Improving the quality of teaching, learning, and assessment of mathematics at higher education: Utilizing Revised Bloom's Taxonomy and facets of metacognition

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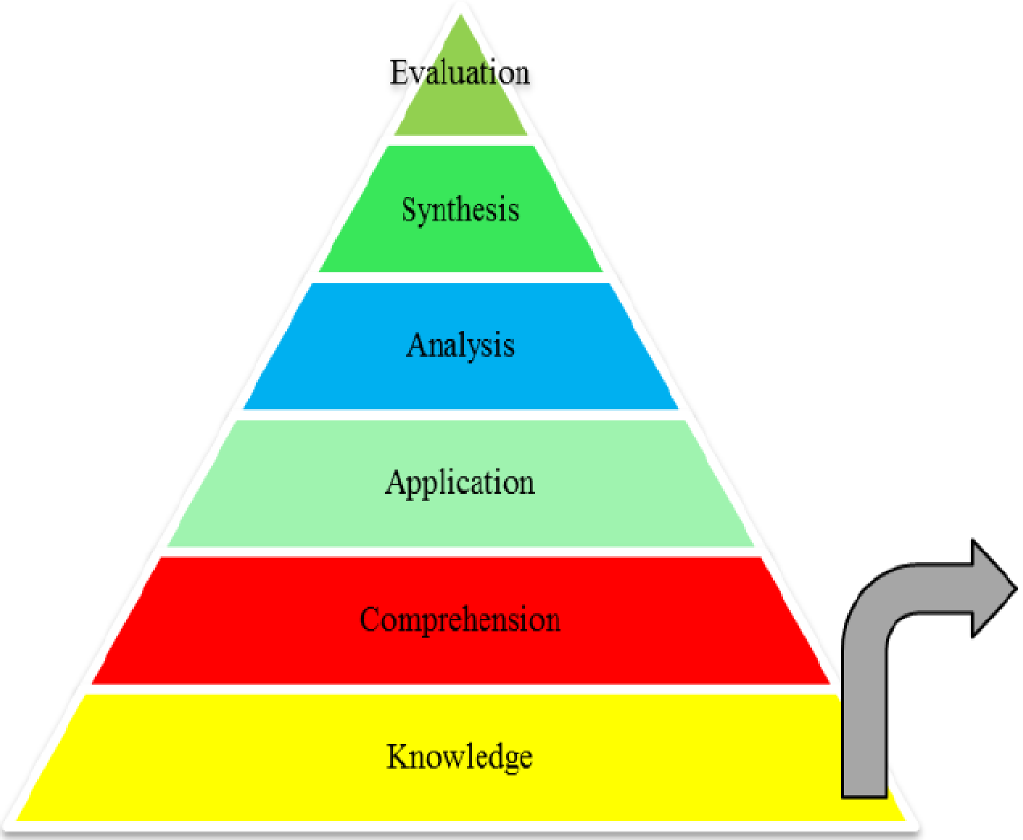
An overview

- Bloom’s Taxonomy and Revised Bloom’s Taxonomy
- Facets of metacognition
- Assessment tasks that activate different cognitive processes
- Exploring students’ **metacognitive knowledge**, **experiences**, and **skills** in relation to integral calculus
- Discussion

Revised Bloom’s Taxonomy



Bloom’s taxonomy

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remembering	2. Understanding	3. Applying	4. Analysing	5. Evaluating	6. Creating
A. Factual knowledge						
B. Conceptual knowledge						
C. Procedural knowledge						
D. Metacognitive knowledge						

Revised Bloom’s taxonomy

Radmehr, F., & Drake, M. (2019). Revised Bloom’s taxonomy and major theories and frameworks that influence the teaching, learning, and assessment of mathematics: a comparison, *International Journal of Mathematical Education in Science and Technology, 50*(6), 895-920.

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Facets of metacognition

Metacognition

Applied metacognition

Metacognitive knowledge (knowledge of cognition)

A type of declarative knowledge or beliefs about factors (i.e., *persons*, *tasks*, *goals*, and *strategies*) that influence cognitive activities.

