Leveraging Adaptive Digital Tools to Enhance Early Mathematics Learning:

Insights from Randomized Controlled Trials

M. Röell, C. de Vulpillières, A. Knops & L. Vagharchakian

Digital Game-Base Learning

- Digital game-based learning (DGBL) a potential **tool for enhancing mathematics instruction** (Clements et al., 2024)?

- Despite its promise, the evidence for the efficacy of DGBL remains mixed (Byun & Joung, 2018), and studies with rigorous methodologies and analyses are limited (Bhatia et al., 2022).

- Persistent issues in its implementation:
  - The limited **pedagogical validity** of many educational games (Bhatia et al., 2022).
  - The insufficient consideration of children's **mathematical thinking** and **developmental progressions** (Clements et al., 2024).
  - Limited scaffolding and instructive feedback (Elia et al., 2023)
  - Limited evidence for the **transfer of skills** acquired in games to real-world problems or assessments (Barnett & Ceci, 2002; Rick & Weber, 2010).

Adaptive Learning Module

- To address these limitations:

1. Modules grounded in evidence-based principals
2. Personalised instruction thanks to AI : Zone of Proximal Development and Empirical Success (ZPDES) algorithm (Clément et al., 2013)
3. Tailored scaffolding and feedbacks to correct misconceptions

Modules grounded in Evidence-Based principals

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.

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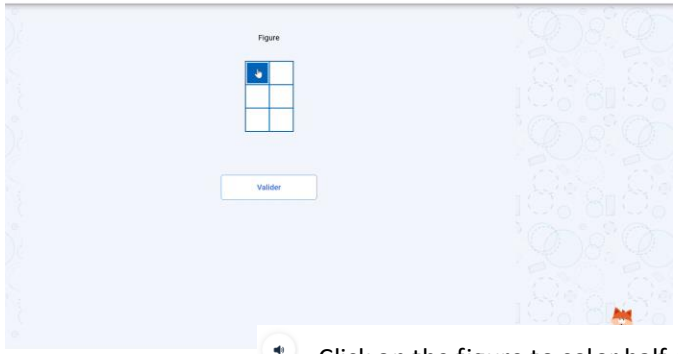

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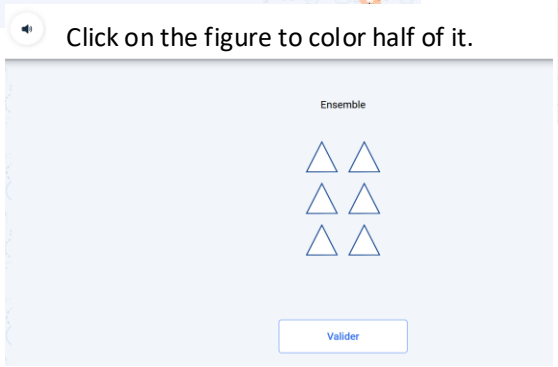
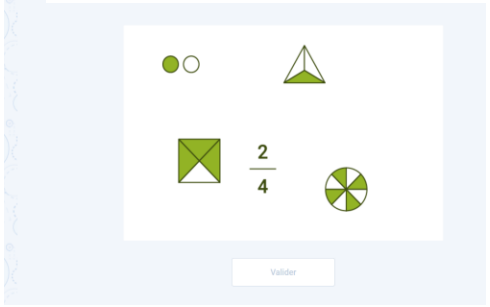
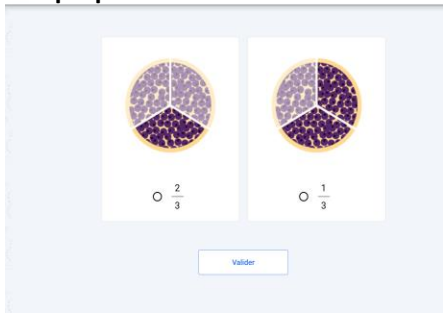


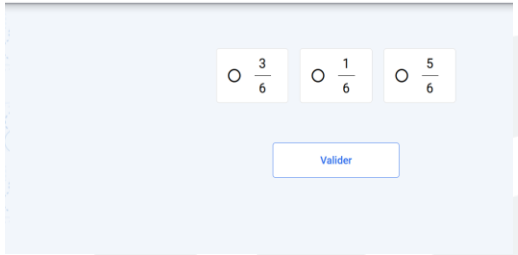
Select all the éléments that represent $\frac{1}{2}$, 1 coloured part out of 2.



Select the cake with the **highest proportion** of slices eaten.



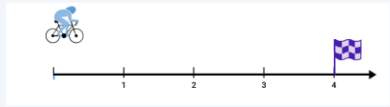
Select the **smallest** fraction.



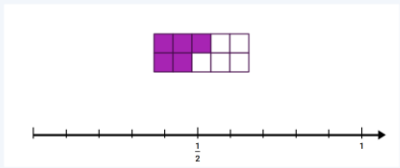
Transition from informal to formal fraction understanding

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.
2. Enriching fraction knowledge using multiple approaches

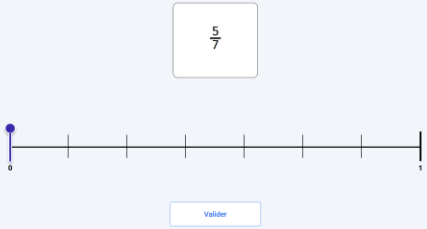
The cyclist is in the middle of his race. Click on the graduation corresponding to his position.



