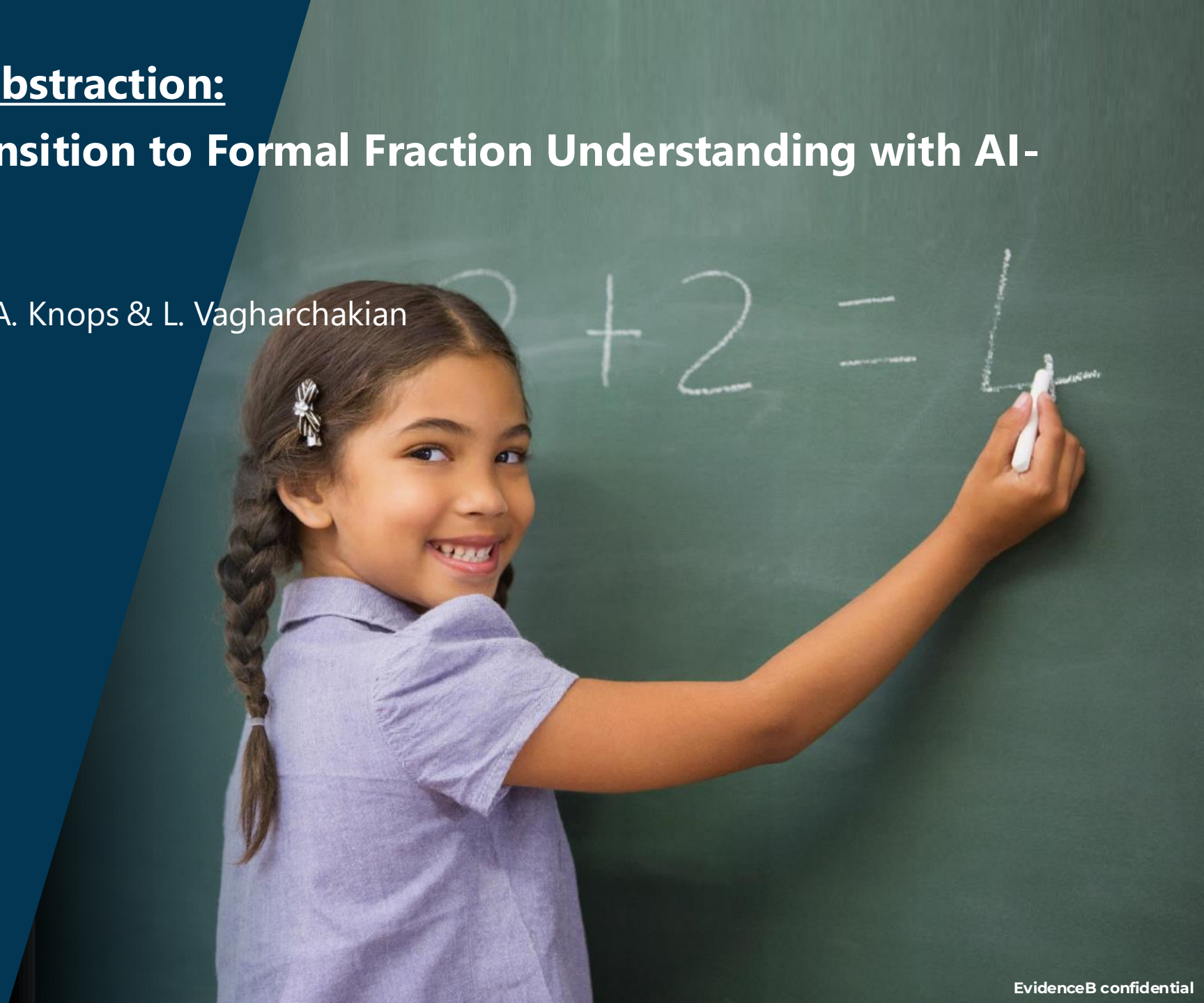
From Intuition to Abstraction:

Supporting the Transition to Formal Fraction Understanding with AI-Powered Tools

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



EvidenceB confidential

Transition from informal to formal fraction understanding

- Human possess an innate ability to understand basic principles of ratio (Jacob, Vallentin, & Nieder, 2012).

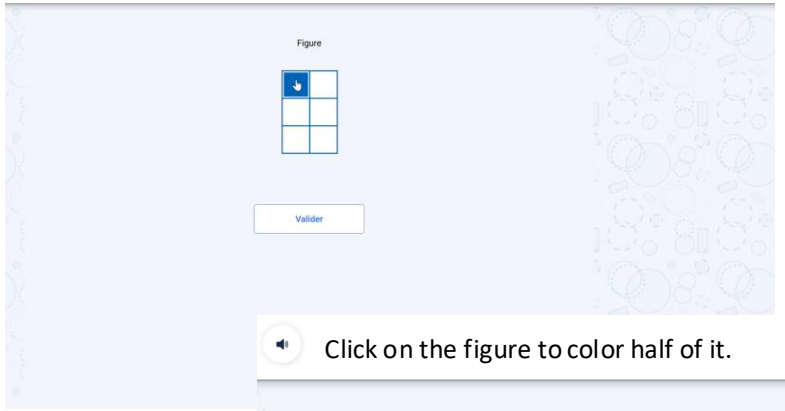
- Even young children demonstrate sensitivity to proportions through visual representations (Mix, Levine, & Huttenlocher, 1999). For instance, McCrink and Wynn (2007) found that infants as young as six months can perceive non symbolic ratios.

- However**, the transition to symbolic fractions** poses **significant challenges** for students, as the link between intuitive understanding and abstract manipulation is often not effectively made.

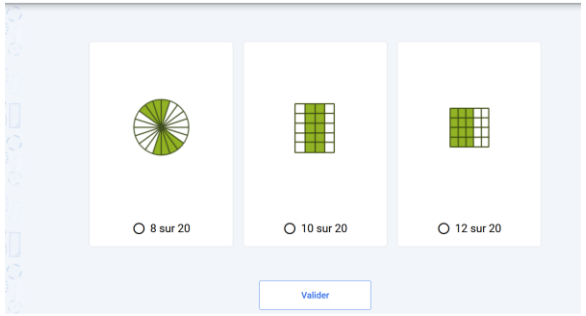
Transition from informal to formal fraction understanding

To address these challenges, we developed a fraction module, Adaptiv'Fraction, based on three principles:

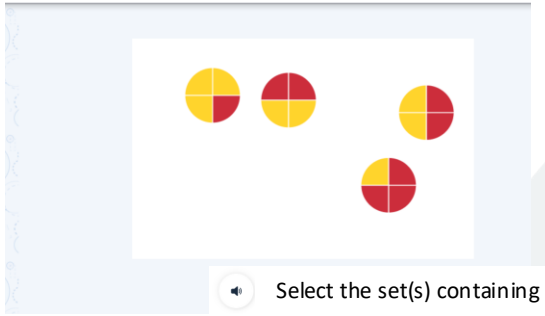
Click on the figure to color half of it.



Select the figure that has **exactly half** of its parts colored.



Select the circle(s) containing 1 red part out of 4.



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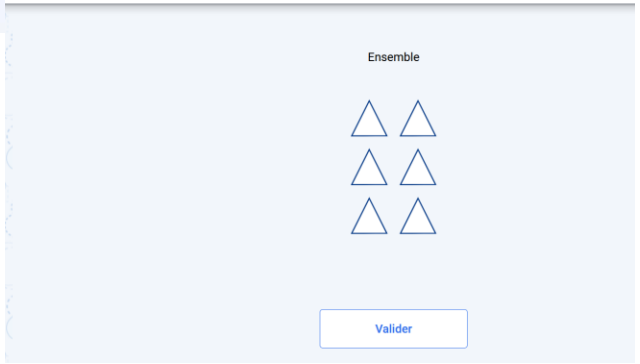

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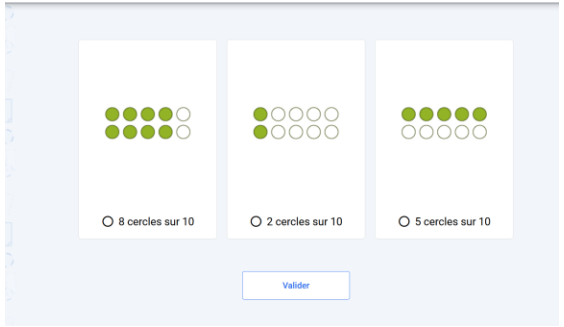
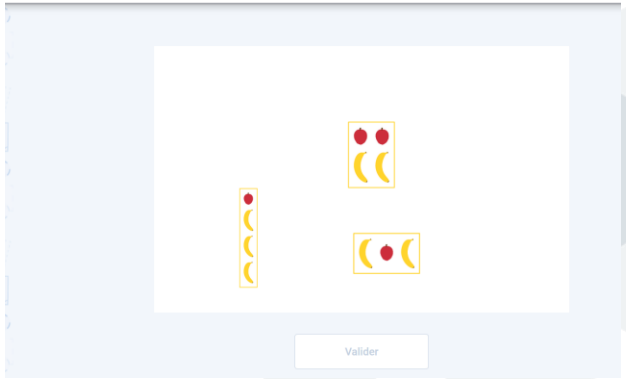


Select the set(s) containing 1 strawberry out of 4 fruits.

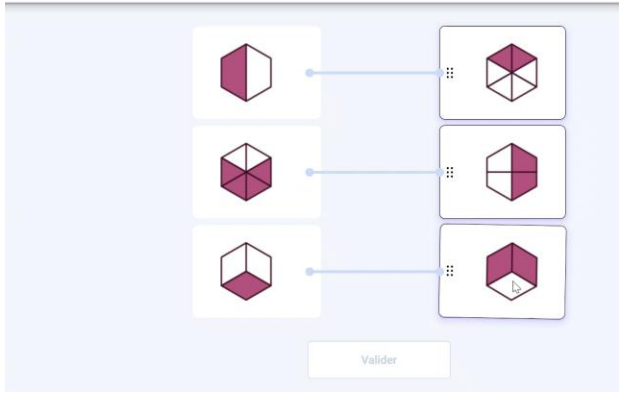


Transition from informal to formal fraction understanding

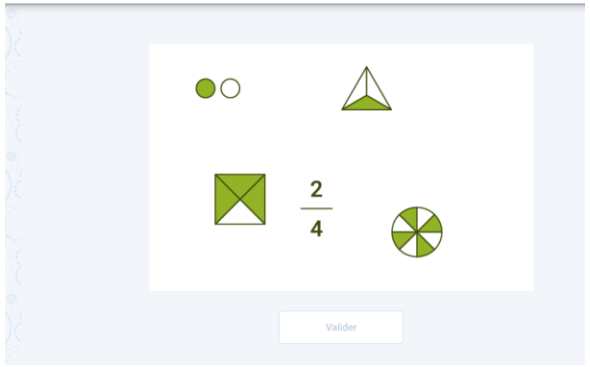
To address these challenges, we developed a fraction module, Adaptiv'Fraction, based on three principles:

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.
    - From continuous to discrete quantities
    - From non symbolic to symbolic representations

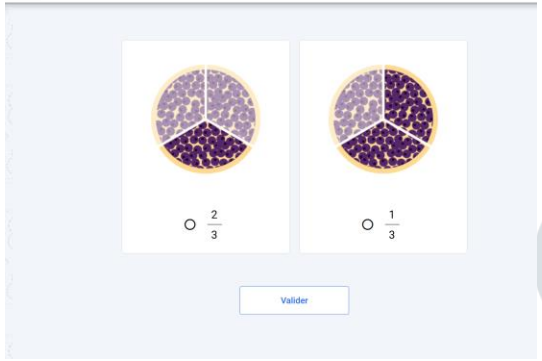
Match figures with the same proportion of coloured parts.