Metacognitive skills (regulation of cognition)

A type of procedural knowledge that are performed deliberately to help individuals control their cognitive activities.

Metacognitive experiences

One's awareness and feelings when engaging in a task and processing its information

(Efklides, 2006, 2008)

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The assessment-based model based on RBT and metacognition

Students' mathematical understanding

- Factual knowledge
- Conceptual knowledge
- Procedural knowledge
- Metacognitive knowledge
- Metacognitive experiences
- Metacognitive skills

Radmehr, F., & Drake, M. (2018). An assessment-based model for exploring the solving of mathematical problems: Utilizing revised bloom's taxonomy and facets of metacognition. *Studies in Educational Evaluation*, *59*, 41-51.

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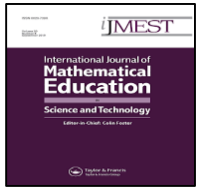
Revised Bloom's Taxonomy

Knowledge dimension of RBT with its subtypes

	Knowledge of …
A. Factual knowledge	Aa. terminology
	Ab. specific details and elements
B. Conceptual knowledge	Ba. classifications and categories
	Bb. principles and generalizations
	Bc. theories, models, and structures
C. Procedural knowledge	Ca. subject-specific skills and algorithms
	Cb. subject-specific techniques and methods
	Cc. criteria for determining when to use appropriate procedures
D. Metacognitive knowledge	Da. Strategic knowledge
	Db. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
	Dc. Self-knowledge



Radmehr, F., & Drake, M. (2017). Revised Bloom's taxonomy and integral calculus: unpacking the knowledge dimension. *International Journal of Mathematical Education in Science and Technology*, *48*(8), 1206-1224.

Revised Bloom’s Taxonomy

Cognitive process dimension of RBT with its subcategories

1. Remembering	2. Understanding	3. Applying	4. Analyzing	5. Evaluating	6. Creating
1.1 Recognizing	2.1 Interpreting	3.1 Executing	4.1 Differentiating	5.1 Checking	6.1 Generating
1.2 Recalling	2.2 Exemplifying	3.2 Implementing	4.2 Organizing	5.2 Critiquing	6.2 Planning
	2.3 Classifying		4.3 Attributing		6.3 Producing
	2.4 Summarizing				
	2.5 Inferring				
	2.6 Comparing				
	2.7 Explaining				

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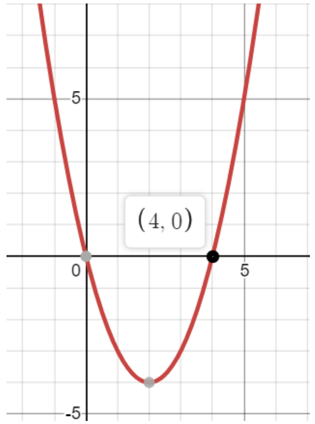
An evaluation task

- **Are these examples solved correctly? Please justify your answer.**



Example.1: Find if possible, the area between the curve $y = x^2 - 4x$ and the x-axis from $x = 0$ to $x = 5$.

$$\int_0^5 (x^2 - 4x)dx = [\frac{x^3}{3} - \frac{4x^2}{2}]_{x=0}^{x=5} = \left[\frac{5^3}{3} - \frac{4(5)^2}{2}\right] - \left[\frac{(0)^3}{3} - \frac{4(0)^2}{2}\right] = \frac{-25}{3}.$$

Example.2: Find if possible, the area enclosed between the curve $y = \frac{1}{x^2}$ and the x-axis from $x = -1$ to $x = 1$.

$$\int_{-1}^{1} \frac{1}{x^2} dx = \int_{-1}^{1} x^{-2} dx = [\frac{(x)^{-1}}{(-1)} = \frac{-1}{x}]_{x=-1}^{x=1} = \frac{-1}{1} - \frac{(-1)}{(-1)} = -2.$$