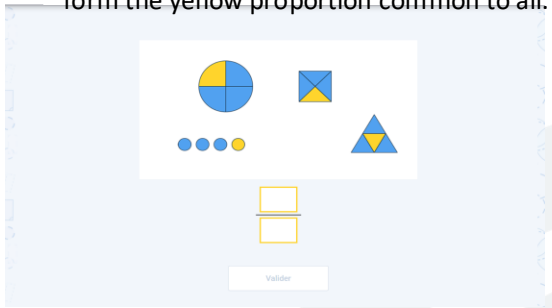
Click on the scale to indicate the proportion of colored elements in this figure.



Click at the right place to position the fraction on the number line.

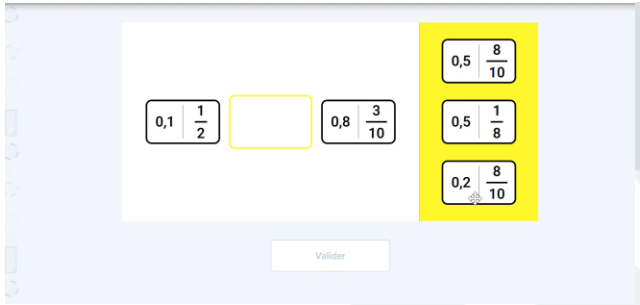


Complete the boxes to indicate in fractional form the yellow proportion common to all.



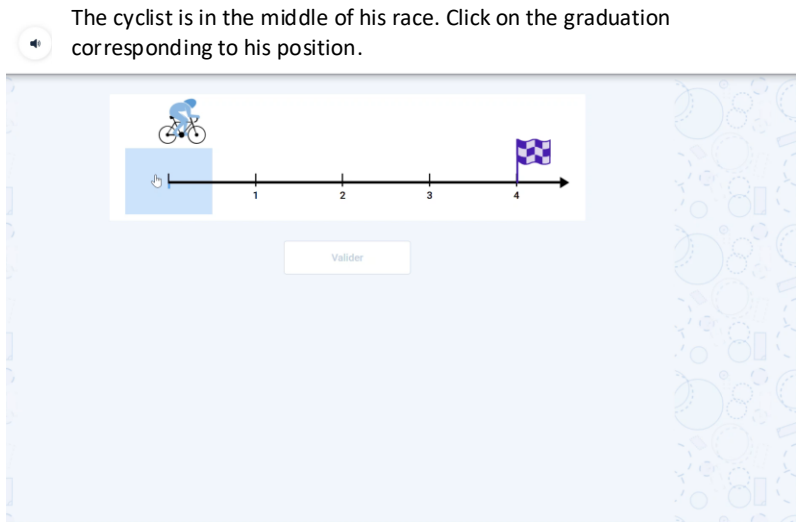
Choose the right dominao to complete the game and place it between the other two.

NB : In this domino game, the numbers written on the side-by-side parts of two different dominoes must be equal.



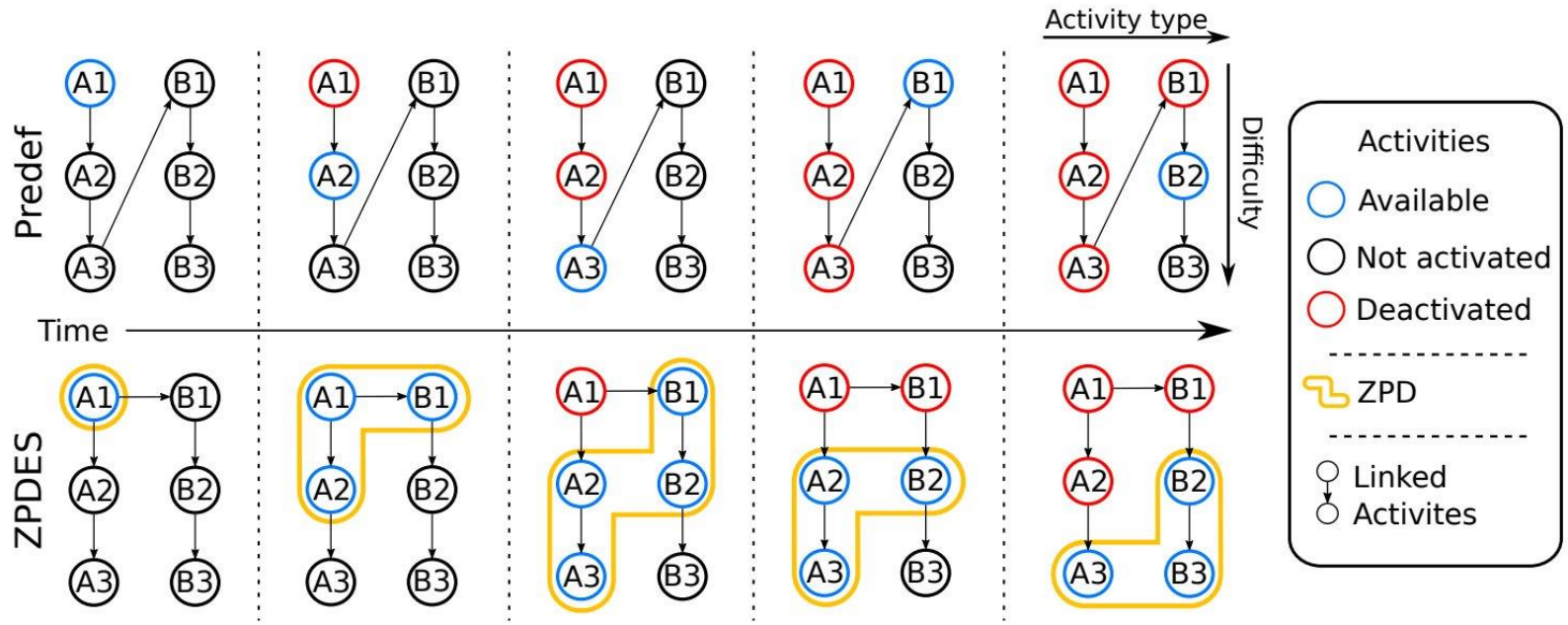
Transition from informal to formal fraction understanding

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.
2. Enriching fraction knowledge using multiple approaches
3. Providing explicit feedback to help students correct errors and refine strategies.



