

#### **A**A f ff ff i Minis f 1 Î ff ff High Quality Questions for **E-Assessment in Mathematics** D. Gallaun, K. Kruse, C. Seifert

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## **Adaptive Questions**

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### Randomisation

### **Proof Puzzles**

### **Survey Results**

17 June 2021



## **Adaptive Questions**





# **Adaptive Computational Tasks**



4

Determine the set of solutions in  $\mathbb{R}^3$  of the system of linear equations

$$\begin{pmatrix} 2 & 2 & 2 \\ 2 & 3 & 1 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}.$$

Bring the system of linear equations in a row echelon form.

$$\left(\begin{array}{rrrr|r} 2 & 2 & 2 & 0\\ 0 & 1 & -1 & 0 \end{array}\right).$$

Determine the free variables.

By passing the variable  $x_3$  to the right-hand side, we get the system of linear equations:

$$\begin{pmatrix} 2 & 2 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = \begin{pmatrix} -2x_3 \\ x_3 \end{pmatrix}.$$

Determine the set of solutions depending on the variable  $x_3$ .

	Pros	Cons
	Efficiently check follow-up errors	Fixed solution path
	Fair & transparent assessment	Enter intermediate results
	Higher learning success	Higher creation effort
7 June 2021		

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- Intermediate steps according to a classical solution
- Sample solutions after every intermediate step
- Handling of follow-up errors

## Randomisation



- Individual tasks make fraud attempts more difficult
- Challenge: comparable level of difficulty
- Appropriate assessment schemes/algorithms needed

#### Randomisation via Reverse Engineering:

Determine the set of solutions in 
$$\mathbb{R}^3$$
 of the system of linear equations
$$\begin{pmatrix} 2 & 2 & 2 \\ 2 & 3 & 1 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}.$$

• Choose the entries of the LU decomposition randomly:

$$\begin{pmatrix} 2 & 2 & 2 \\ 2 & 3 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ \mathbf{1} & 1 \end{pmatrix} \begin{pmatrix} \mathbf{2} & \mathbf{2} & \mathbf{2} \\ 0 & \mathbf{1} & -\mathbf{1} \end{pmatrix}$$

• Control over the complexity of the calculation steps

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# **Proof Puzzles**



- Assess proofs electronically
- Sort via drag'n'drop
- Grading algorithm
  - Edit distance
  - Works even with several sample solutions

Pros	Cons
Quite intuitive input	Fixed structure
Automatic grading	Only short proofs
Assess logical reasoning	Sentence structure exploitable

Let  $n \in \mathbb{Z}$ . Find a proof for the statement

"If n is even, then  $n^2$  is also an even number".

#### [4,2,1,5,6]

Proof:	
Let $n\in\mathbb{Z}$ be an even number.	4
This means, it exists a number $p\in\mathbb{Z}$ such that	2
n=2p holds.	1
This implies $n^2=(2p)^2=2(2p^2).$	5
Hence, it holds $n^2=2m$ with $m:=2p^2\in\mathbb{Z}.$	6
Not used: Consequently, $n^2$ is even. Consequently, $n^2$ is even.	3
$n=p^2$ holds.	8
Suppose that $n\in\mathbb{Z}$ is odd.	7

## **Survey Results**





- It is good that adaptive questions give directly response on my answer.
- Adaptive questions are well suited to grade the calculation path of a math question.
- Proof puzzles are well suited to grade mathematical proof in an electronic exam.
- Using a computer, I could better demonstrate that I am able to practically apply the taught concepts than with pencil and paper alone.

Results of surveys conducted in the courses Mathematics for engineers (questions 1-3, N=415) and Stochastics (question 4, N=41).



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