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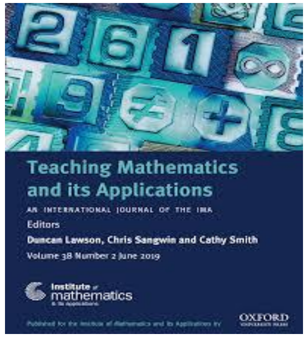
A problem-posing task

- **Please can you pose a problem about the area enclosed between a curve and a line with any two arbitrary bounds that will give an answer of 1 (i.e., the enclosed area will be equal to one).**

Christou, C., Mousoulides, N., Pittalis M., Pitta-Pantazi, D., & Sriraman, B. (2005). An empirical taxonomy of problem posing process. *ZDM*, *37*(3), 149-158.

Students’ performance on the tasks



Radmehr, F., & Drake, M. (2019). Students’ mathematical performance, metacognitive experiences and metacognitive skills in relation to integral-area relationships. *Teaching Mathematics and its Applications: An International Journal of the IMA, 38*(2), 85-106.

Radmehr, F., & Drake, M. (2017). Exploring students' mathematical performance, metacognitive experiences and skills in relation to fundamental theorem of calculus. *International Journal of Mathematical Education in Science and Technology, 48*(7), 1043-1071.

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Exploring students' metacognitive knowledge in relation to integral calculus

- Metacognitive knowledge
  - Strategic knowledge
    - Learning strategies
    - Monitoring strategies
    - Problem solving strategies
  - Knowledge about cognitive task
  - Self-knowledge
    - Strength and weaknesses in the topic
    - Goal orientation and attitudes

Exploring students’ metacognitive knowledge in relation to integral calculus

When you are studying integral calculus do you think about the justification or rationale behind the formulas or do you just try to apply the formulas? Why?

Reasons for not thinking about justifications

Themes	Sub-themes	Case 1	Case 2	Total
Negative attitude towards justifications	Not need to know it/ not in the examinations or questions	0	4	4
	Do not have time to think about them	2	0	2
	Sometimes justifications are more complicated than memorizing them	1	0	1
	Justifications confuse me	0	1	1
No access to justification	Have not seen a thorough justification for the topic	0	3	3
	Does not mention it in the textbook	0	1	1

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Reasons of thinking about the justifications behind the formulas

Themes	Sub-themes	Case 1	Case 2	Total
Helpful for remembering, applying, or reproducing formula	Help to reproduce the formula when necessary	4	0	4
	Help to remember the formula	2	0	2
	Do not need to remember the formula	1	0	1
	It is easier to apply formula when you understand it	1	0	1
Have a better understanding	To have a better understanding about the topic	2	1	3
	Remembering the formula is not sufficient	1	0	1
Have a better performance in exams, and when answering questions	It is easier not to make a mistake	1	0	1
	Helpful for checking workings	1	0	1
	To answer some questions, knowing the justification is necessary	0	1	1
	Maybe a question about the justification being asked in the scholarship exam	N/A	1	1

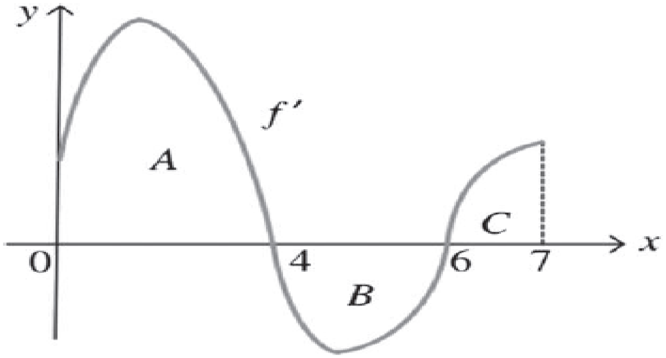
Exploring students' metacognitive experiences in relation to integral calculus

Question ……	
How well do you think you can solve this question*?*	
I am sure I will solve this question.	
I am not sure whether I will solve this question correctly or incorrectly.	
I am sure I cannot solve this question.	
Please, explain why	
Solution:	
Rate your confidence for having found the correct answer.	
I am sure I solved this question correctly.	
I am not sure whether I solved this question correctly or incorrectly.	
I am sure I solved this question incorrectly.	
Please, explain why	

Jacobse, A. E., & Harskamp, E. G. (2012). Towards efficient measurement of metacognition in mathematical problem solving. *Metacognition and Learning*, *7*(2), 133-149.

