How can Learning Design and Learning Analytics support the validity of e-assessment in mathematics?

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RAPIDE
Relevant assessment and pedagogies for inclusive digital education

Why assessment validity?

- Many aspects of our work have been changed even though we haven't changed our job
  - Classroom setting, administration, teaching equipment, students' pre-knowledge and motivation, etc.
- But assessment has changed the least, at least until the pandemic
- At the same time, assessment is a very powerful tool that can activate a deeper students' approach to learning
- In order to use that tool properly, the tool should be valid
- Validity can be ensured by
  - Learning Design in the Planning Phase
  - Learning Analytics in the Implementation and Evaluation Phase

Assumptions

Develop sound, student-centred learning design (LD), assessment is constructively aligned with the intended learning outcomes (LO)

Constructive alignment is crucial for ensuring the validity of an assessment program

Learning analytics (LA) can provide insights that help develop valid assessment programs

What this presentation adds?

- **prioritization of LOs**
- **continuous improvement of LD**
- **clustering of students**
- **enable the development** of databases of assessment tasks, recommendation systems, self-regulated learning, informed-decision making by teachers and students

Learning Design – elements

Link between LOs and content, structure, timing

Pedagogical strategies, sequence of teaching and learning activities

Type and frequency of assessment in the course

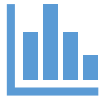
Students' workload

Feedback to students and collaboration

Nature of technology used to support learning

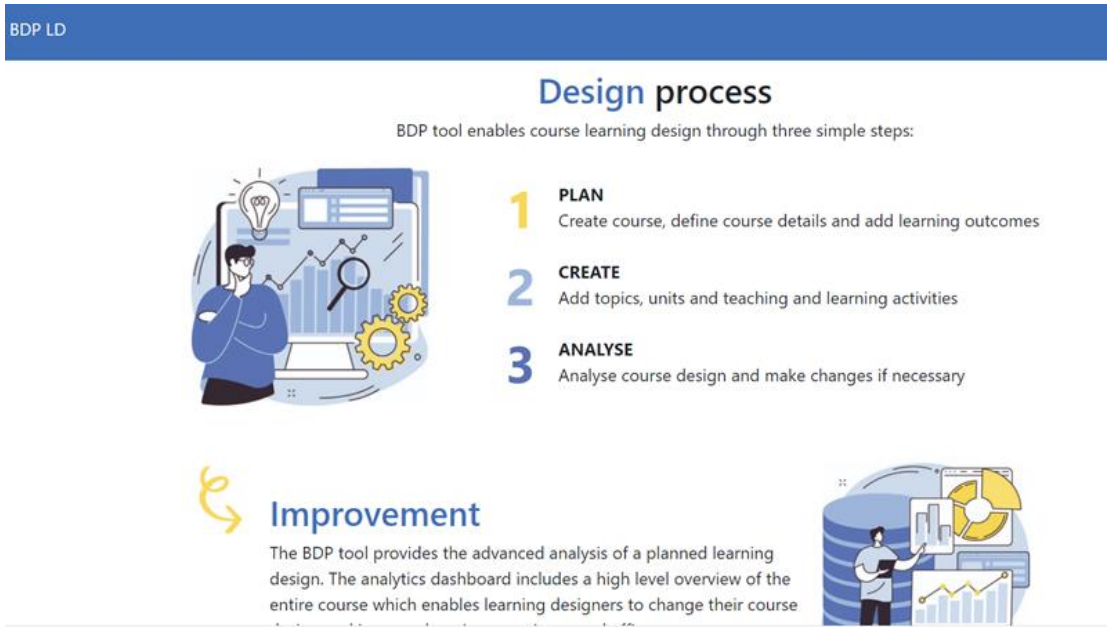
Mode of delivery

Learner group size



Learning analytics

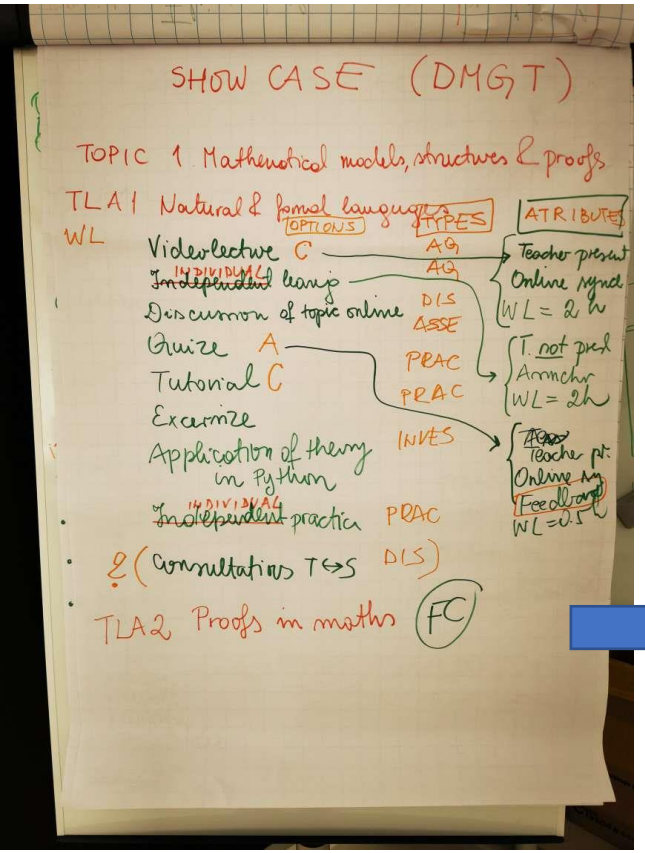
Learning Design - tool

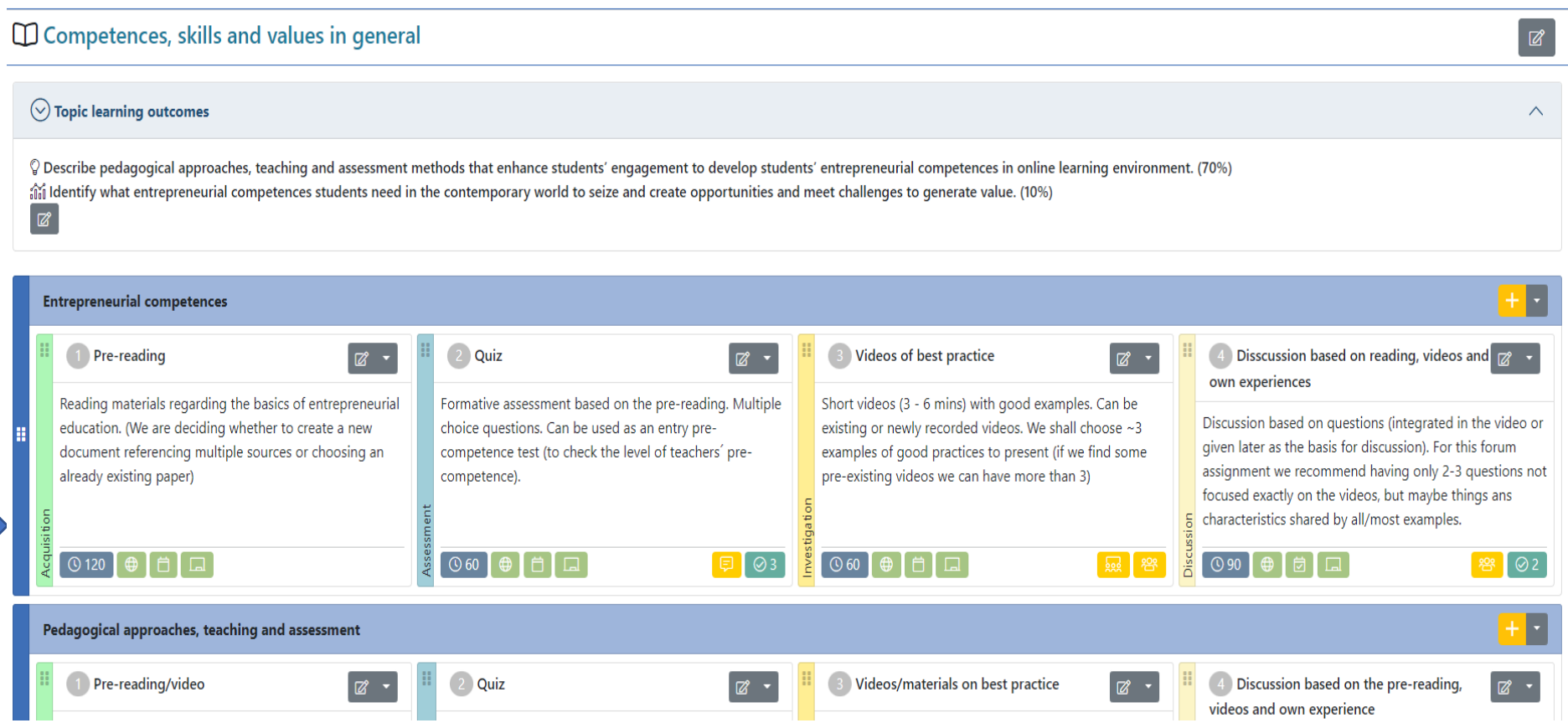


- LD has two aspects: **conceptual** and **technological**
- A range of LD tools developed
- Concept of sharing and reusing, possibilities for co-creation
- **Balanced Learning Design Planning – BDP**
- https://learning-design.eu – free to use

B. Divjak, D. Grabar, B. Svetec, P. Vondra (2022) „Balanced Learning Design Planning: Concept and Tool." Journal of Information and Organizational Sciences. 2/2022. Available: https://www.researchgate.net/publication/359320864_Balanced_Learning_Design_Planning_Concept_and_Tool

From paper-based planning to the BDP tool https://learning-design.eu





Mathematics courses for IT students with an e-assessment program

Course	Study level year	No of students	Assessment program Formative	Assessment program Summative
Mathematics 1	Undergraduate 1st year	350	Weekly e-quizzes *Automated grading & feedback* Bi-weekly assignments	3 monthly tests *(e-exam bank)* Essay on a math topic *Workshop with a rubric*
Mathematics 2	Undergraduate 1st year	350	Weekly e-quizzes *Automated grading & feedback* Assignments	3 tests *(e-exam bank)* Essay with problem-solving *Workshop with a rubric*
Mathematical Methods for IT	Undergraduate 2nd year	250	Weekly e-quizzes *Automated grading & feedback*	3 tests *(e-exam bank)* Problem solving with programming *Workshop with a rubric*