Personalised Instructions

- Personalised learning path thanks to the **ZPDES** (Zone of Proximal Development and Empirical Success) a multi-armed bandit algorithm



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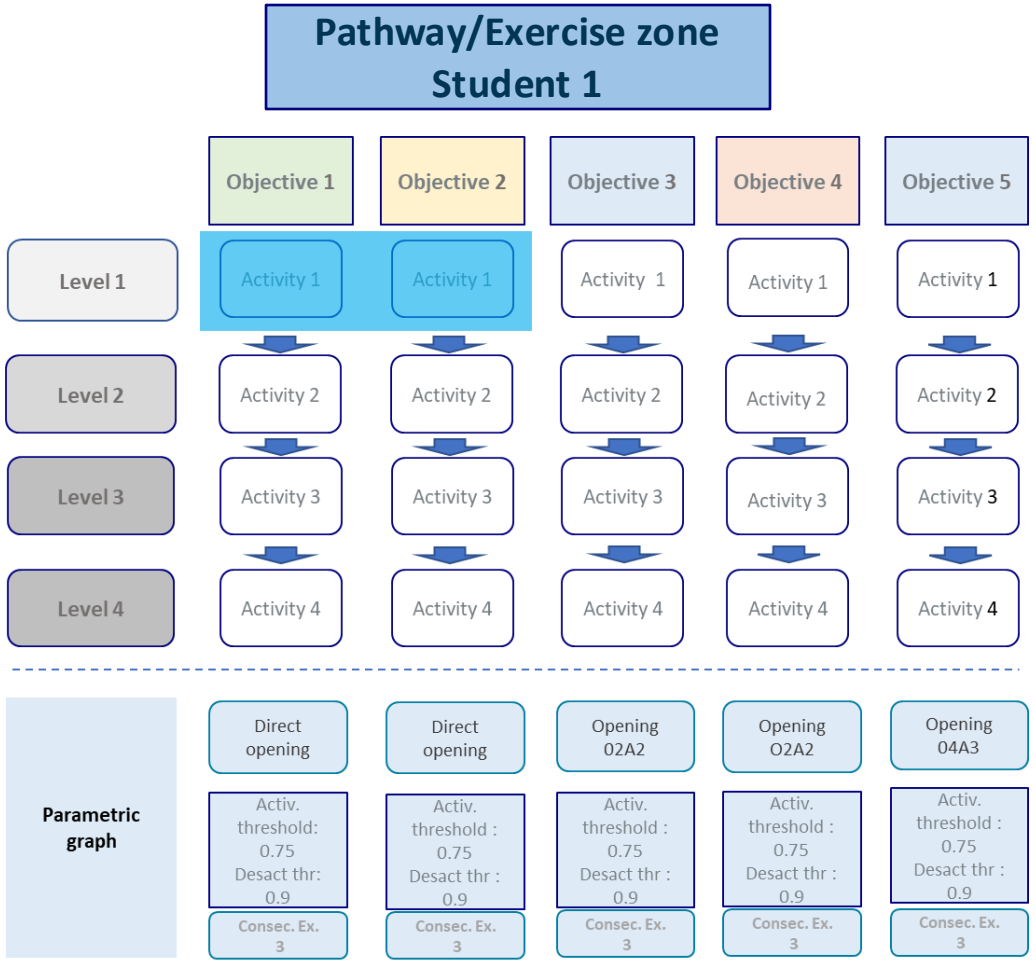

