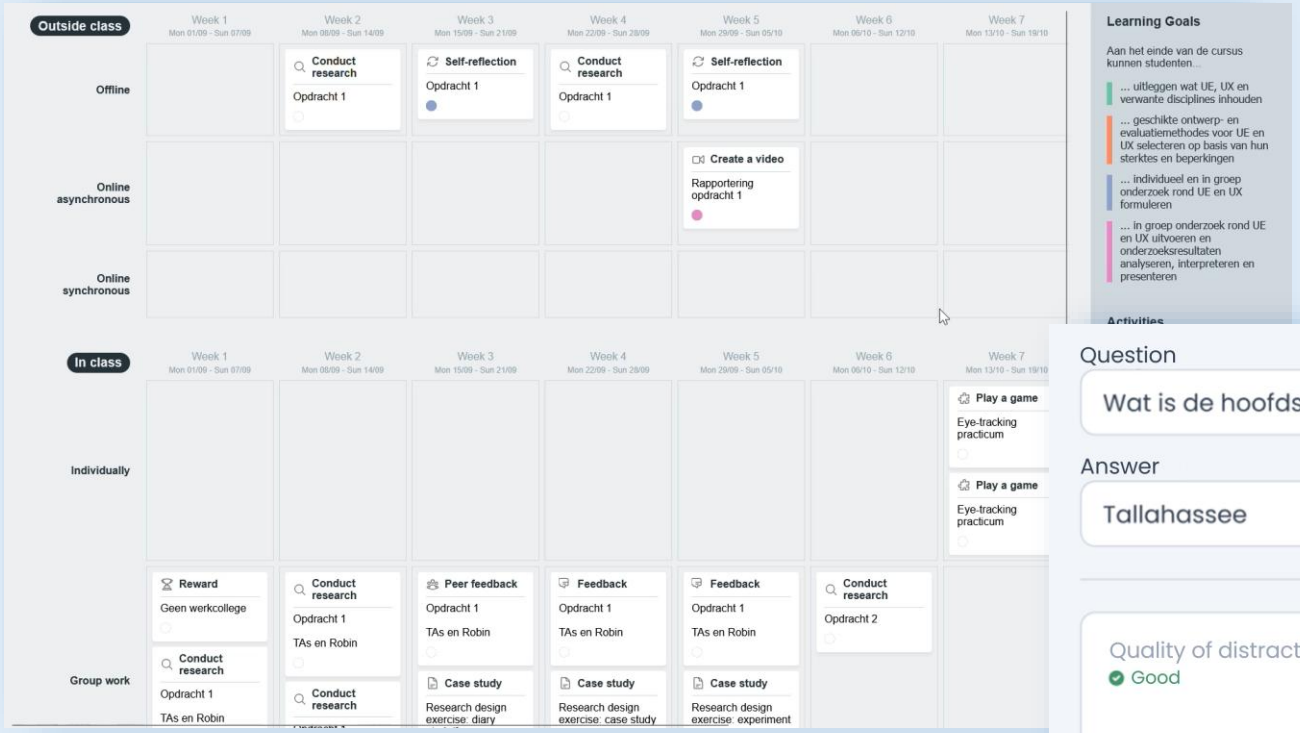
How can digital systems differentiate to **motivate** in universities?

How can digital systems help with differentiation* in education?

*in the sense of individualisation/personalisation

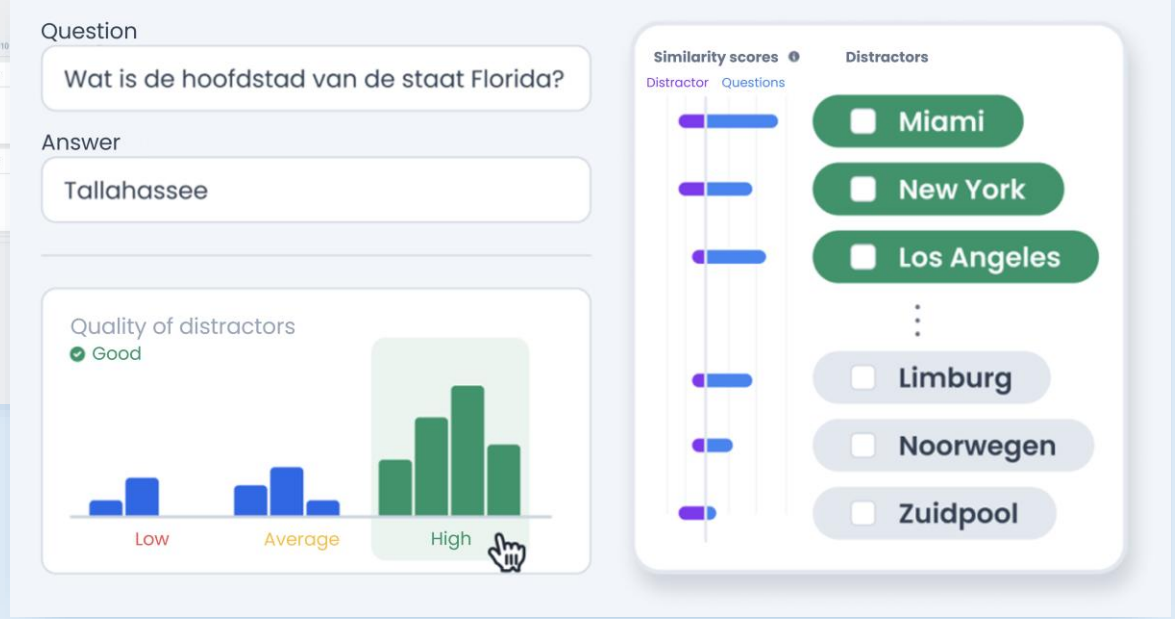
Make learning experiences more
1 adaptive, 2 transparent, and 3 motivating

I did much more research…



Help teachers plan blended learning

Help teachers create new content with AI



Maxwell Szymanski*, Jeroen Ooge*, Robin De Croon, Vero Vanden Abeele & Katrien Verbert. Feedback, Control, or Explanations? Supporting Teachers With Steerable Distractor-Generating AI. In *Proceedings of the 14th Learning Analytics and Knowledge Conference*, March 2024, 690–700, https://doi.org/10.1145/3636555.3636933

Check out **jeroenooge.be** and reach out for projects together!

Poster at BBG 4.21