Discrete Mathematics & Graph Theory	Graduate 1st year	120	Weekly e-quizzes *Automated grading & feedback*	2 tests *(e-exam bank)* Team project with programming *Workshop with a rubric*

Utility framework for assessment

- According to Van der Vleuten & Schuwirth (2005), the utility framework for assessment depends on 5 factors:
  - **Validity**
  - **Reliability** (the accuracy of pass and fail decisions)
  - **Educational impact**
  - **Acceptability**
  - **Cost of assessment**
- A single assessment method can never be perfect for all the criteria and assessment involves a compromise
- Our aim: to use learning design and learning analytics to support planning, monitoring and evaluation of an assessment program according to the utility framework

Utility assessment elements

Utility elements	How to evaluate?	Who? By which method?
Validity	Constructive alignment Weights of assessment tasks based on weights of LOs	Group decision making with MCDM Teachers
Reliability	Reliability of assessment tasks Composite index on the course level	Learning analytics of LMS data *Coefficient of internal consistency-CIC* https://docs.moodle.org/dev/Quiz_report_statistics
Educational impact	Questionnaires and reports Analysis of LMS data Learning Design improvement	Students, Alumni, Learning analytics based on LMS activity data
Acceptability of the method to the stakeholders	Questionnaires Focus groups Interviews	Students, Teachers (staff), Employers, Experts, University management
Cost of assessment	Cost, time Available human resources	University management Teachers