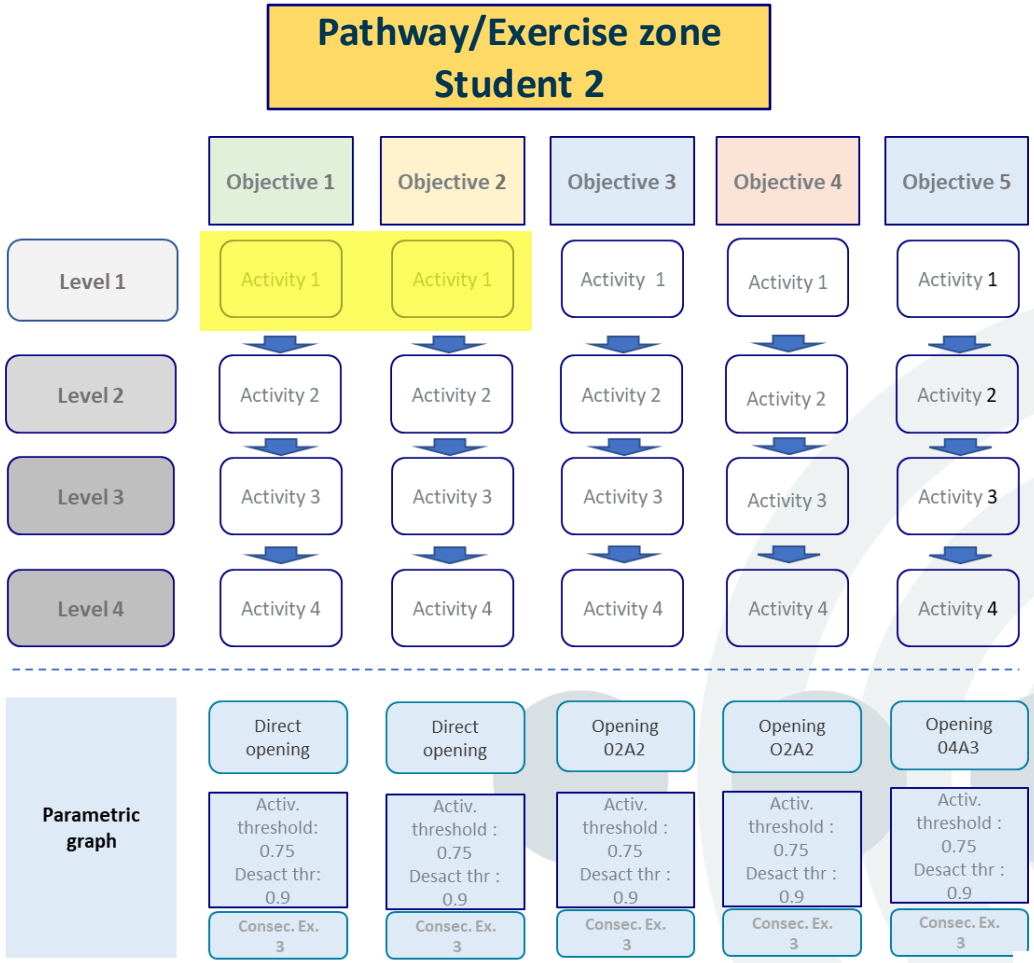

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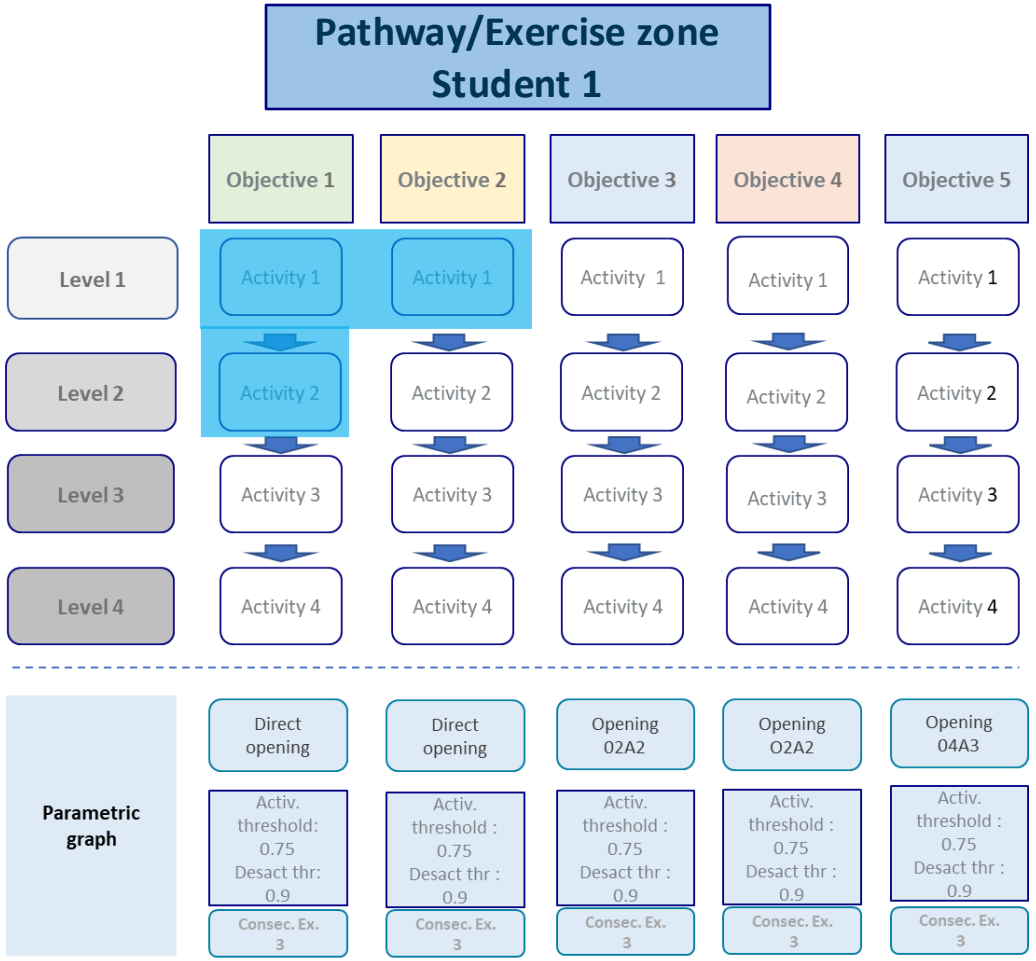

