

# Student models to generate automated feedback on intermediate steps in solving mathematical problems

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## Motivation

Using ICT for **assessing** mathematics achievement:

- | Targeted at 12-15 years old students.
- | Setting up algebraic expressions and equations, and simplifying and solving them.

Detailed assessment of free-form answers to mathematical problems:

- | Analysis of **intermediate steps**.
- | Determining the **solution approach**.

## Research approach

- | Focus on obtaining a detailed picture with strengths and weaknesses of the student.
- | No restrictions in complexity of the task. Going beyond easily verifiable questions such as multiple-choice or closed items.
- | Complex tasks with multiple solution strategies.

Our **research goal**: analysing free-form input to mathematical problems in a formative assessment setting

## Task

**Task 02 Car rental**

Mark wants to rent a car for a day. The above graph shows the total cost depending on the number of kilometers he drives, if he hires at the "Rent-it" company: you pay € 20.00 for the day plus € 0.25 for every kilometer you drive. Company "Go for it" offers a day price of € 43.00 without extra charge per km. Calculate how many km Mark needs to drive at least as to prefer the "Go for it" offer and explain your answer. Write down your intermediate steps.

**Your work** (formula editor):

```

fix
43.00
20.00 = 0.25 * s
43.00 - 20.00 = 23.00
23.00 * 0.25 = |
  
```

Labels: *task*, *free-form input*, *formula editor*

## Strategies

Choose variables

$$\begin{aligned} \text{cost} &= 20.00 + 0.25 \cdot \text{dist} \\ 20.00 + 0.25 \cdot \text{dist} &= 43.00 \\ 0.25 \cdot \text{dist} &= 43.00 - 20.00 = 23.00 \\ \text{dist} &= 23.00 / 0.25 = 92.00 \end{aligned}$$

Answer: 92 km or more

| algebraic strategy, equation

Choose variables

$$\begin{aligned} \text{cost} &= 20.00 + 0.25 \cdot \text{dist} \\ 20.00 + 0.25 \cdot \text{dist} &> 43.00 \\ 0.25 \cdot \text{dist} &> 23.00 \\ \text{dist} &> 92.00 \end{aligned}$$

Answer: 92 km or more

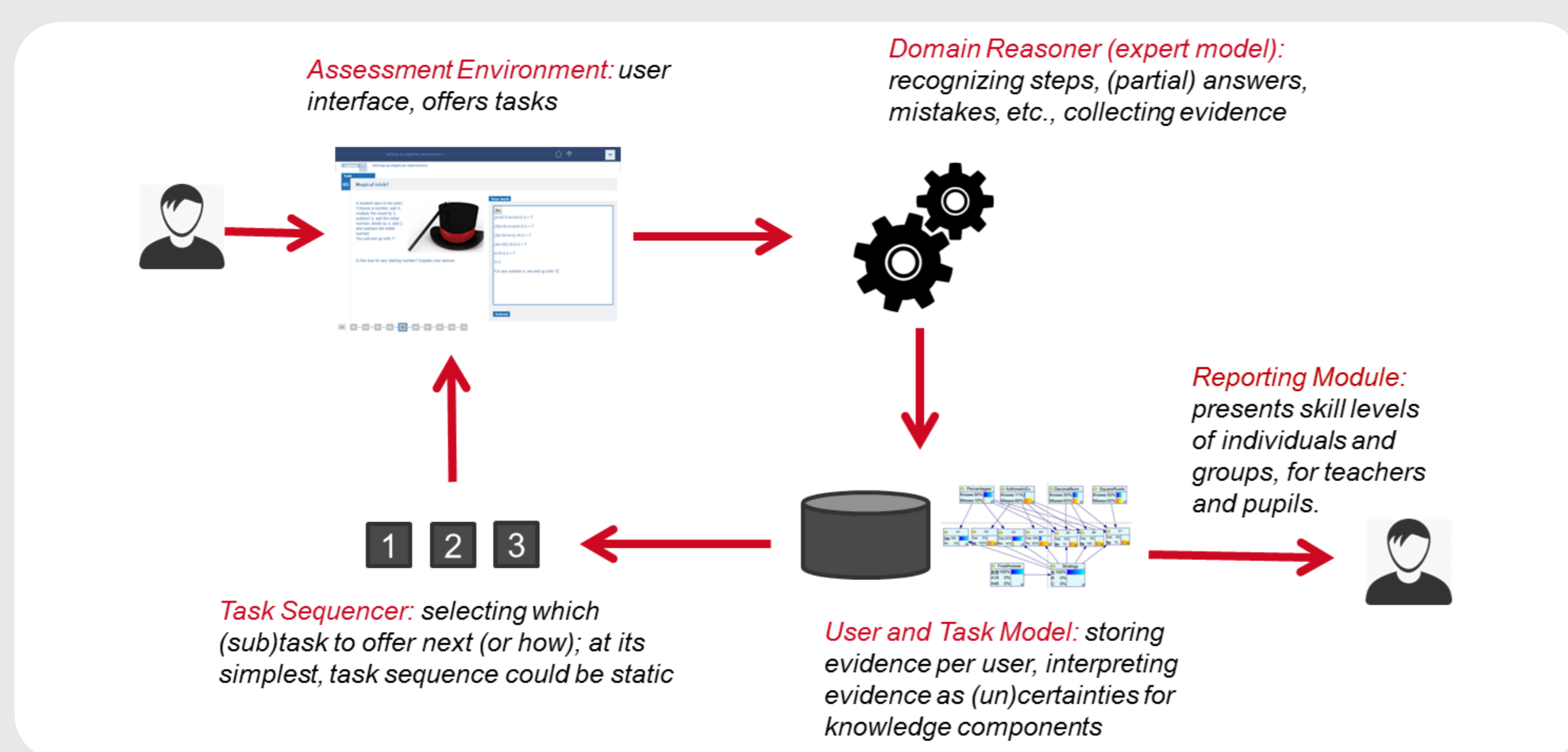
| algebraic strategy, inequality

$$\begin{aligned} 20.00 + 0.25 \cdot \langle \text{number} \rangle & \\ &= \langle \text{other number} \rangle \\ 20.00 + 0.25 \cdot 92 &= 43.00 \end{aligned}$$