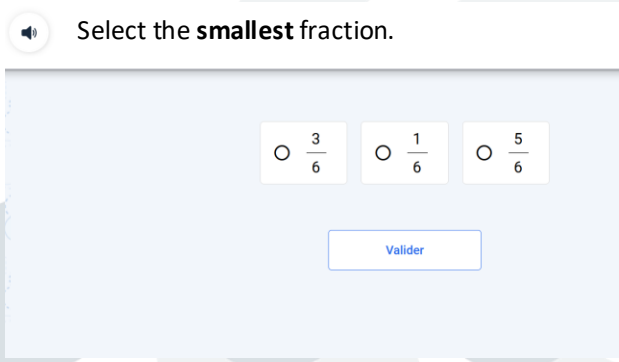
Select all the éléments that represent $\frac{1}{2}$, 1 coloured part out of 2.



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



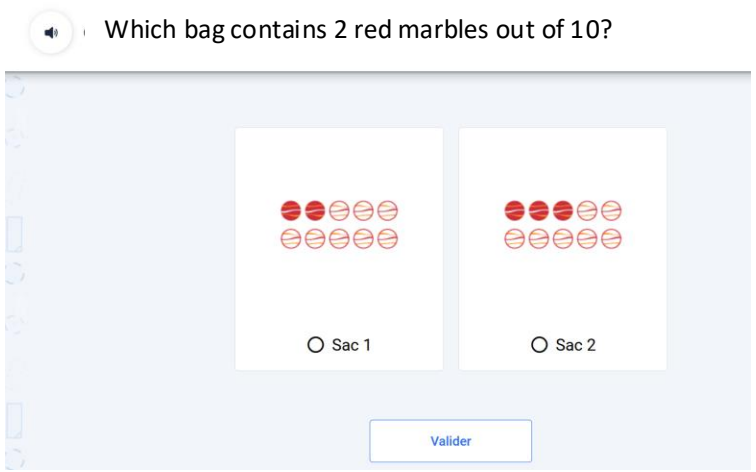
Select the **smallest** fraction.

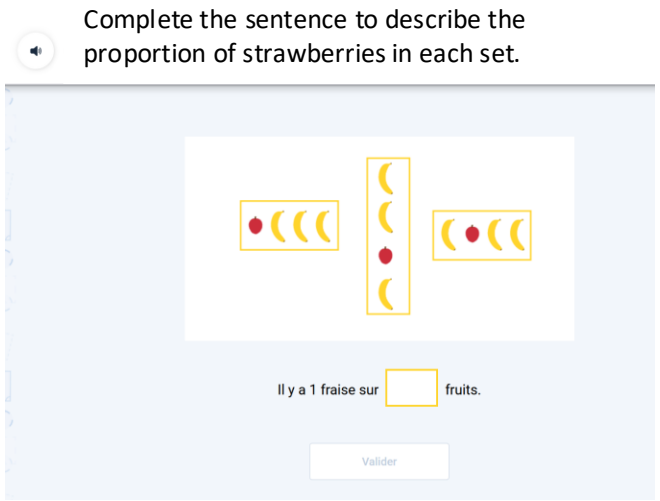


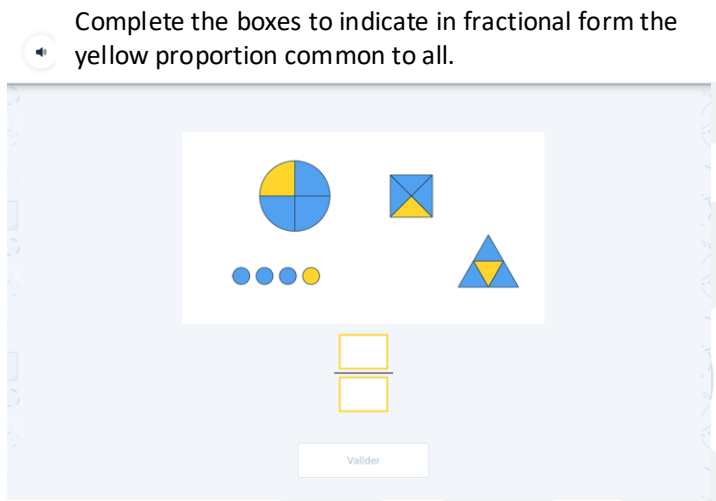
Transition from informal to formal fraction understanding

To address these challenges, we developed a fraction module, Adaptiv'Fraction, based on three principles:

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.
2. Enriching fraction knowledge using multiple approaches
   - From identification to the production of proportions and fractions





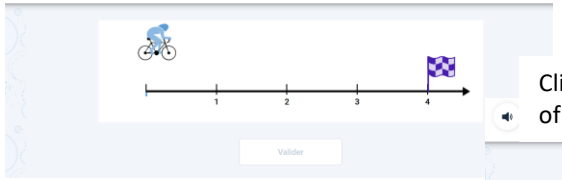


Transition from informal to formal fraction understanding

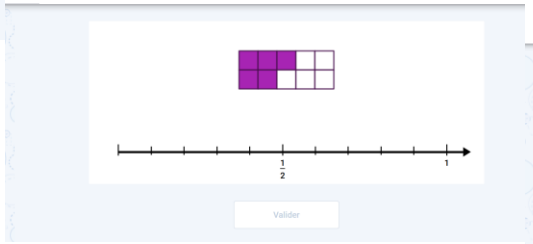
To address these challenges, we developed a fraction module, based on three principles:

1. Leveraging intuitive abilities through highly visual representations, with gradual transitions to abstract notation.
2. Enriching fraction knowledge using multiple approaches
   - From identification to the production of proportions and fractions
   - Multiple approaches using Mental Number line, different symbolic representations, Fraction comparison…

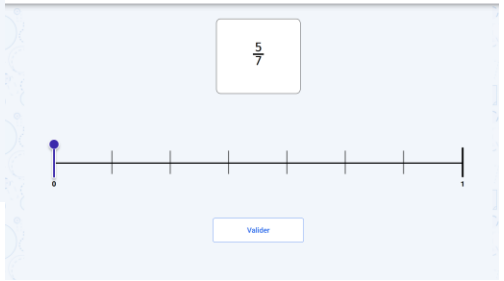
The cyclist is in the middle of his race. Click on the graduation corresponding to his position.



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

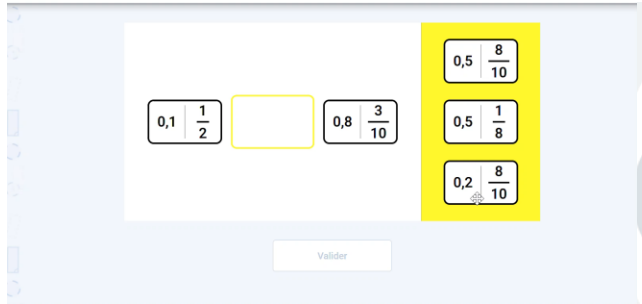


Click at the right place to position the fraction on the number line.



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

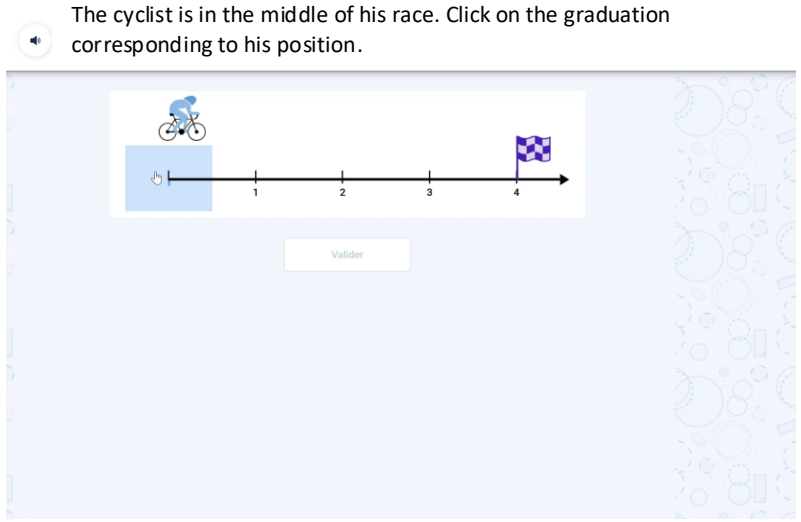
NB : In this domino game, the numbers written on the side-by-side parts of two different dominoes must be equal.