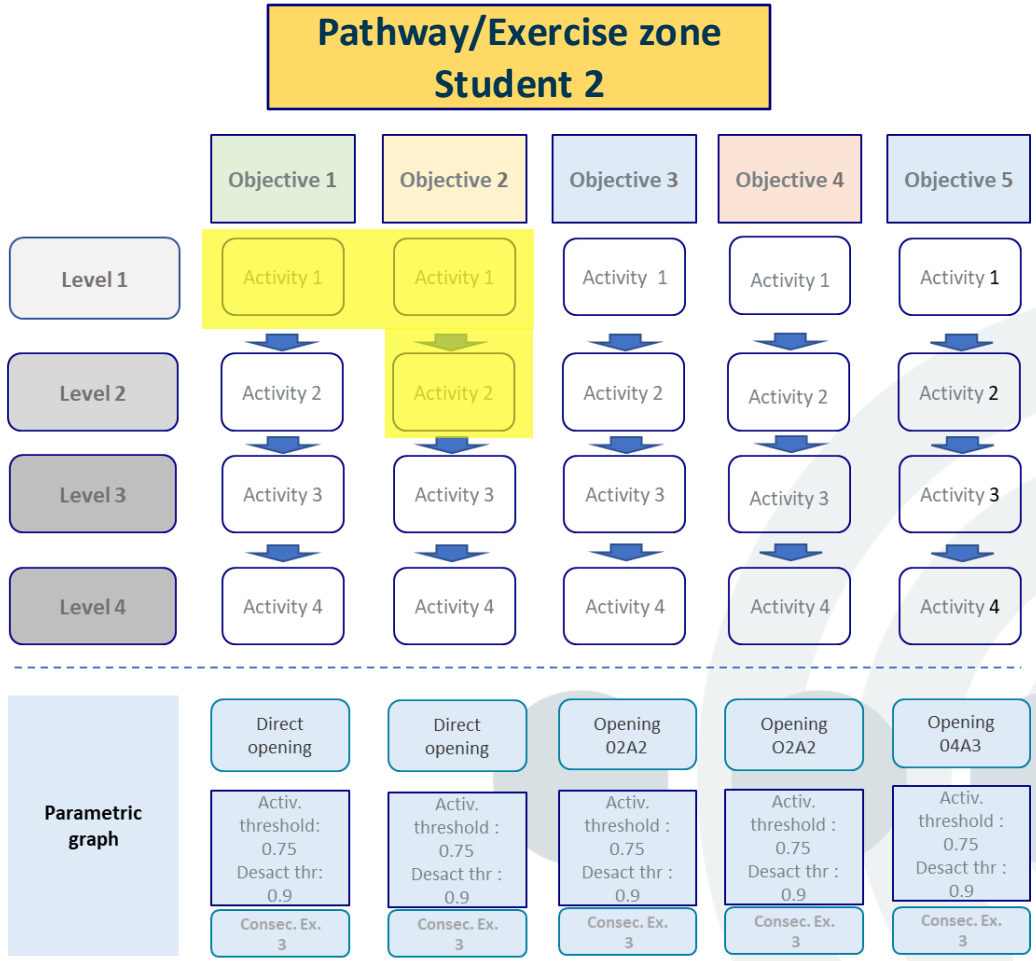

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