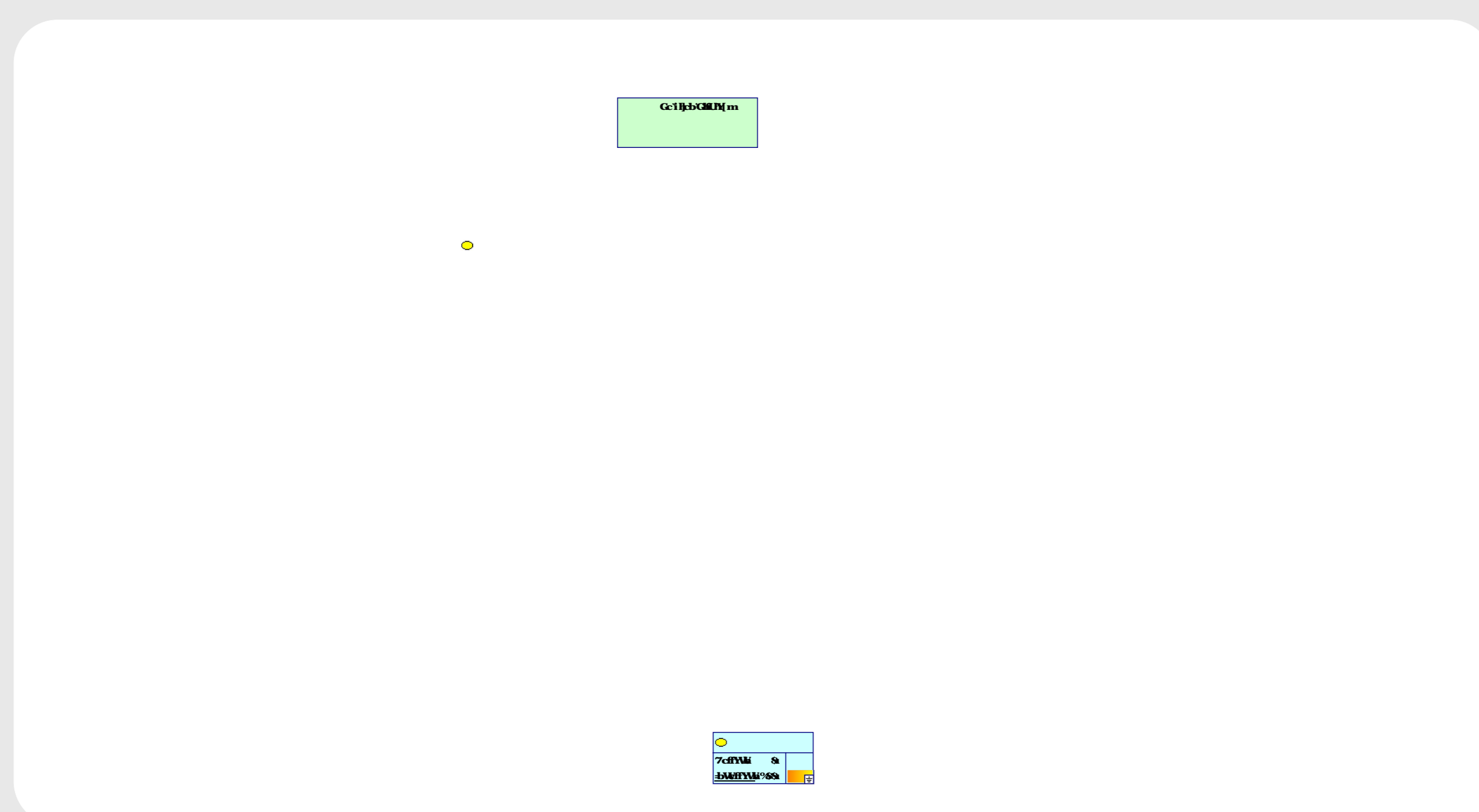
Answer: 92 km or more

| numerical strategy

## High-level architecture



Example of a **task model**:



## Pilot and evaluation studies

Students worked on **10 tasks** and answered a short **questionnaire**.

Small-scale pilot:

- | Germany (N=19), France (N=6) and the Netherlands (N=37).
- | We used the data to improve the tasks, the domain reasoner, and the task and student models.

Evaluation studies:

- | Germany (N=114), France (N=96) and the Netherlands (N=130).
- | We made a comparison between the automated feedback given by the domain reasoner and human assessment.

## Conclusion

- | We have developed a framework for formative **assessment** of **free-form** solutions to **complex mathematical problems**.
- | The domain reasoner finds evidence for intermediate steps and solution approaches.
- | The data from the evaluation studies still needs further processing.

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