Transition from informal to formal fraction understanding

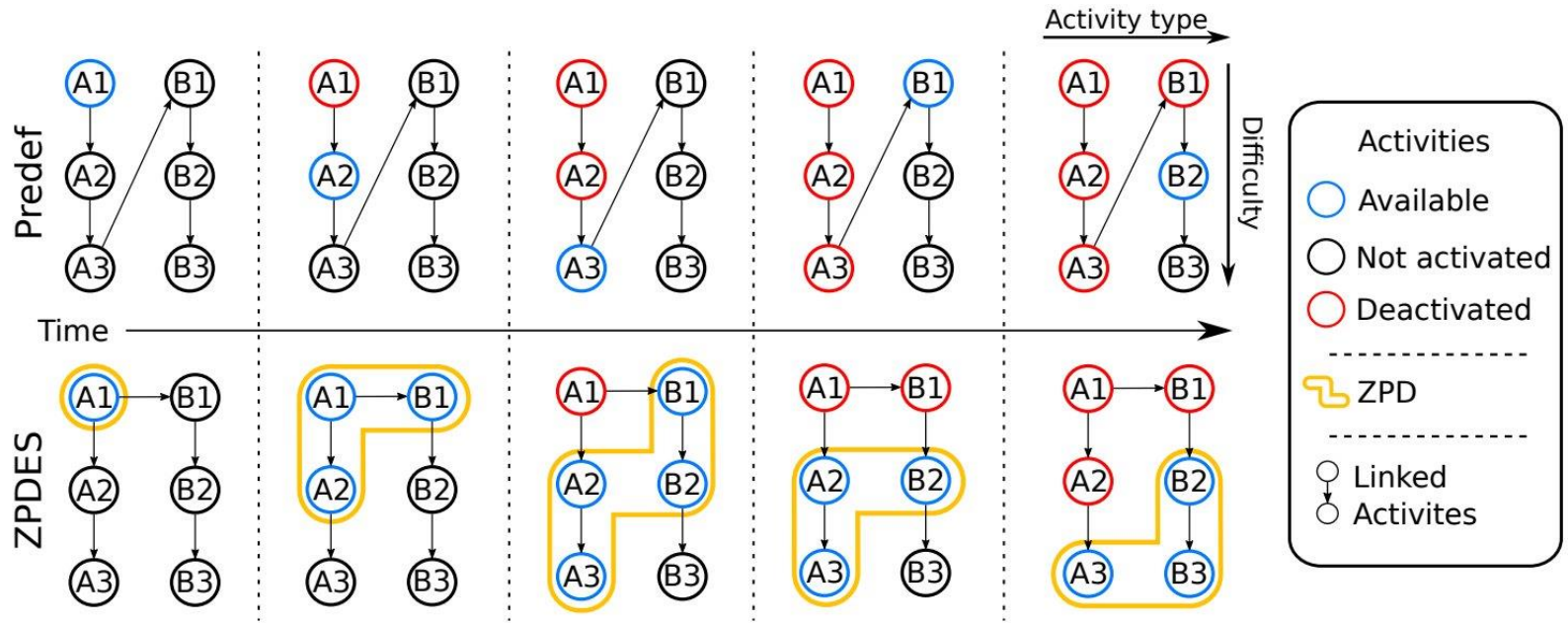
To address these challenges, we developed a fraction module, Adaptiv'Fraction, based on three principles:

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.



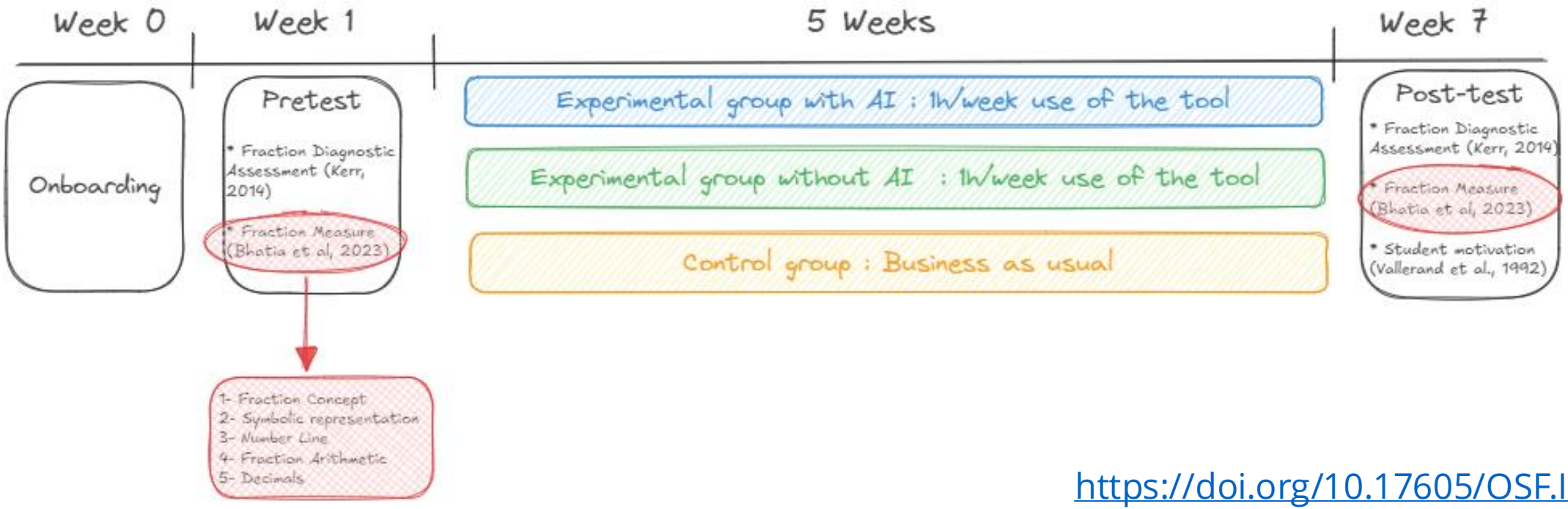
Incorporating Artificial Intelligence

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



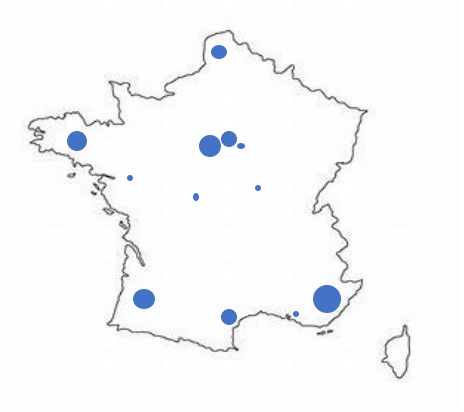
Study Objectives & Protocol

- Does the fraction module improve Grade 4 French students' **understanding of fractions**?
- Does the module impact **different components** of fraction understanding differently?
- Do **AI-based features** enhance students' learning outcomes compared to the same module without AI?



https://doi.org/10.17605/OSF.IO/V2GYA

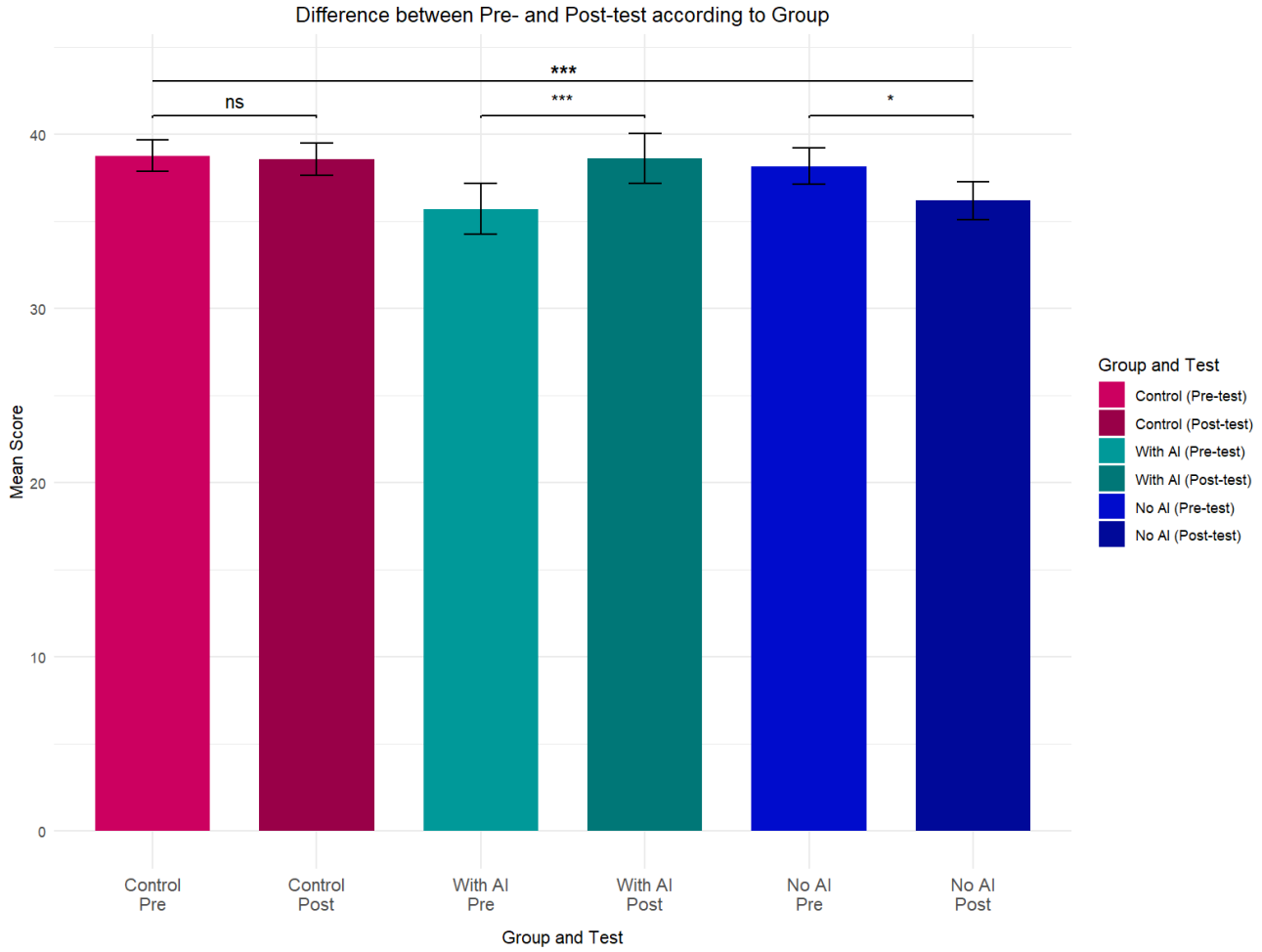
Demographic Information



- **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 (IPS)

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	142	105 176	79 328	0	11 364	14 484
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

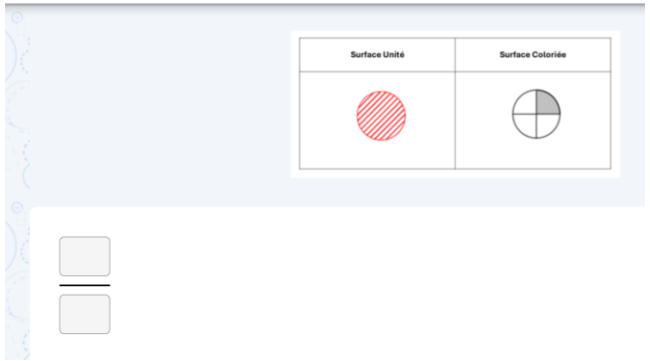


- No Significant Main effect of Group or Time
- Significant interaction of Group x Time:
  $F(2, 562) = 11.01, p < .001$

Results : Competencies

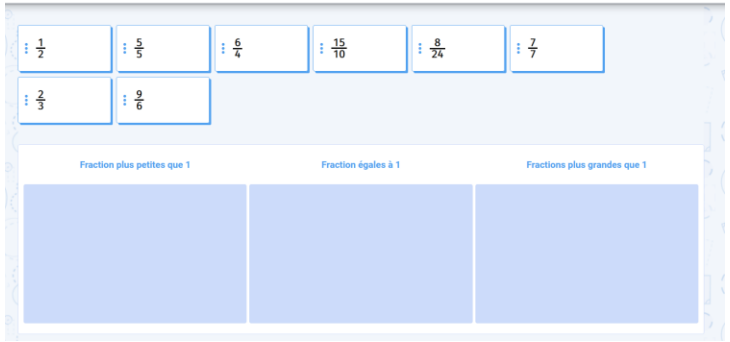
Fraction Concept

Indicates the area that has been colored gray.