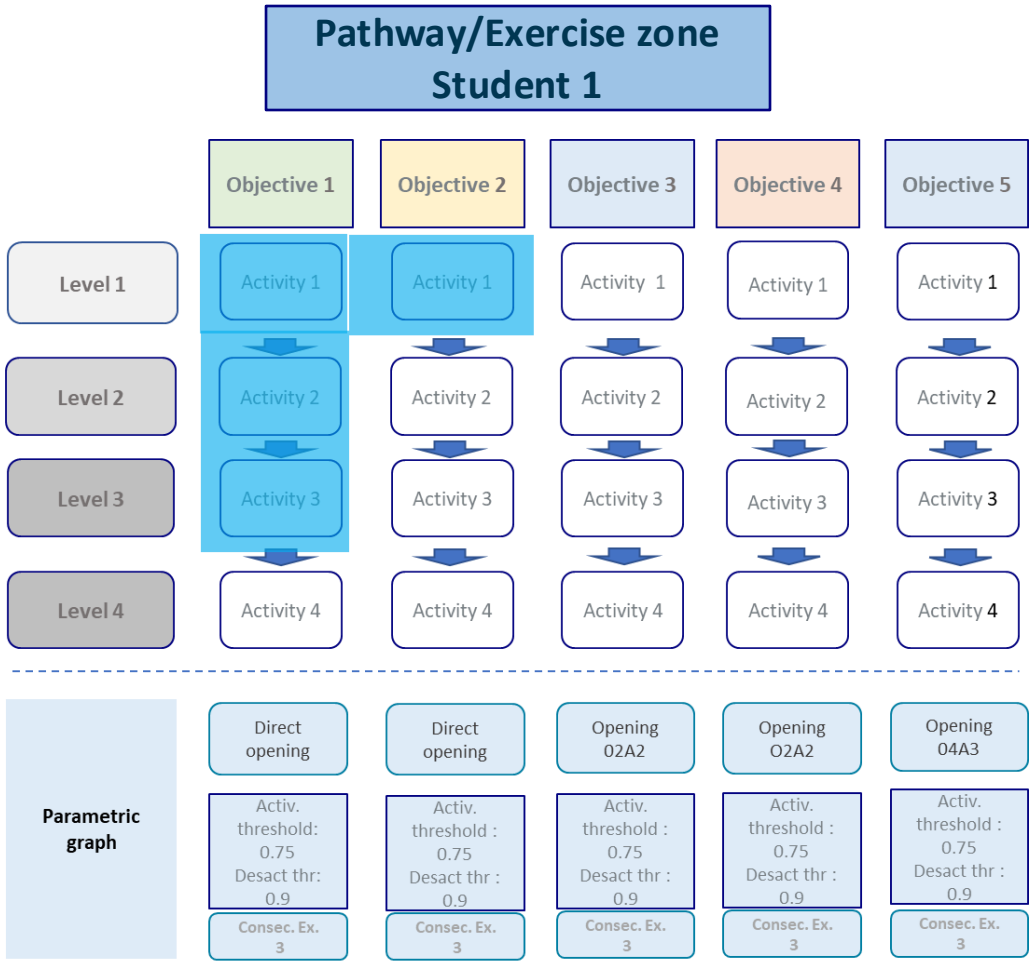
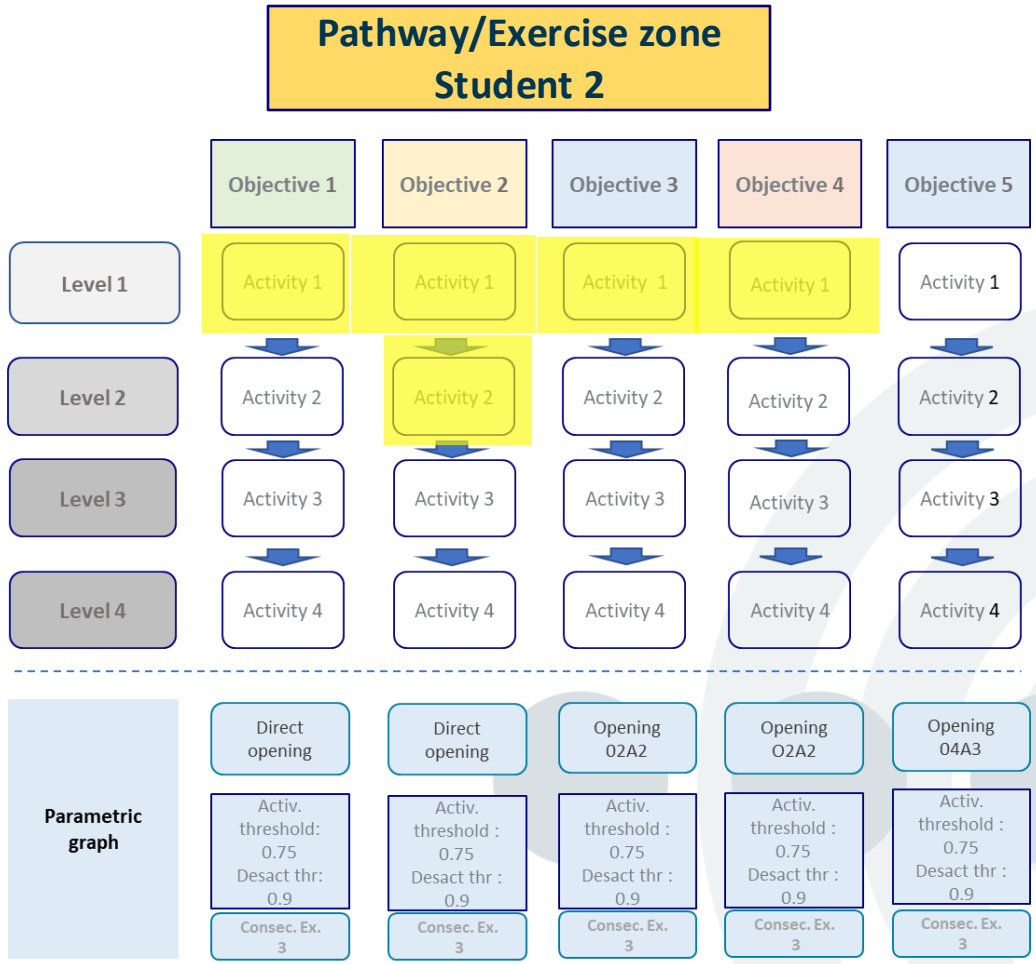


