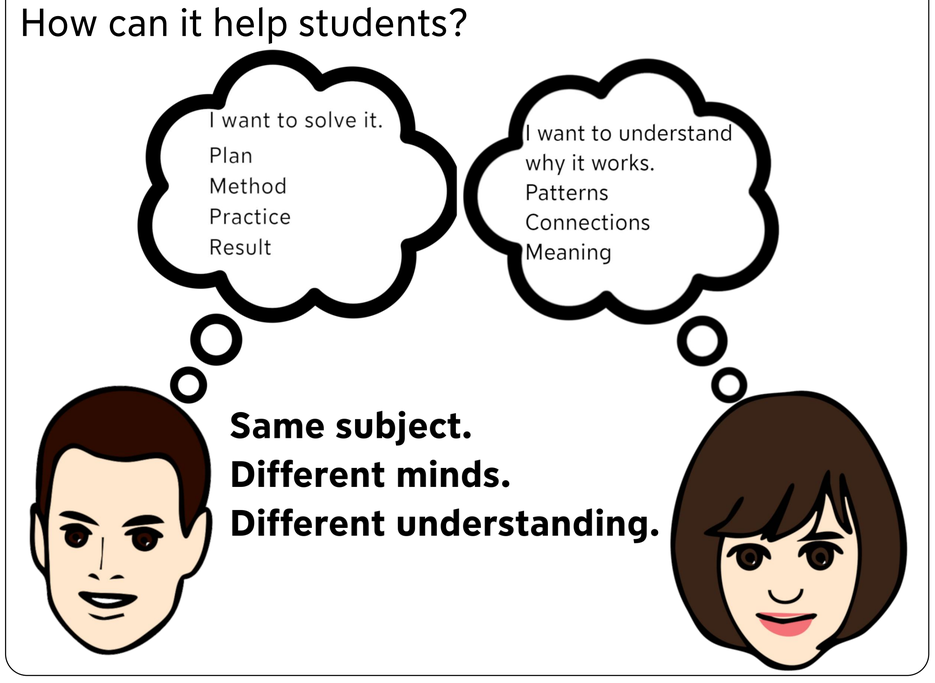
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Technische Fakultät

Modelling Learner Competencies

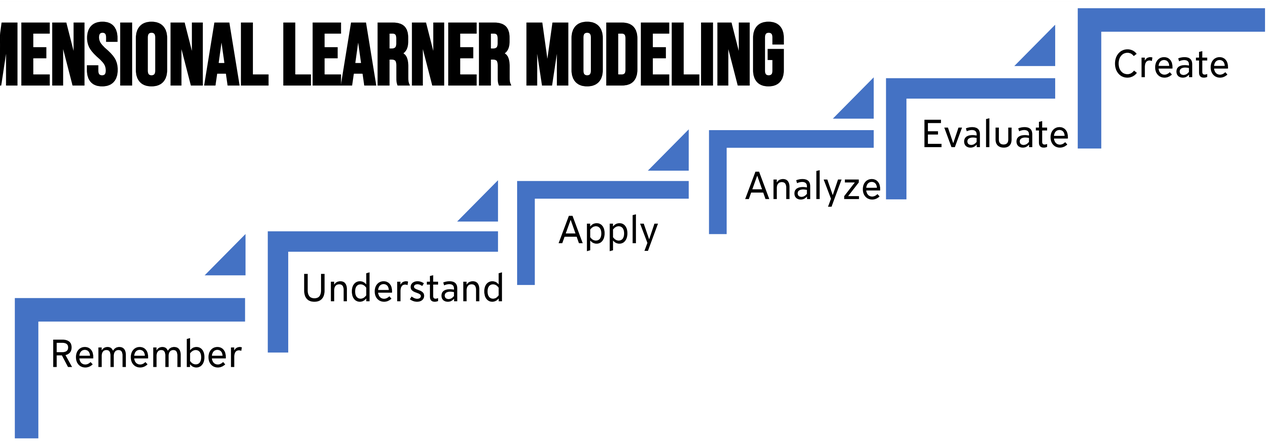
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INTRODUCTION

Understanding is not one-size-fits-all.
Learners understand concepts at different levels.
How can we model this phenomenon?
How can it help students?



MULTIDIMENSIONAL LEARNER MODELING



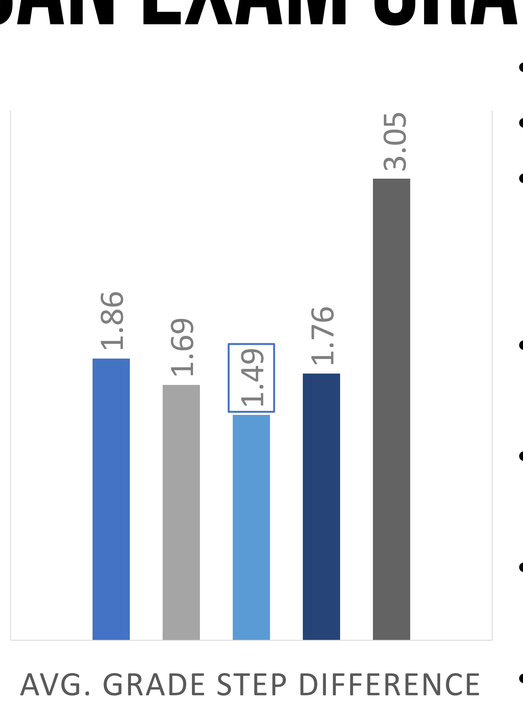
Learner **competence** is modeled using an adapted **Bloom's taxonomy** comprising six cognitive dimensions and distinguishing between **knowledge interpretation** and **knowledge production**. This multidimensional approach captures diverse learning abilities and supports personalized learning services.