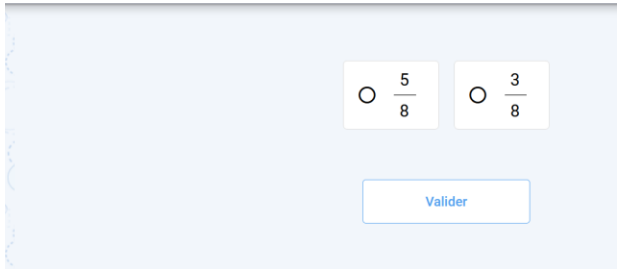


Select 2/5 of the collection

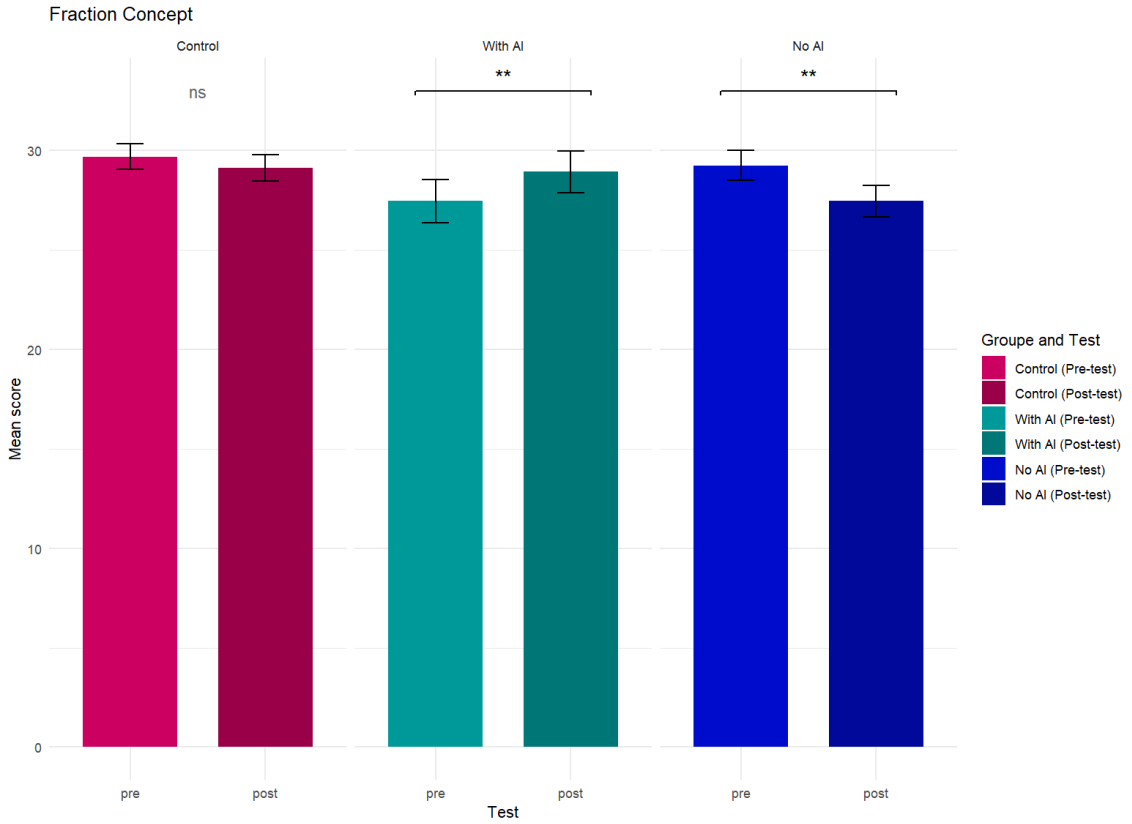
Complete the table by moving the fractions.



Select the largest fraction



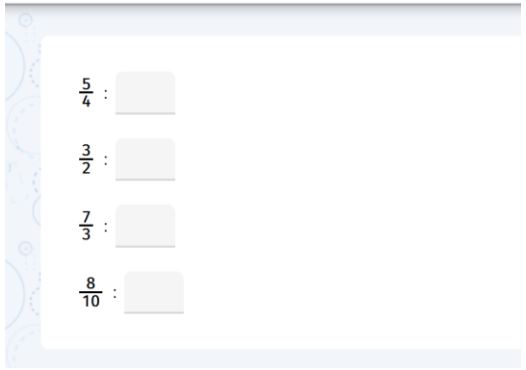
➢ Significant interaction of Group x Time:
$F(2, 562) = 7.51, p < .001$



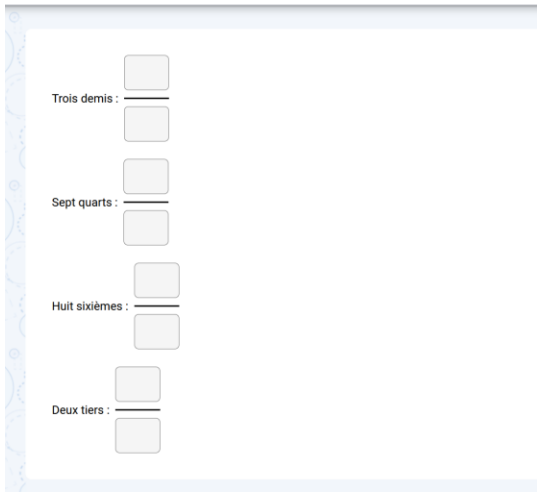
Results : Competencies

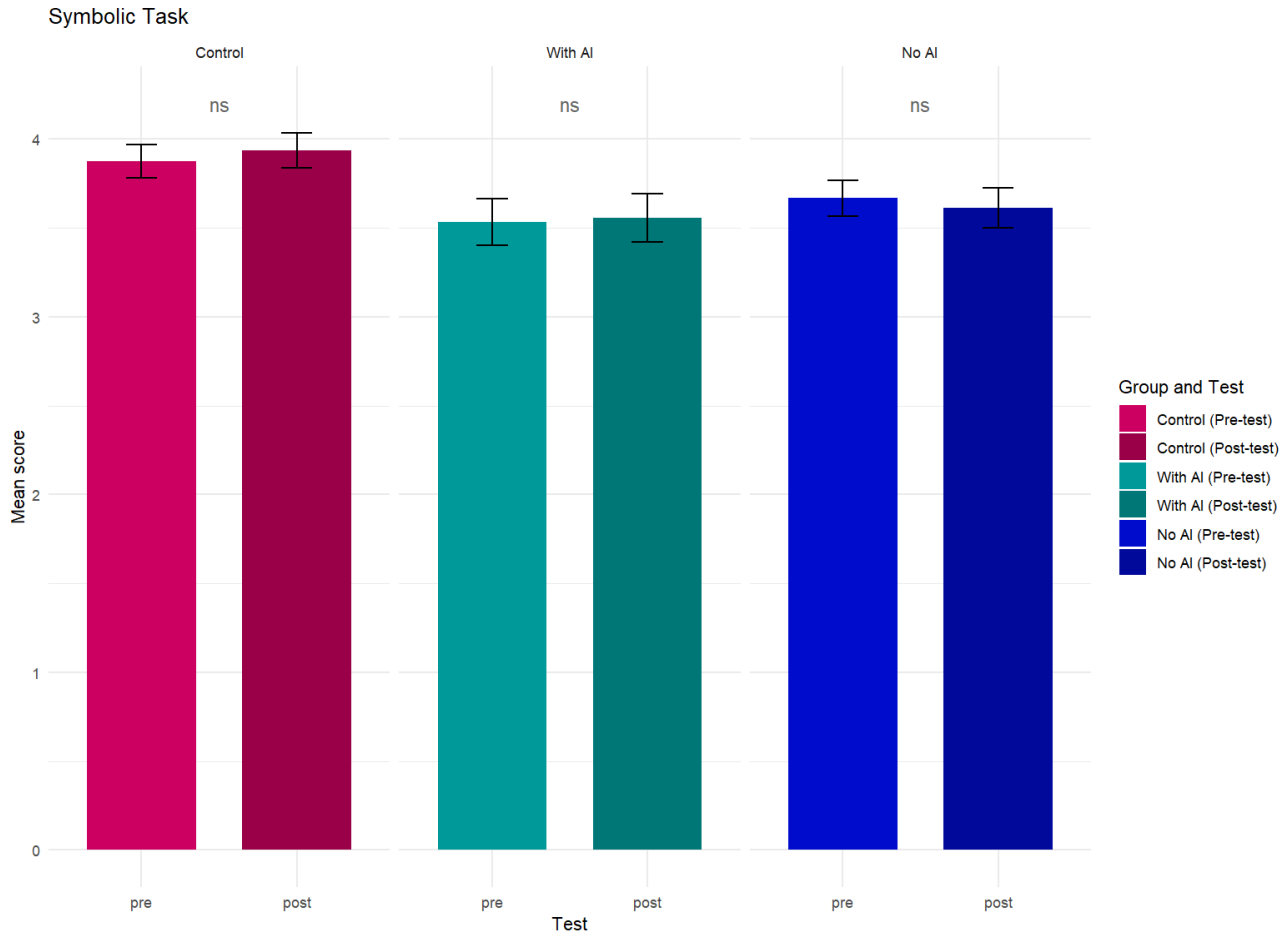
Symbolic Representation (Transcoding)

Write out these fraction in words.



Write the corresponding fractions using numbers.