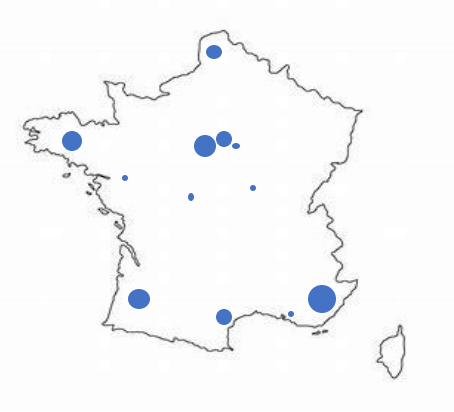


Study Objectives & Protocol

- Does the fraction module improve Grade 4 French students' **understanding of fractions**?
- Do **AI-based features** enhance students' learning outcomes compared to the same module without AI?
- Are there any **gender differences** ?

[OSF Registries | Leveraging Adaptive Digital Tools to Enhance Early Mathematics Learning: Insights from Randomized Controlled Trials]

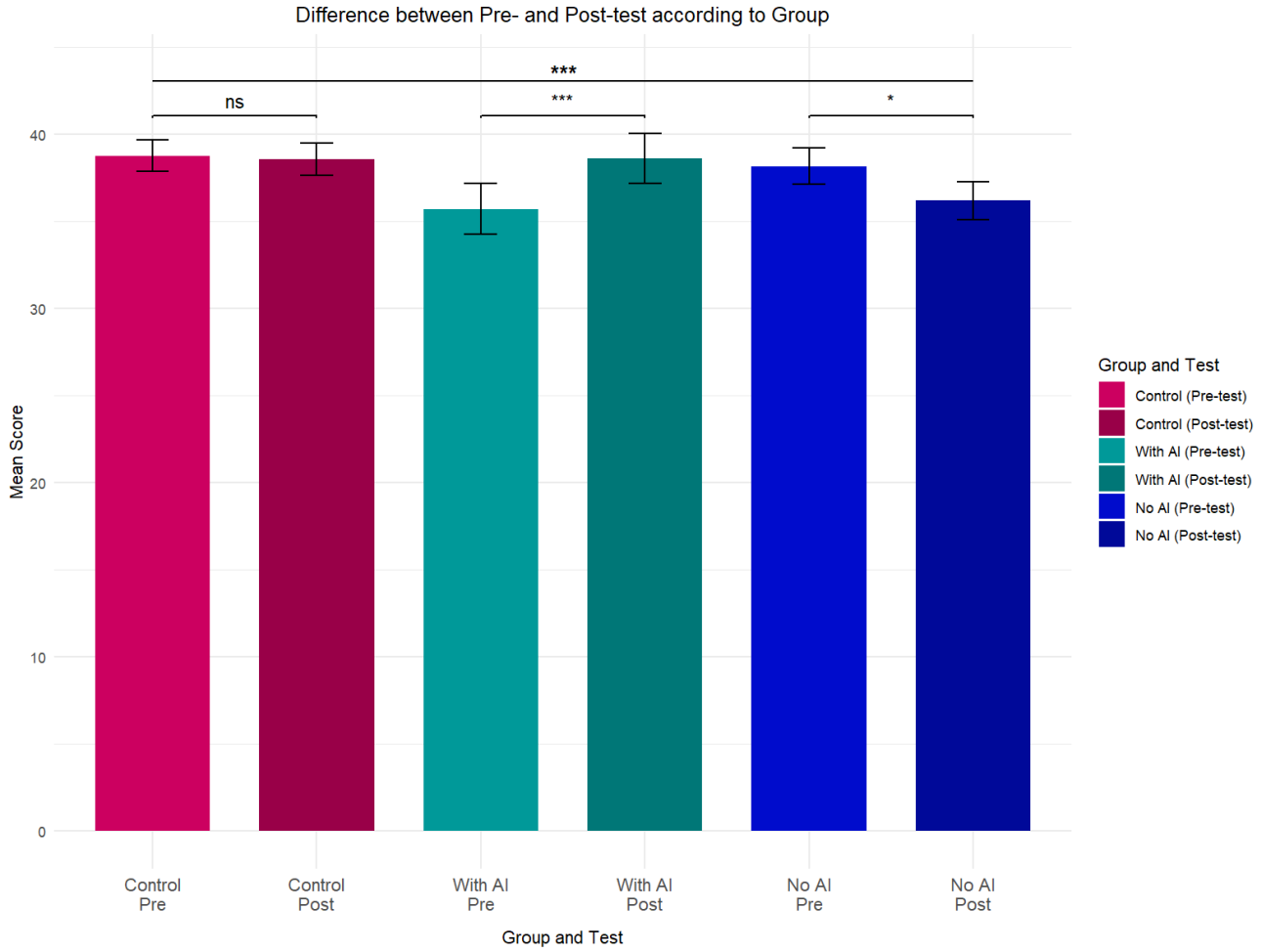
Demographic Information



- **Overall Sample size :**
  - n = 565 (M_{age} = 9.78 ± 0.64)
  - Grade 4
  - 33 Classrooms distributed in 12 academies
- Randomised at the classroom level according to Academies, gender distribution, SES indicators

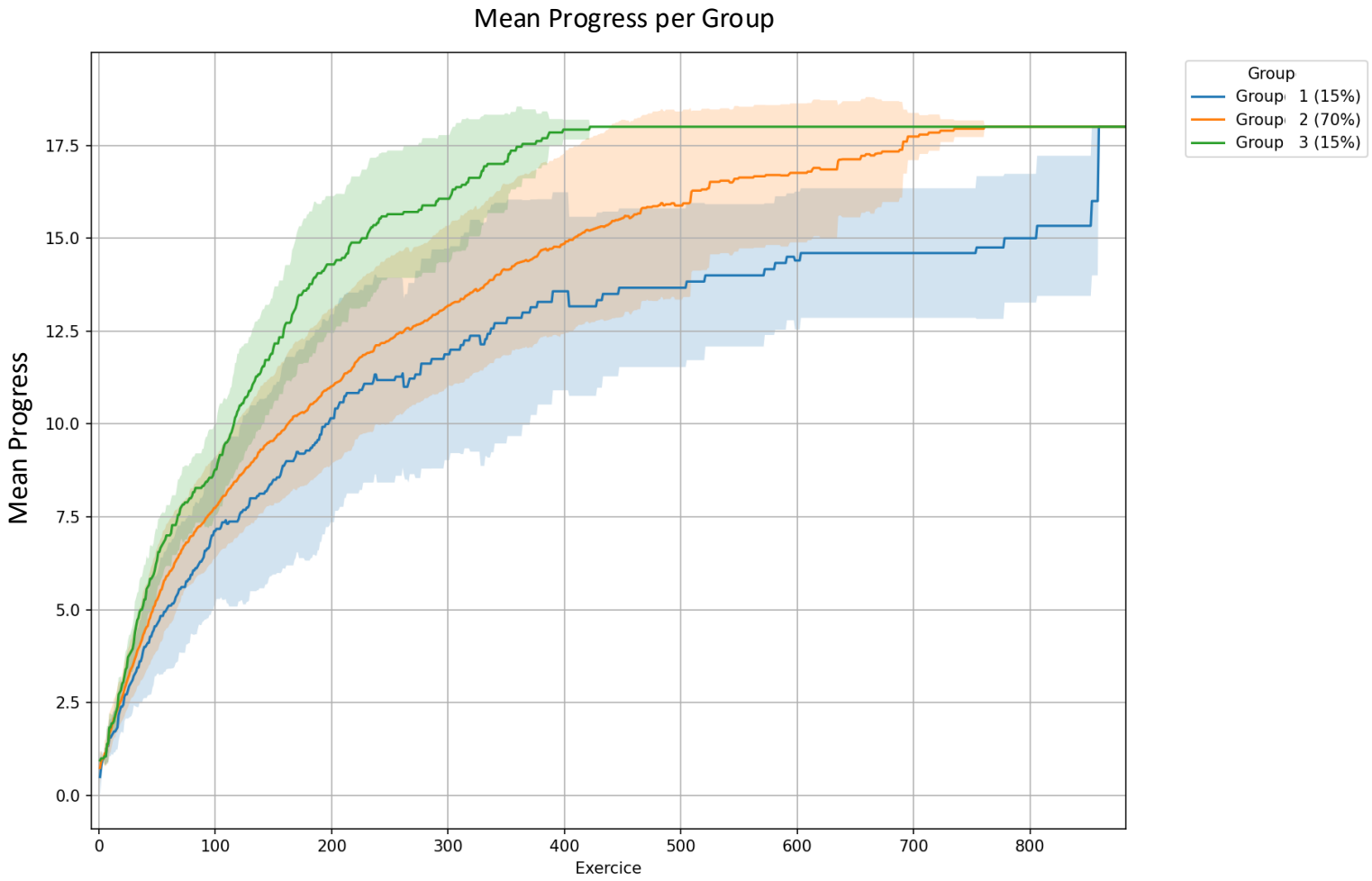
Group	Age	Gender (Female/ Male)	Number of participants	Total Nb Exercises	Exercices Module	Exercices Playlist	Exercices Pré-test	Exercices Post-test
Control	9.81 ± 0.61	194/191	237	43 665	0	0	19 348	24 317
AI	9.80 ± 0.69	102/119	167	124 018	92 570	0	13 514	17 934
No AI	9.71 ± 0.65	120/127	206	140 667	0	101 232	16 991	22 444