Aspects of assessment validity

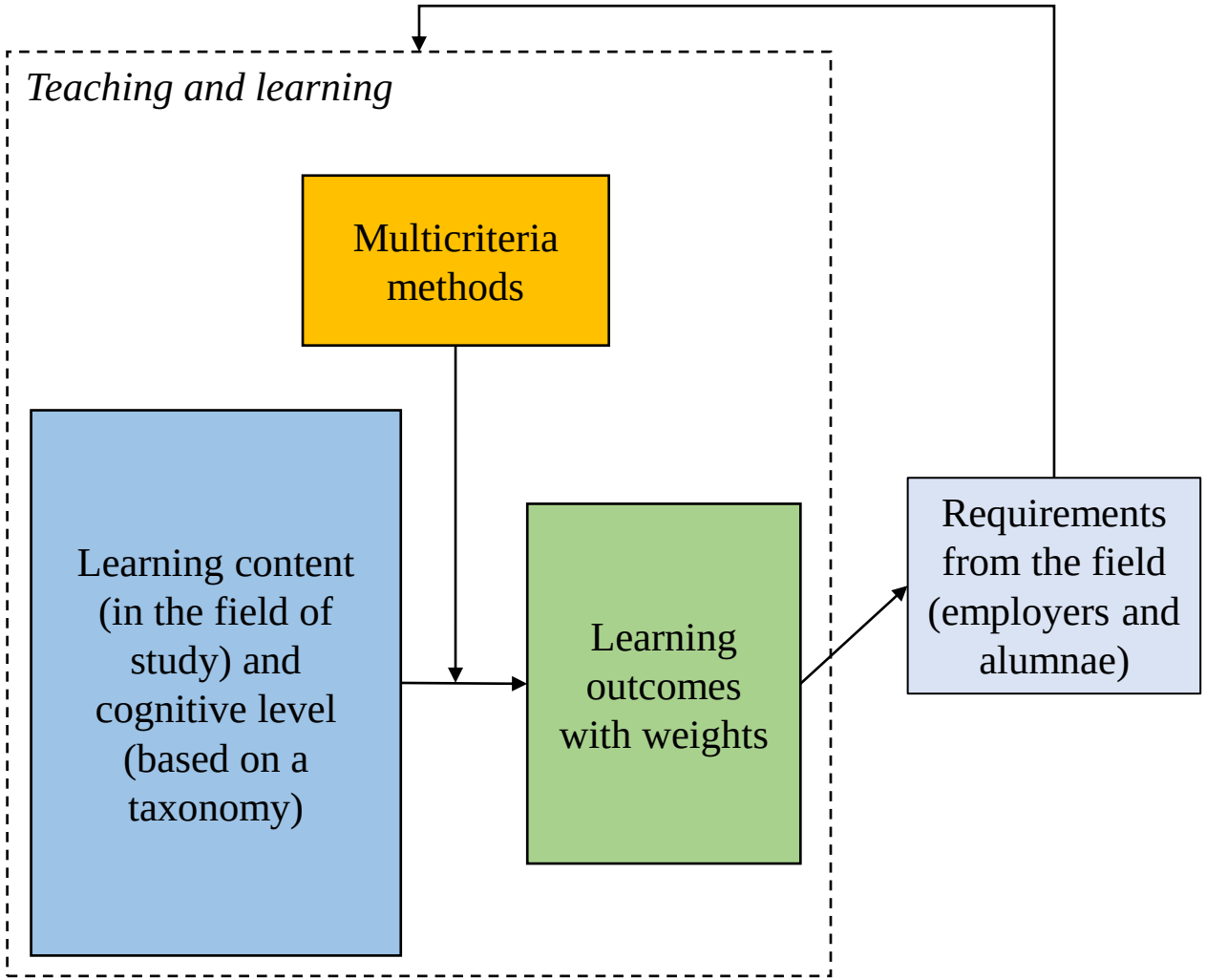
- **Content validity** - extent to which essential aspects of a domain are represented in assessment
  - linking assessment with LOs
- **Criterion validity** – how assessment scores are correlated with relevant external measures
  - developing assessment in line with LO weights
- **Construct validity** – how what is actually assessed corresponds with what is intended to be assessed
  - assessment weights to reflect the LO prioritization
- **Consequential validity** – use of assessment and its consequences for teaching and learning
  - Impact on learning

(Pellergino et al., 2016)

Validity

- Assessment to be judged based on its purpose
- Whole assessment program: link assessment to the intended learning outcomes
- Use of the analytic hierarchy process (AHP) and the analytic network process (ANP) methods to select evaluation criteria and determine weights of evaluation criteria and the consequent weights of LOs
- Constructive alignment (Biggs, 2003)
- Use of assessment rubrics

- Divjak B., Kadoić N., Žugec B. The Use of Decision-Making Methods to Ensur Assessment Validity. 2021 *IEEE Technology & Engineering Management Conference - Europe*