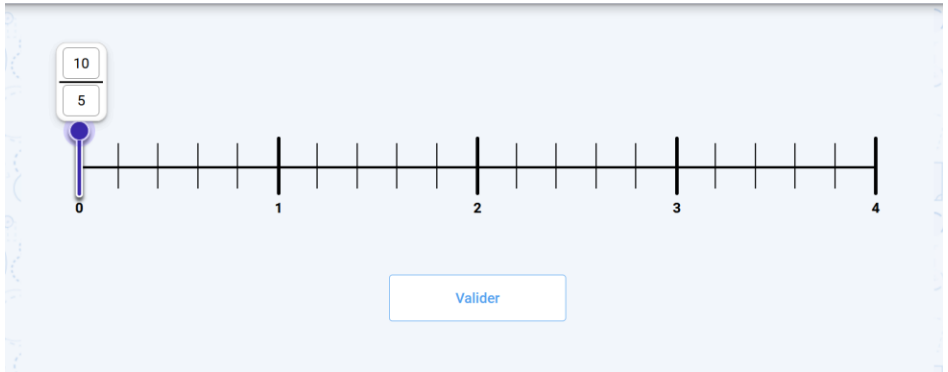




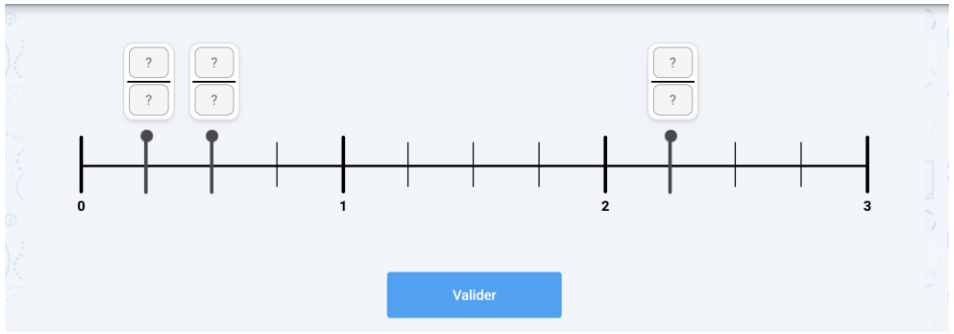
Results : Competencies

Number Line

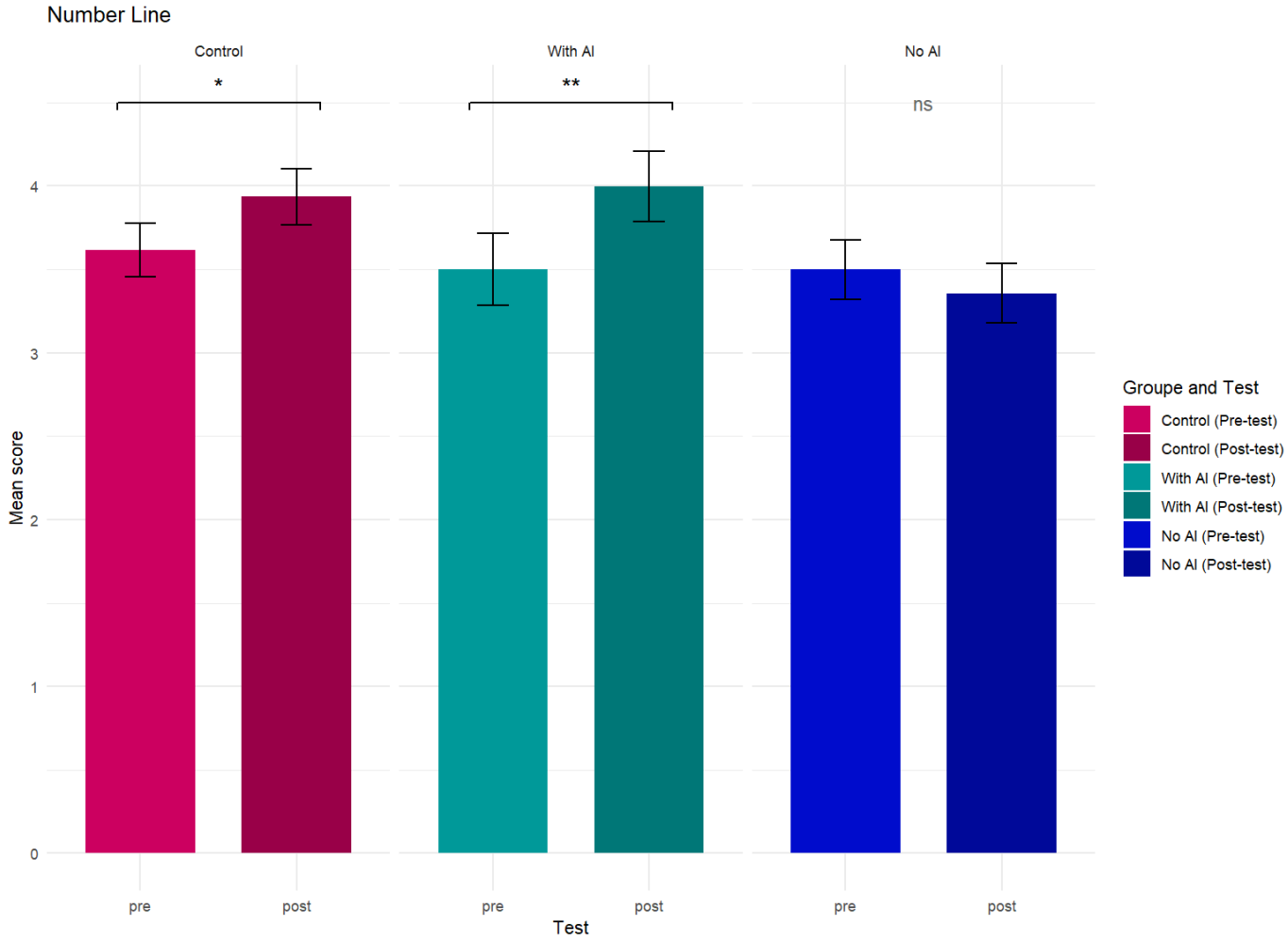
Place each of the following fractions on the number line



Find a fraction that corresponds to each landmark.



- Main effect of Time : $F(1, 542) = 8.36$, $p < .001$
- Significant interaction of Group x Time: $F(2, 542) = 4.67$, $p < .001$



Results : Competencies

Fraction Arithmetic

Write each sum as a single fraction.

$1+\frac{1}{5}=\frac{\square}{\square}$

$4+\frac{1}{2}=\frac{\square}{\square}$

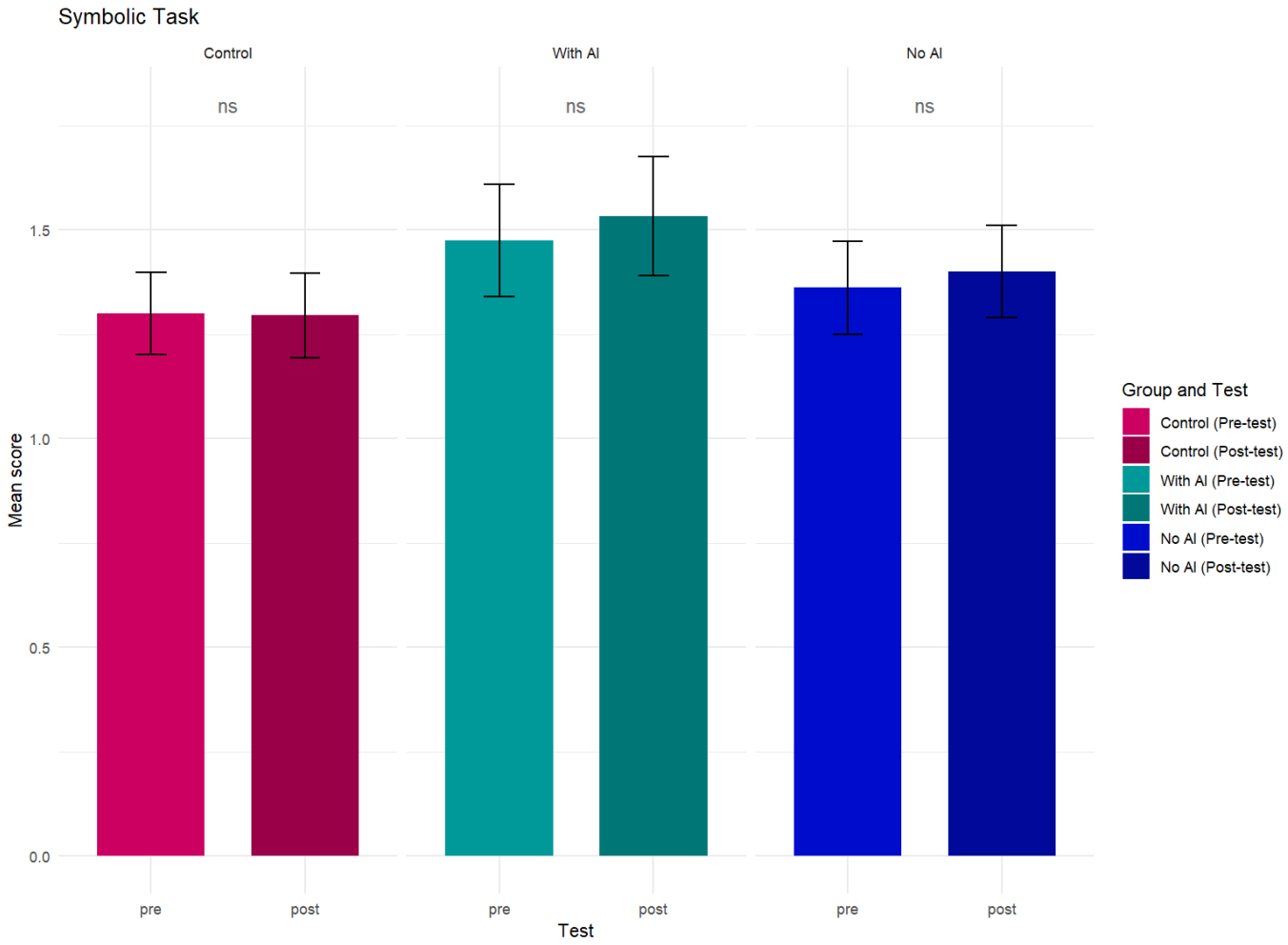
$5+\frac{3}{4}=\frac{\square}{\square}$

Decompose each fraction as the sum of a whole number and a fraction smaller than 1.