Results : Impact of the Fraction Module on Fraction Understanding

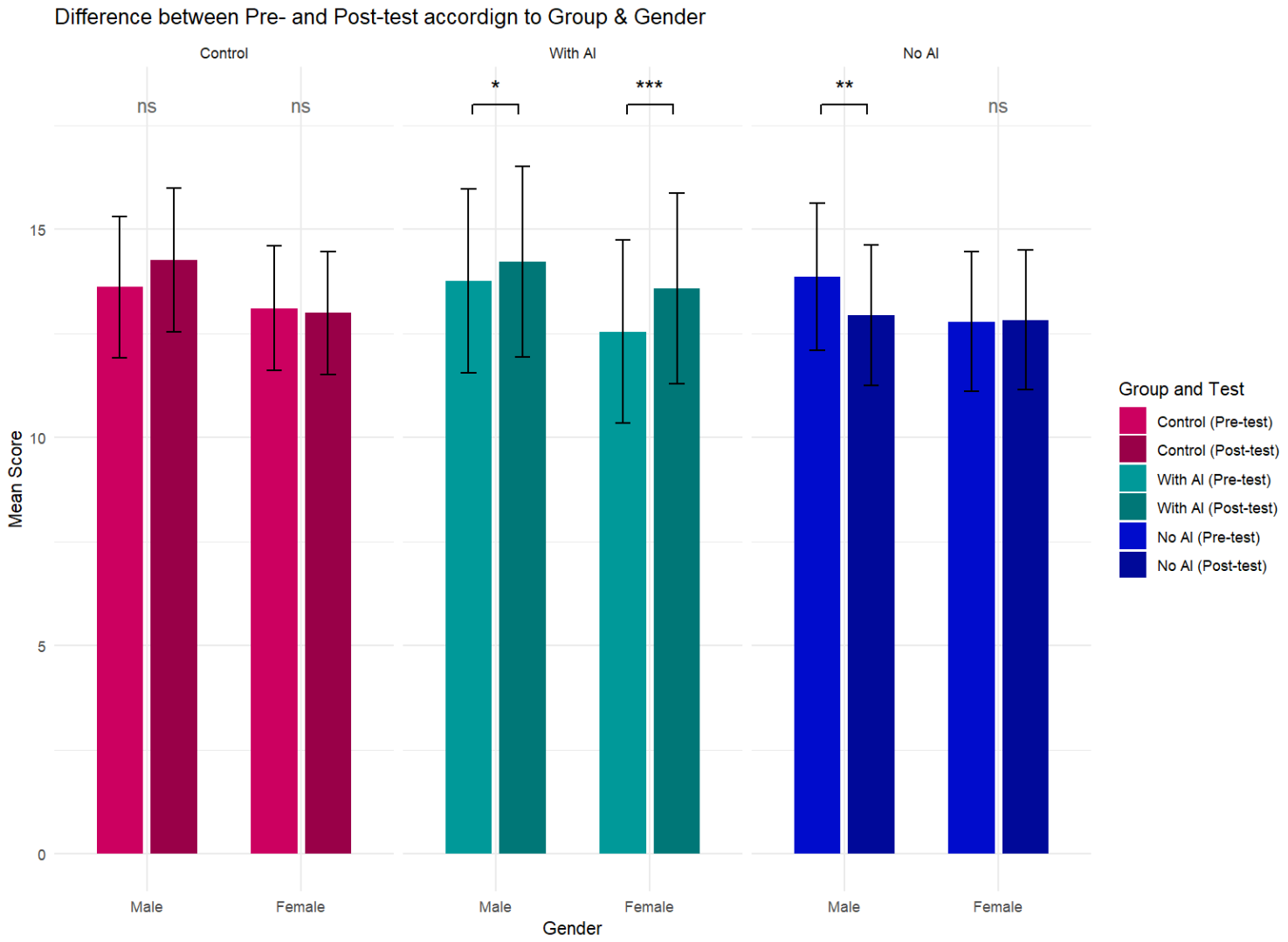


- No Significant Main effect of Group or Time
- Significant interaction of Group x Time:
  $F(2, 562) = 11.01, p < .001$

Results: Examining the learning trajectories



Results : Gender differences



- No Significant Main effect of Group or Time
- Slight Main effect of Gender :
  $F(1, 549) = 3.56$, $p = .05$
- Significant interaction of Group x Time:
  $F(2, 549) = 10.27$, $p < .001$

Conclusion

Impact of the module & AI features on fraction learning

- The module combined with AI seems to have a positive impact on fraction learning.
- However the module without AI seems to have a negative impact on fraction learning.

Time consuming nature of the playlists, lack of understanding of cognitive activities?
A secondary study, with a group without AI and a predifined playlist would allow us to test the added value of the AI.

Gender-based differences

- The module combined with AI had a positive impact on both Male and Female participants.

Examine the impact on math anxiety.

Thank you

Questions? Want to connect?

Email : margot-r@evidence-b.com