Exploring students' metacognitive experiences in relation to integral calculus

Q. 'The graph of $f'(x)$, the derivative of $f(x)$, is sketched below. The area of the regions A, B and C are 20, 8 and, 5 square units, respectively. Given that $f(0) = -5$, find the value of $f(6)$' (Mahir, 2009, p. 203).



	Case 1	Case 2	Solved the task correctly		A sample response
			Case 1	Case 2	
I am sure I will solve this question	3	1	2	0	"We know the area of important parts of the $f(x)$ and area is related to the anti-derivative."
I am not sure whether I will solve this question correctly or incorrectly.	5	6	1	0	"I am not sure because I have to change the area to $f(x)$. but I am not sure I can calculate it Correctly."
I am sure I cannot solve this question.	1	1	1	0	"I do not know how to find out the $f(x)$ because I do not recognize the graph type of $f'(x)$."

Exploring students' metacognitive skills in relation to integral calculus

Metacognitive Skills

- **Read, explore, and analyze** (Orientation)
  - Example: Making a drawing related to the problem
- **Plan and implement** (Systematical Orderliness)
  - Example: designing an action plan before actually calculating
- **Verify** (evaluation and reflection)
  - Example: checking calculations and answers

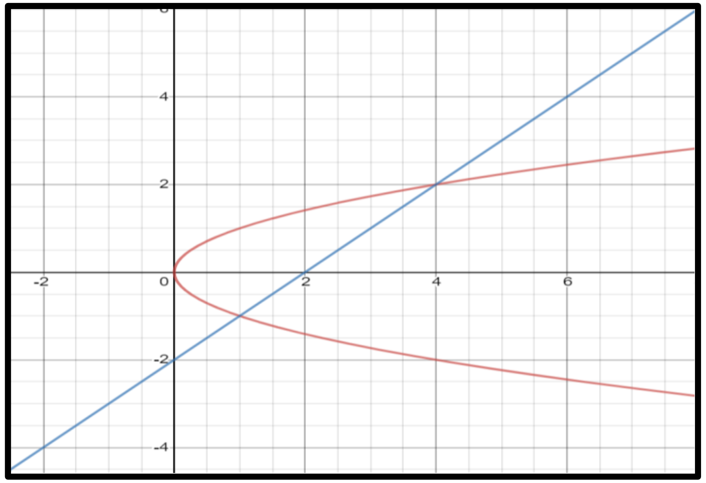
Jacobse, A. E., & Harskamp, E. G. (2012). Towards efficient measurement of metacognition in mathematical problem solving. *Metacognition and Learning*, *7*(2), 133-149.

Exploring students' metacognitive skills in relation to integral calculus

Q. Please calculate the area enclosed between the curve $x = y^2$ and $y = x - 2$ in two ways. Which way is better to use? Why?

Relationship between a correct drawing and finding the area with respect to the x- and y-axes

		Finding the area with respect to the x-axis			Finding the area with respect to the y-axis		
		Correct	Incorrect	Did not use the method	Correct	Incorrect	Did not use the method
Correct sketch ($N = 11$)	Case 1 ($N = 7$)	3	4	0	5	2	0
	Case 2 ($N = 4$)	1	2	1	2	1	1
Incorrect sketch ($N = 6$)	Case 1 ($N = 2$)	0	2	0	0	1	1
	Case 2 ($N = 4$)	0	4	0	0	0	4