$\frac{7}{5}=\square+\frac{\square}{\square}$

$\frac{10}{3}=\square+\frac{\square}{\square}$

$\frac{11}{9}=\square+\frac{\square}{\square}$



Results : Competencies

- Main effect of group : F(1, 499) = 2.84, p = .01
- Main effect of Time : F(1, 499) = 38.97, p < .001
- Significant interaction of Group x Time: F(2, 499) = 8.75, p < . 001

Decimals

Write the decimal form of each fraction.

$\frac{3}{4}$ =

$\frac{5}{2}$ =

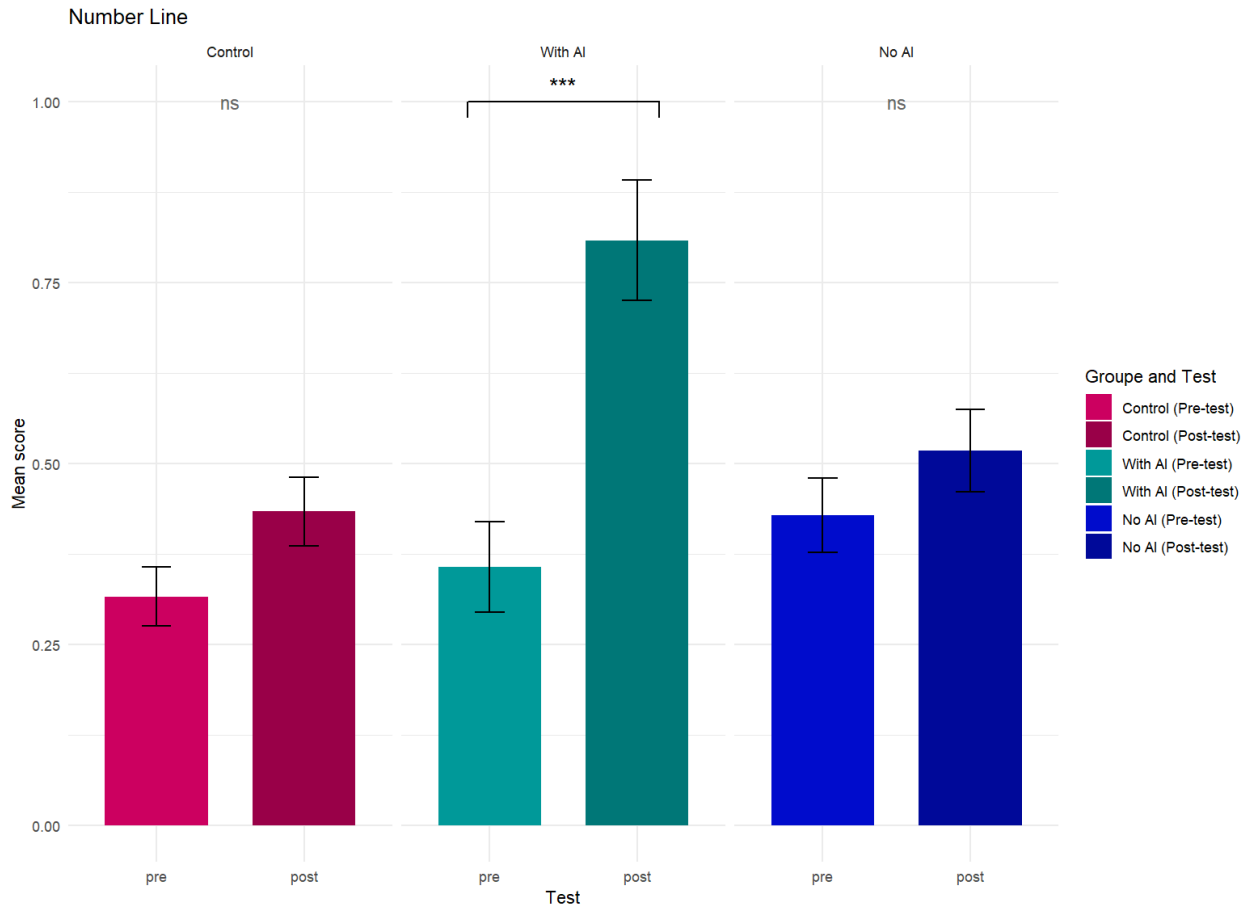
$\frac{7}{10}$ =

Write each decimal number as fraction.

0,25 = $\frac{\square}{\square}$

1,5 = $\frac{\square}{\square}$

0,8 = $\frac{\square}{\square}$



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.

Clear added value of the module with AI on grade 4 fraction learning

Impact of the module on different components of fraction understanding

- Significant positive impact of the module on Fraction Conception, Number line and decimals.

In line with the nature of the module, little transfer to transcoding or fraction arithmetic.

Reflection

Why such a negative impact of the Modules without AI?

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

➔ Could it explain the lack of effects in the past studies examining the effects of numerical fraction training?

••• Thank you

Questions? Want to connect?

Email : margot-r@evidence-b.com

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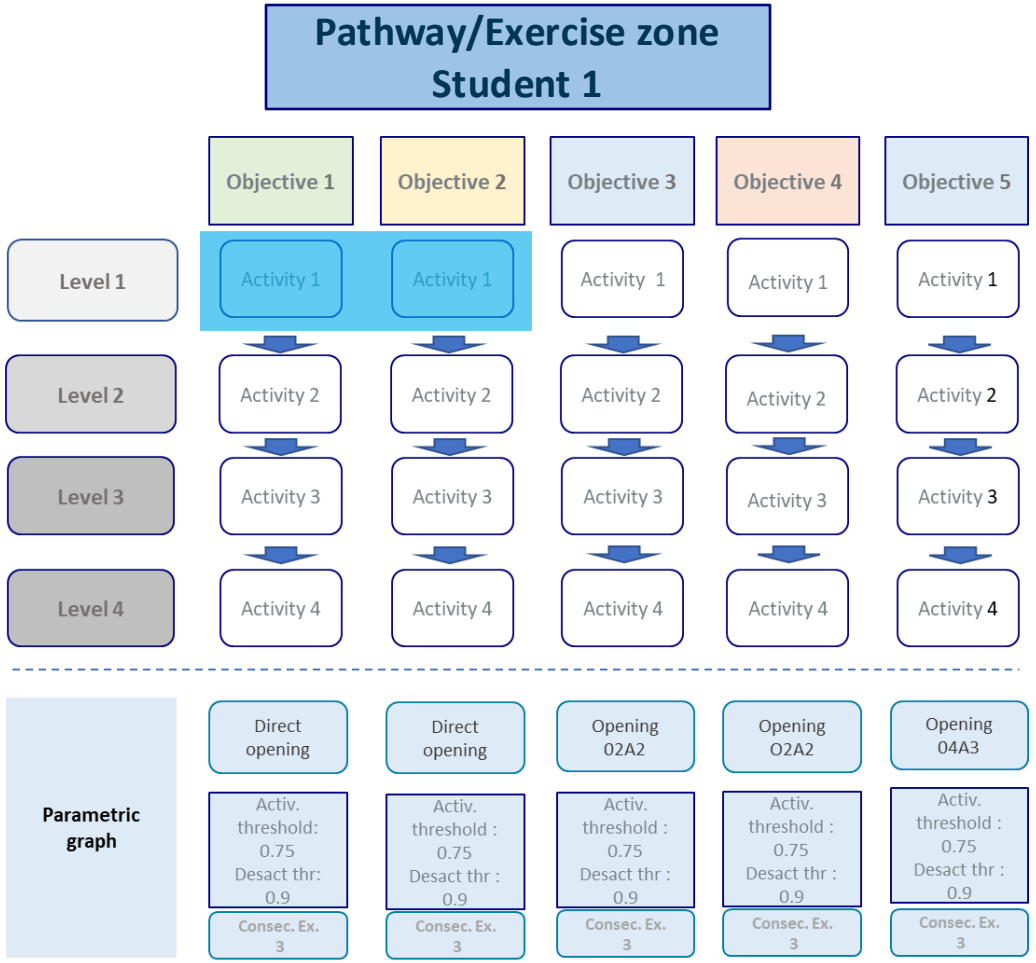