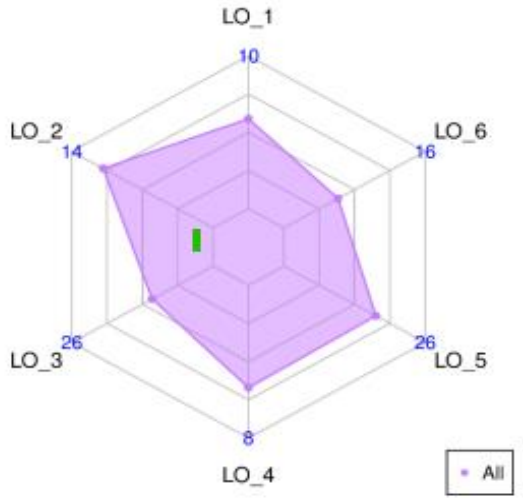
Case: Discrete Mathematics with Graph Theory (DMGT)

- DMGT course at the graduate level of IS/software engineering study; 120 students
- **Evaluation criteria** (order of priority):
  - C1 - Importance of the topic or context for the future profession
  - C2 – Required level of the LO based on Bloom's taxonomy
  - C3 - Contribution to the development of the 21st-century generic skills
  - C4 - Student workload needed to fulfill the LO

Learning outcomes	C1	C2	C3	C4	Total priorities
	0,42	0,23	0,22	0,13	
LO1 - Identify structures and types of proofs in mathematics	0,08	0,24	0,13	0,22	0,15
LO2 - Identify and classify binary relations on sets, knowing their properties and characteristic examples	0,13	0,17	0,11	0,13	0,14
LO3 - Apply theory and algorithms based on number theory to problems from cryptography	0,19	0,16	0,18	0,17	0,18
LO4 - Define and connect fundamental notions and problems in the scope of graph theory	0,16	0,11	0,14	0,11	0,14
LO5 - Effectively work in a team on problem posing and solving real problems related to graph theory and discrete mathematics	0,28	0,18	0,29	0,22	0,25
LO6 - Apply theorems and algorithms from graph theory to standard exercises from graph theory	0,15	0,14	0,15	0,14	0,15