Learner knowledge is modeled per **concept**(C), **learner**$(\mathrm{Id_L})$, and **cognitive dimension**$(\mathbb{D})$. Each tuple is associated with a **competence** and **confidence** value in $[0, 1]$, enabling detailed tracking of learning progress.

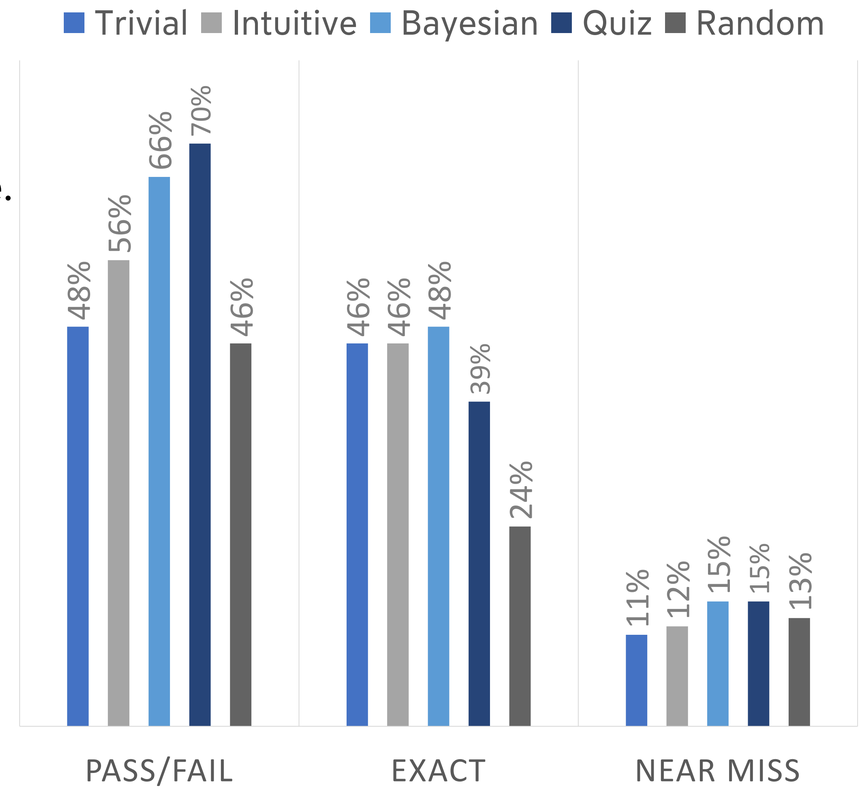
$$\mathrm{C} \times \mathrm{Id_L} \times \mathbb{D} \to (\mathbb{I} \times \mathbb{I})$$

The learner model is updated using evidence collected from quizzes, assessments, and learner interactions.

CAN EXAM GRADES BE PREDICTED?

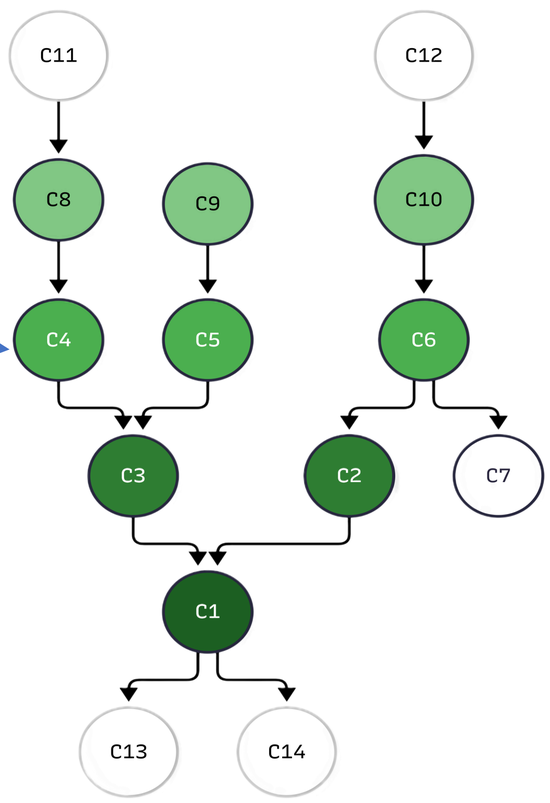


- **Random:** Serves as a baseline for comparison.
- **Quiz**: Predicts final grades solely from quiz performance.
- Model performance was evaluated using Pass/Fail accuracy, Exact predictions, Near Misses, and Average Grade Step Difference.
- Bayesian achieved the best overall grade prediction performance.
- Semantic concept dependencies improved predictive accuracy beyond quiz scores alone.
- Dependency-aware learner modeling outperformed the Trivial baseline.
- Learner models can support early identification of students at risk.



UPDATE MECHANISMS

- **Trivial:** direct competence update from assessment scores.
- **Intuitive:** ripple-based propagation across dependent concepts as illustrated.
- **Bayesian:** evidence-based probabilistic competence estimation.
- Dependency-aware propagation improves learner state estimation and grade prediction.
- A concept depends on another concept if that concept appears in one of its definitions.
- Concept dependencies are represented and stored in a knowledge graph.



CONCLUSION

- Semantic learner modeling and concept dependency relations significantly improve learner model accuracy.
- The Bayesian learner model achieved the best predictive performance among the evaluated approaches.
- Mathematical Knowledge Management (MKM) techniques provide an effective foundation for learner modeling and adaptive learning.
- Semantic annotations enable meaningful interpretation of learner interactions and educational data.
- Although semantic modeling requires higher initial effort, its reusability across applications helps justify the investment.

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WHERE DO YOU THINK WE CAN USE IT?