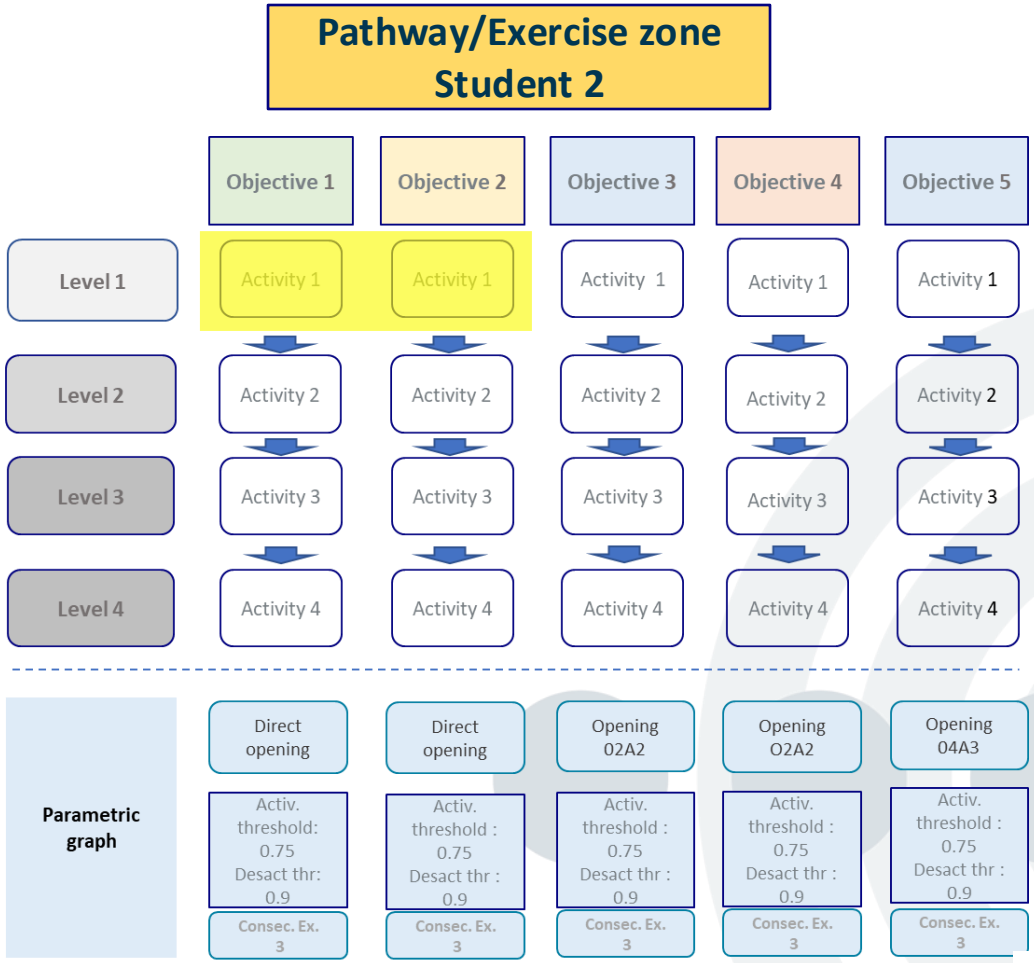

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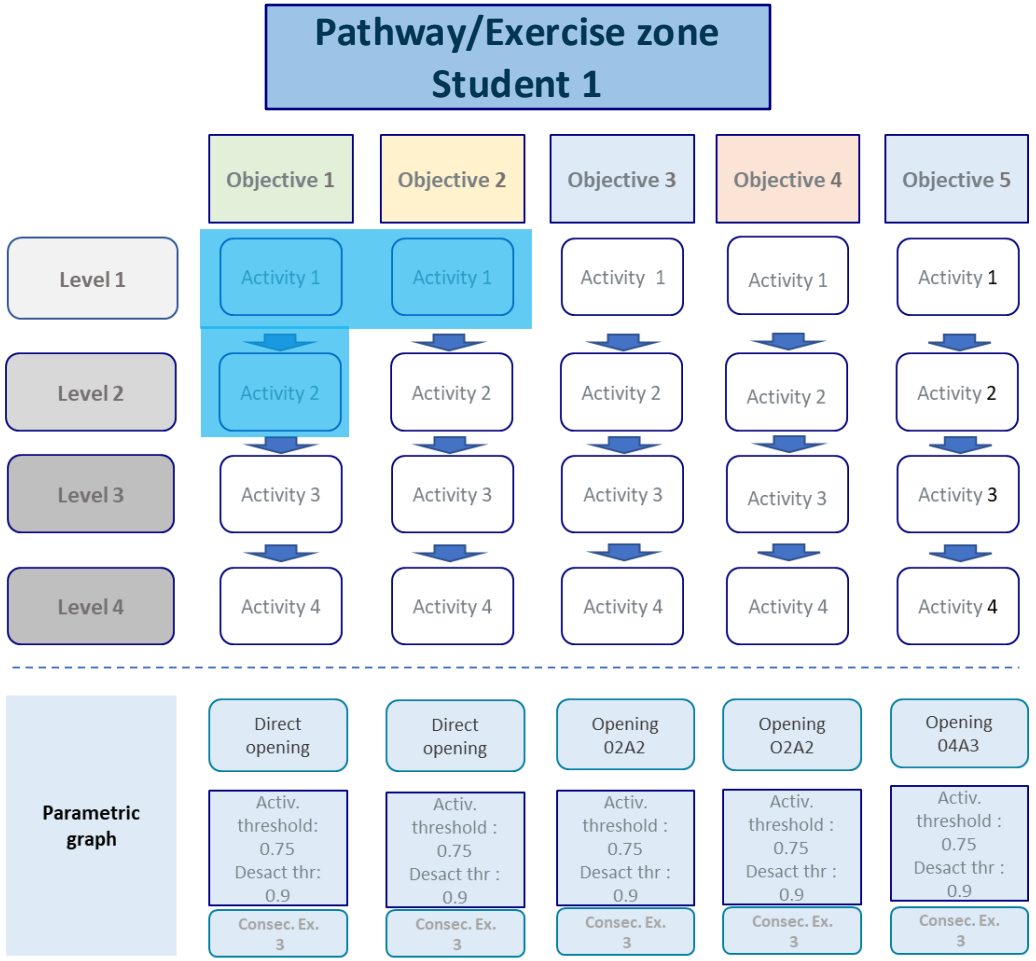