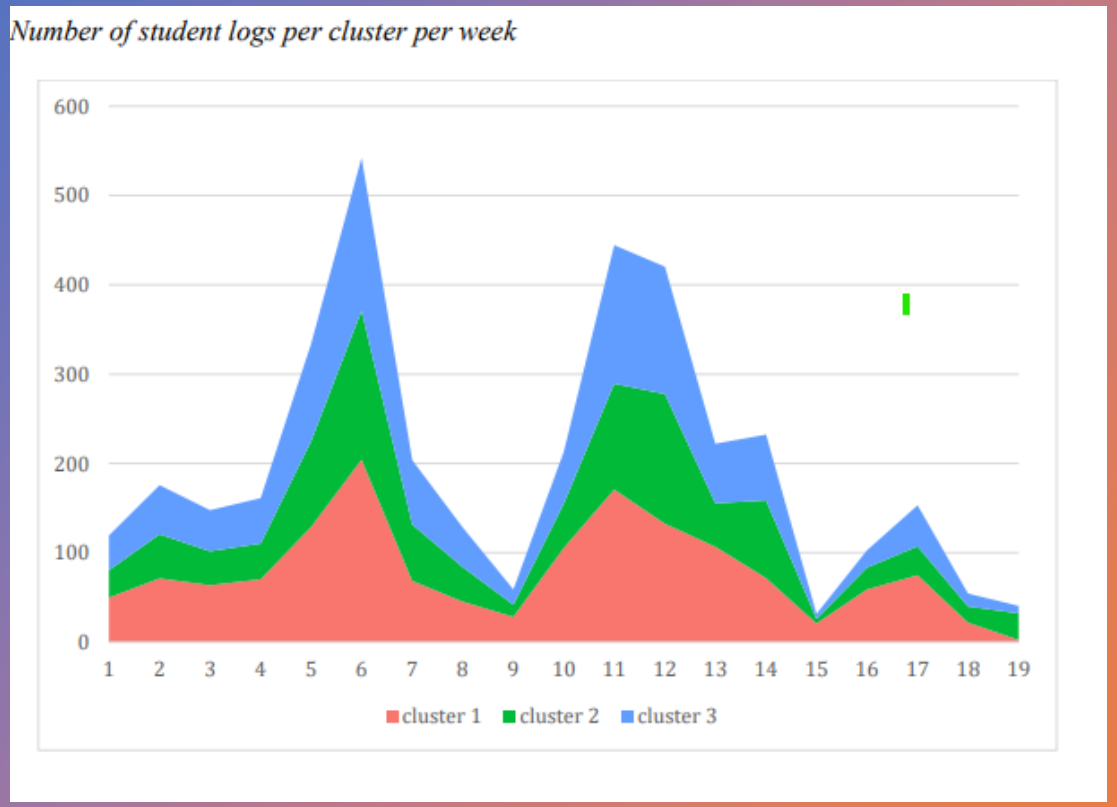
DMGT

- The DMGT course LOs, with levels according to the revised Bloom's taxonomy
- Ideal weight determined using MCDM in group decision-making with 3 course teachers
- Actual assessment weights (maximum points) based on the mapping of assessment assignments to the LOs
- Overall percentage of achievement - actual students' results divided by the maximum number of points
- LOs at lower levels (Understanding, Applying) were acquired more successfully, whereas those at higher levels (Evaluating) were acquired less successfully



LOs with levels, weights and students' achievement

LO		LO level	Ideal LO weight	Actual assessment weight (AAW)	Overall LO achievement in relation to AAW
LO1	Define and classify binary relations on sets, knowing their properties and characteristic examples	Understanding	14	10	59%
LO2	Define and connect fundamental notions and problems in the scope of graph theory	Understanding	14	14	78%
LO3	Effectively work in a team on problem posing and solving the real problem related to graph theory and discrete mathematics	Evaluating	25	26	43%
LO4	Identify structure and type of proofs in mathematics	Applying	14	8	67%
LO5	Apply theorems and algorithms from graph theory to standard exercises from graph theory	Applying	15	26	65%
LO6	Solve real problems by applying theory and algorithms based on number theory	Evaluating	18	16	38%
	Total		100	100	



LA trace data DMGT

- Further analysis based on clustering of students and trace data (LA)
- Peaks in activity around the two periodical exams, and a decrease at the end of the semester, when students worked on PBL and could cooperate outside the LMS

Reliability

- *Reliability - extent to which an assessment method measures consistently the performance of the student*
- *Assessments are usually expected to produce comparable outcomes, with consistent standards over time and between different learners and examiners*
- Reliability of assessment task (test) and assessment program
- Data from the LMS (Moodle)
- Our approach:
  - **Coefficient of Internal Consistency** (CIC)
  - Cronbach alpha - coefficient of reliability/consistency for assessment tasks
  - Target: >70%
  - Build composite index for the whole assessment program – based on weighted arithmetic mean or weighted geometric mean

DMGT composite reliability index (2020/2021)

Composite CIC for DMGT – based on a weighted arithmetic mean	**Composite CIC for DMTG – based on a weighted geometric mean**
72.73 %	72.54 %

Assessment tasks	Weights of tasks	**CIC (Cronbach alpha)**	Weighted arithmetic CIC	Weighted geometric CIC
Test 1	0.3204	67.81	21.72	3.86
Test 2	0.2913	72.44	21.10	3.48
Quizzes	0.0971	87.85	8.53	1.54
Project (team)	0.2913	73.41	21.38	3.49

“Ideal task”

- Based on CIC
- Mathematics 1 – Exam 3

Zadan je sustav linearnih jednadžbi

$$\begin{aligned} px - 2y &= -18 \\ -4x - y - 3z &= -7 \\ x + z &= 0\,. \end{aligned}$$

a) Za koju je vrijednost parametra p matrica sustava singularna

$p =$ ____ .

b) Za $p = -3$ odredite inverz matrice sustava A.