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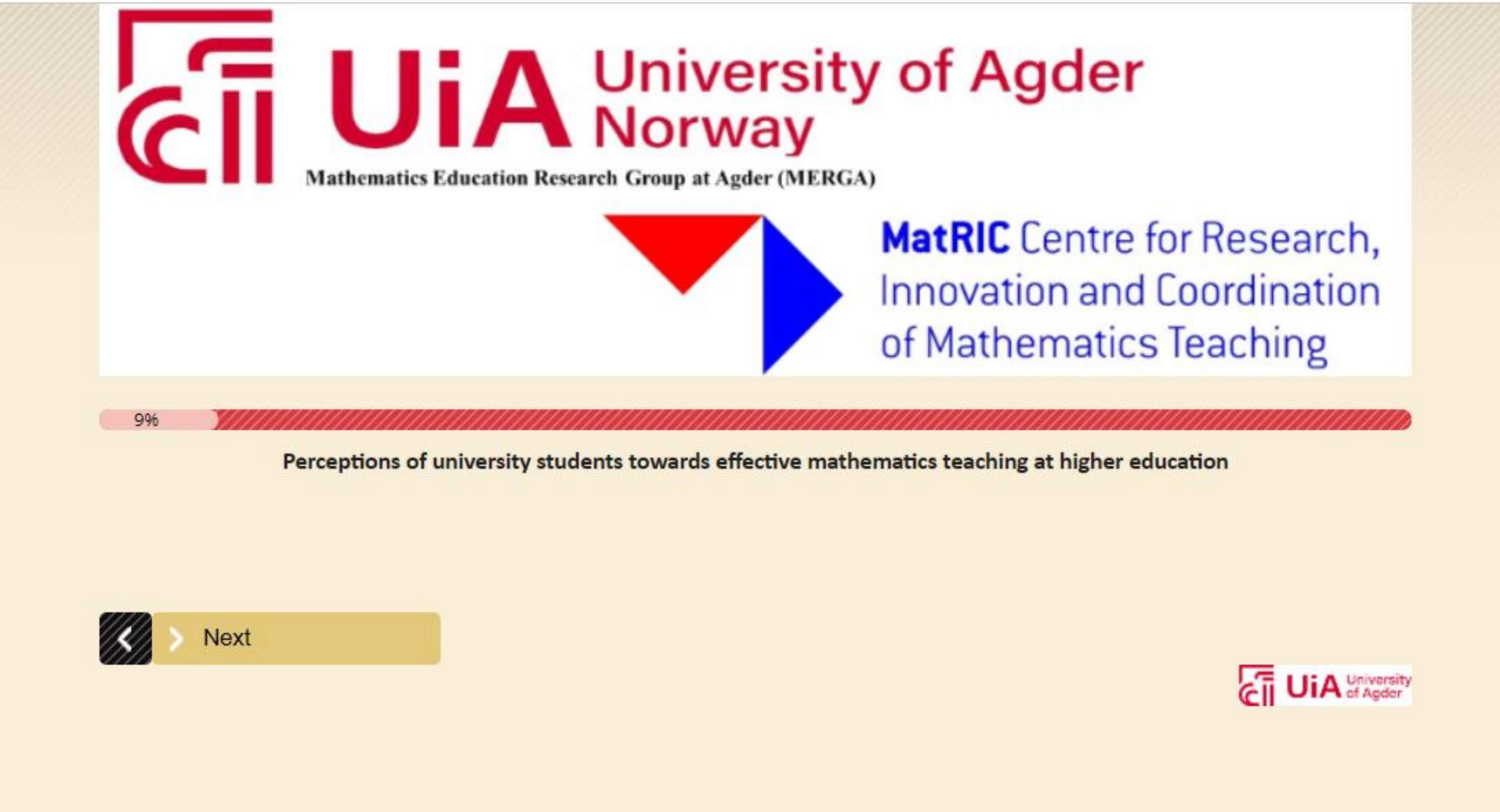
Next steps…

- **Using the framework to explore students' mathematical understanding in other topics.**
- **Designing teaching activities based on RBT that promote higher-order thinking and improve students' metacognition.**
- **Designing a classroom observational tool based on RBT.**
- **Describing how students learn mathematics using RBT terms.**

Perceptions of university students towards effective mathematics teaching at higher education



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