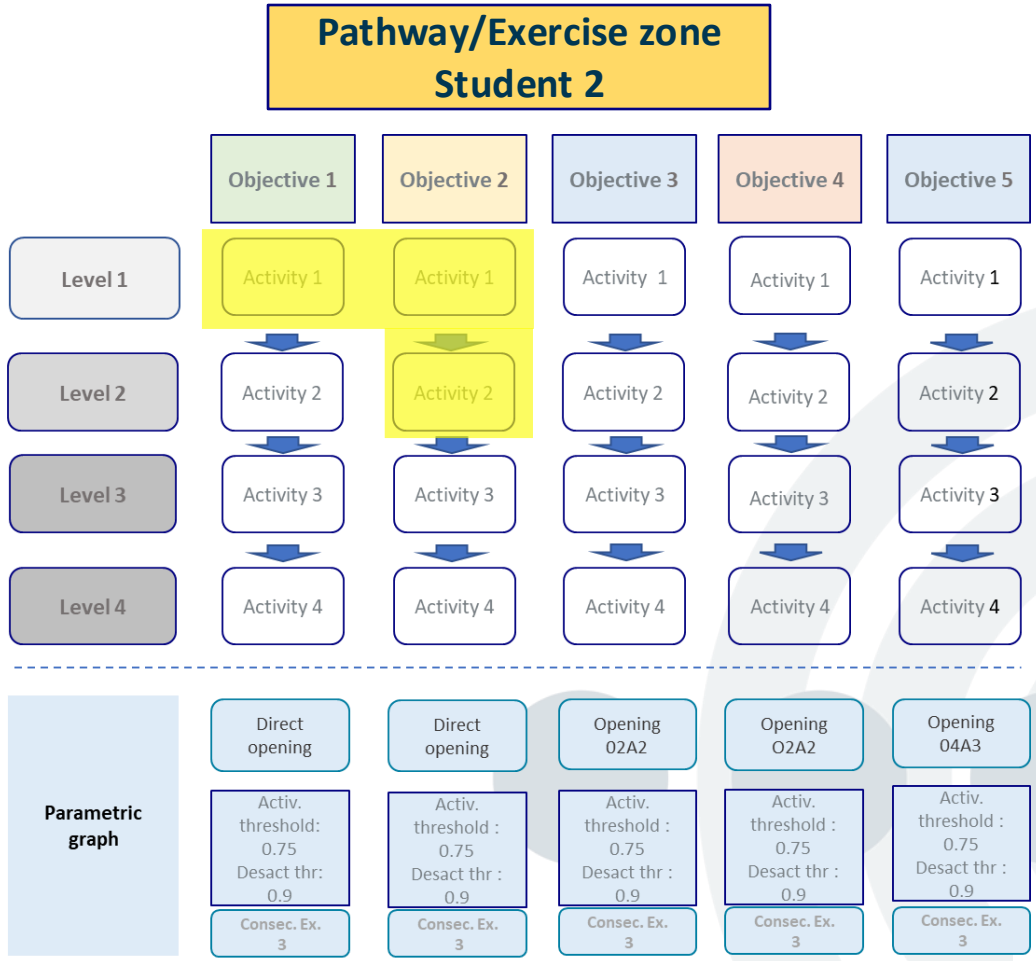

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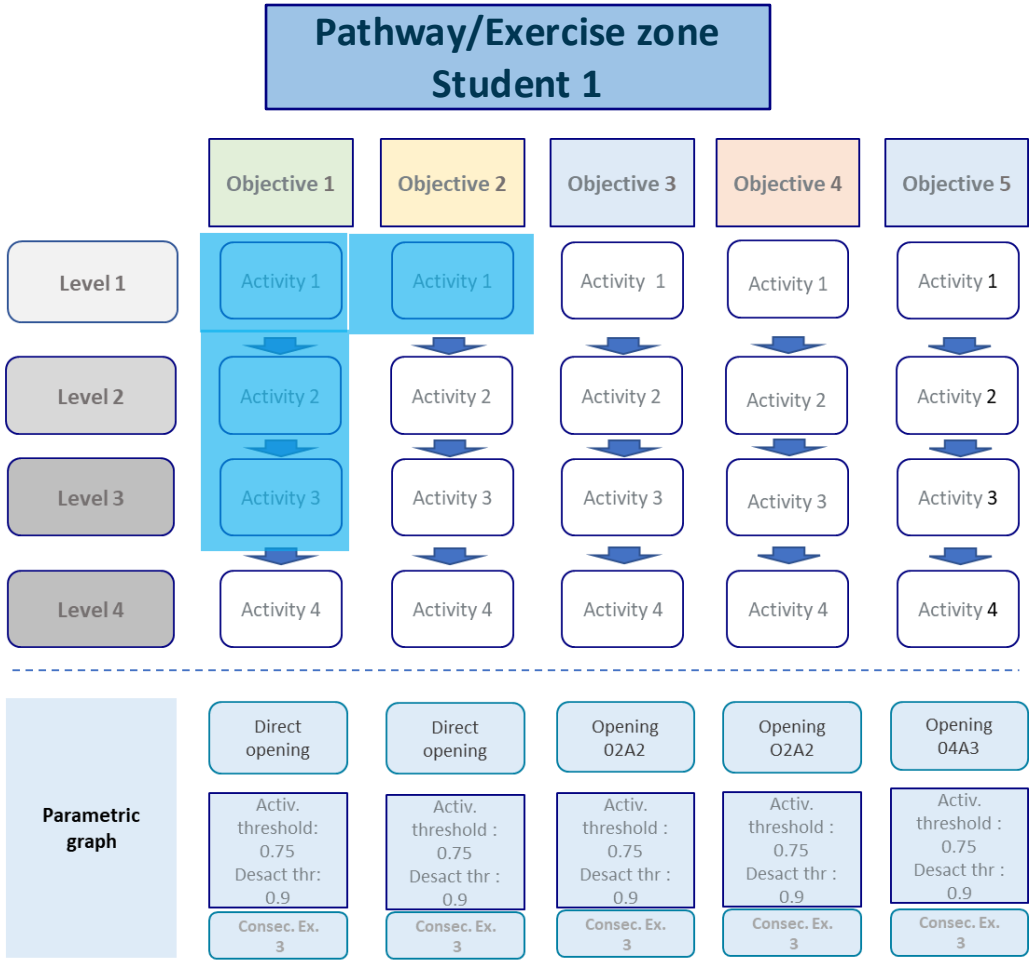
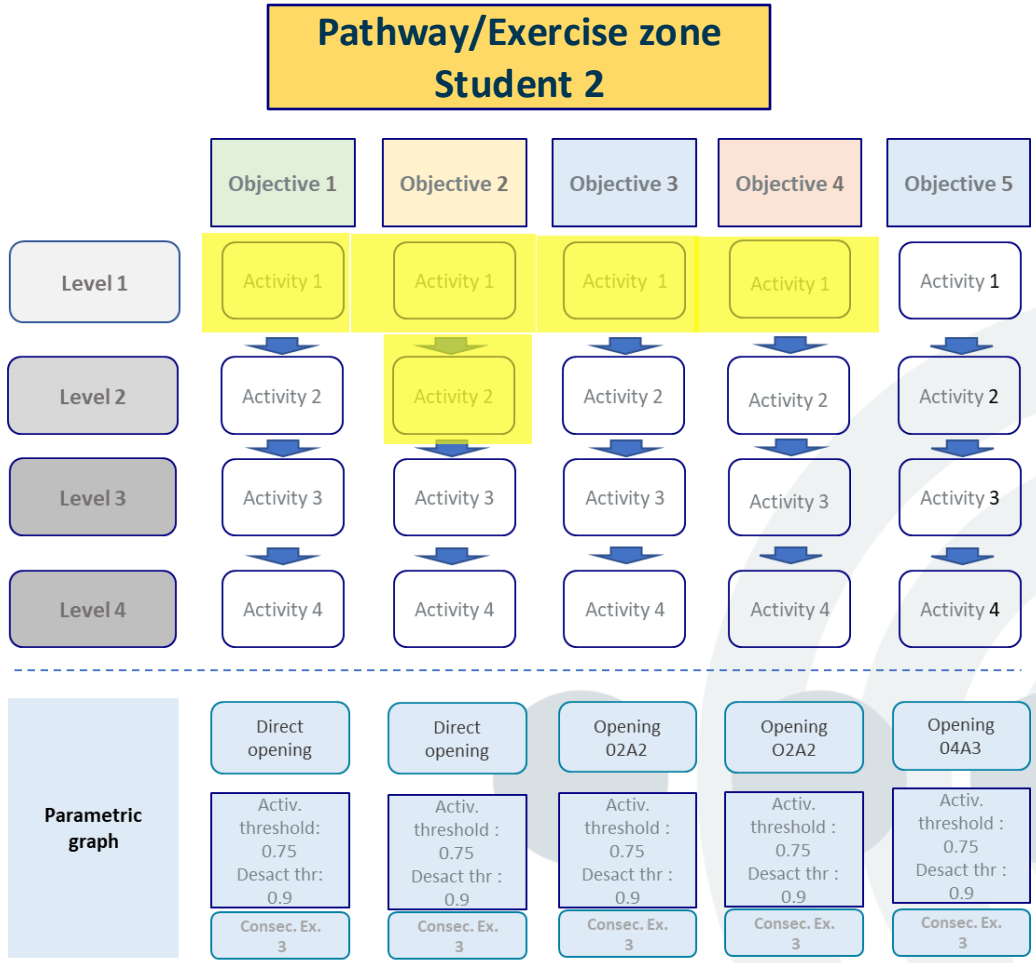
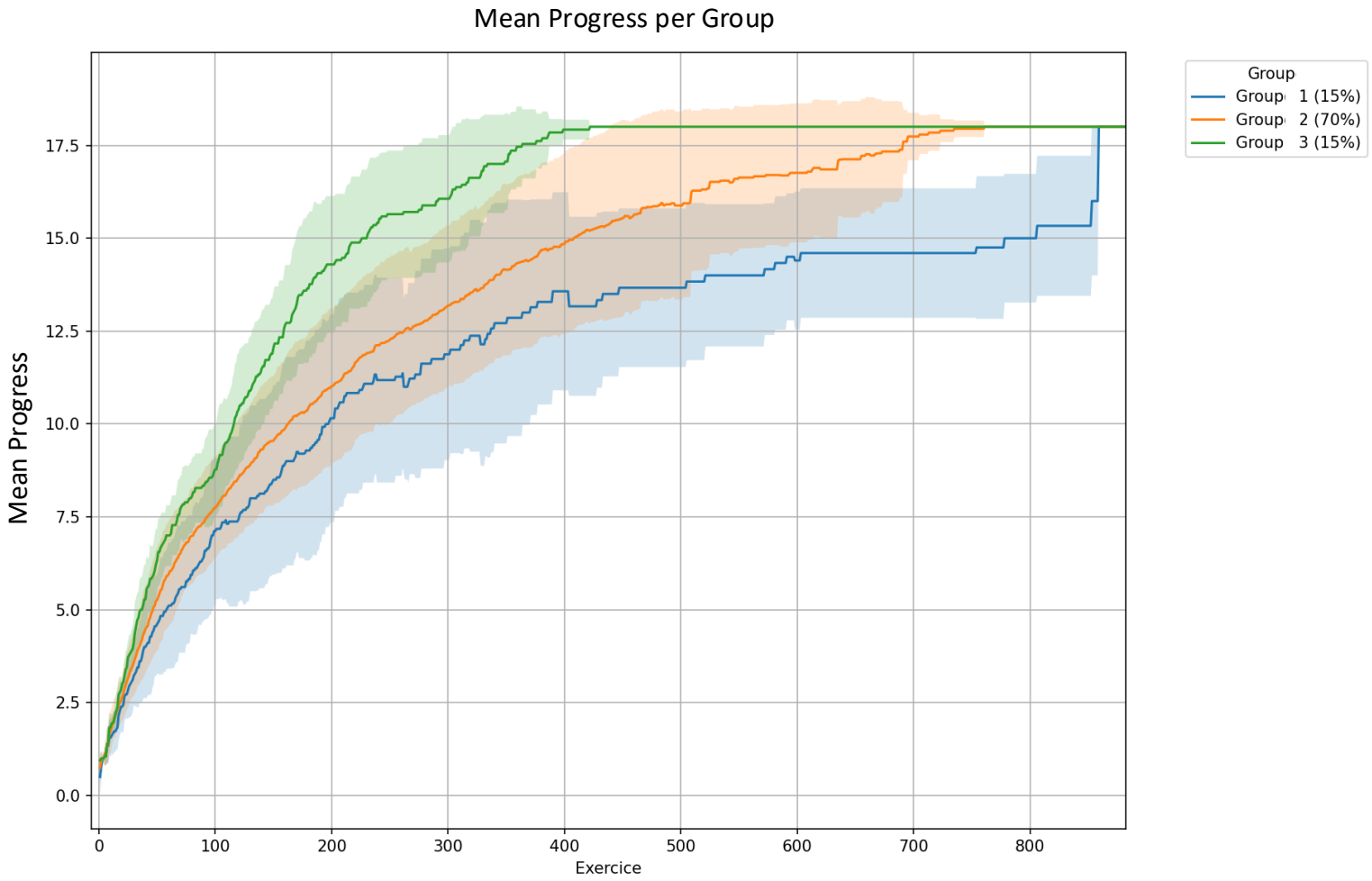
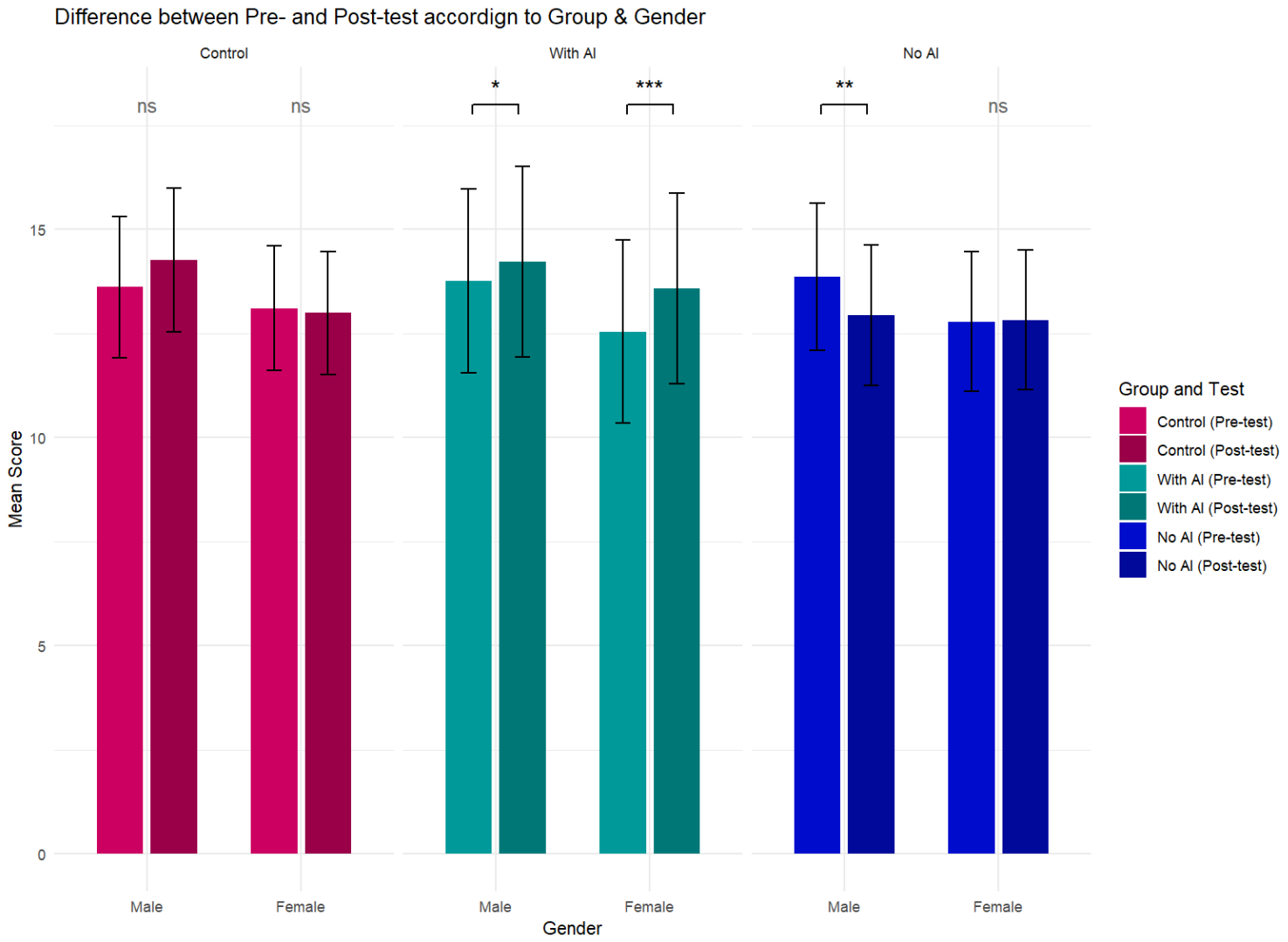




Results: Examining the learning trajectories



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:
  $F(2, 549) = 10.27$, $p < .001$