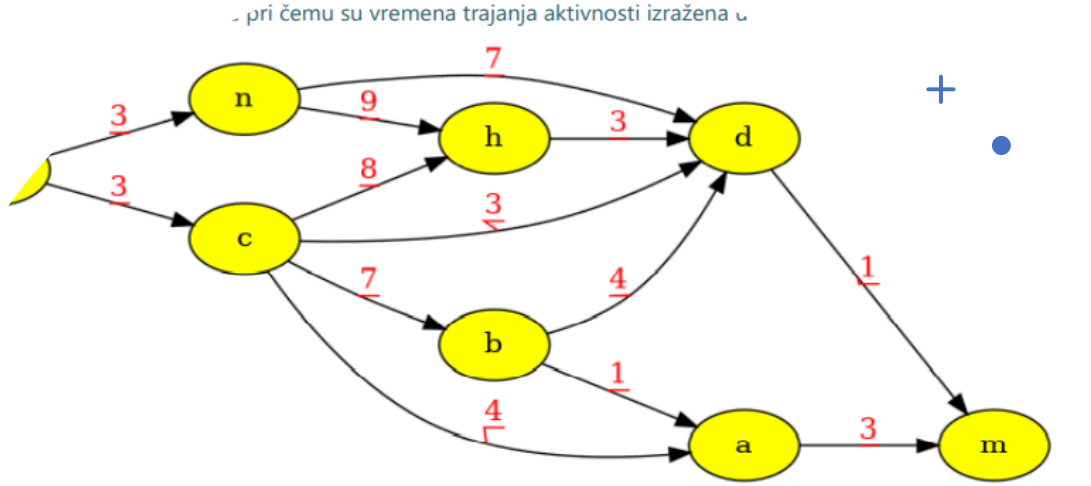
$$A^{-1} = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix}.$$

c) Riješite sustav za $p = -3$ pomoću inverzne matrice iz b) po

Rješenje. (____ , ____ , ____)

“Ideal” task

- Task based on CIC
- DMGT
- Exam 2



nite sljedeću tablicu ako je **V(v)** najranije vrijeme početka događaja **v**, a **K(v)** najkasnije vrijeme završetka događaja **v**.

a	b	c	d	e	h	m	n
11 ✔	10 ✔	3 ✔	15 ✔	0 ✔	12 ✔	16 ✔	3 ✔
13	11 ✔	4 ✔	15 ✔	0 ✔	12 ✔	16 ✔	3 ✔

nalno mjeseci traje projekt.

Tasks – problem-oriented and numerous DMTG,
No of students 120

Balance

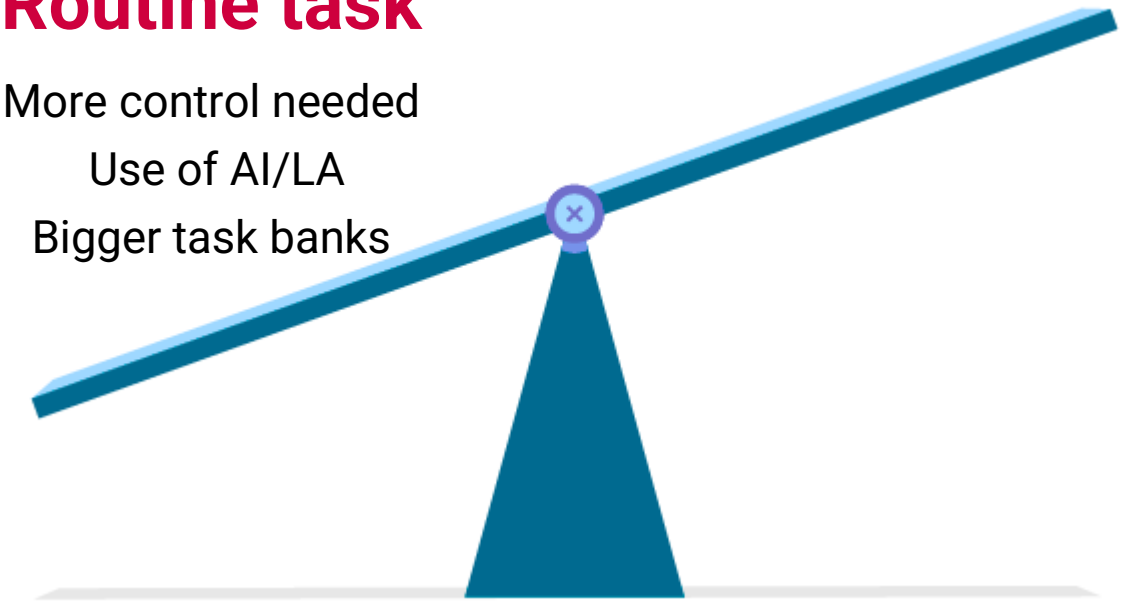
Complex READ task

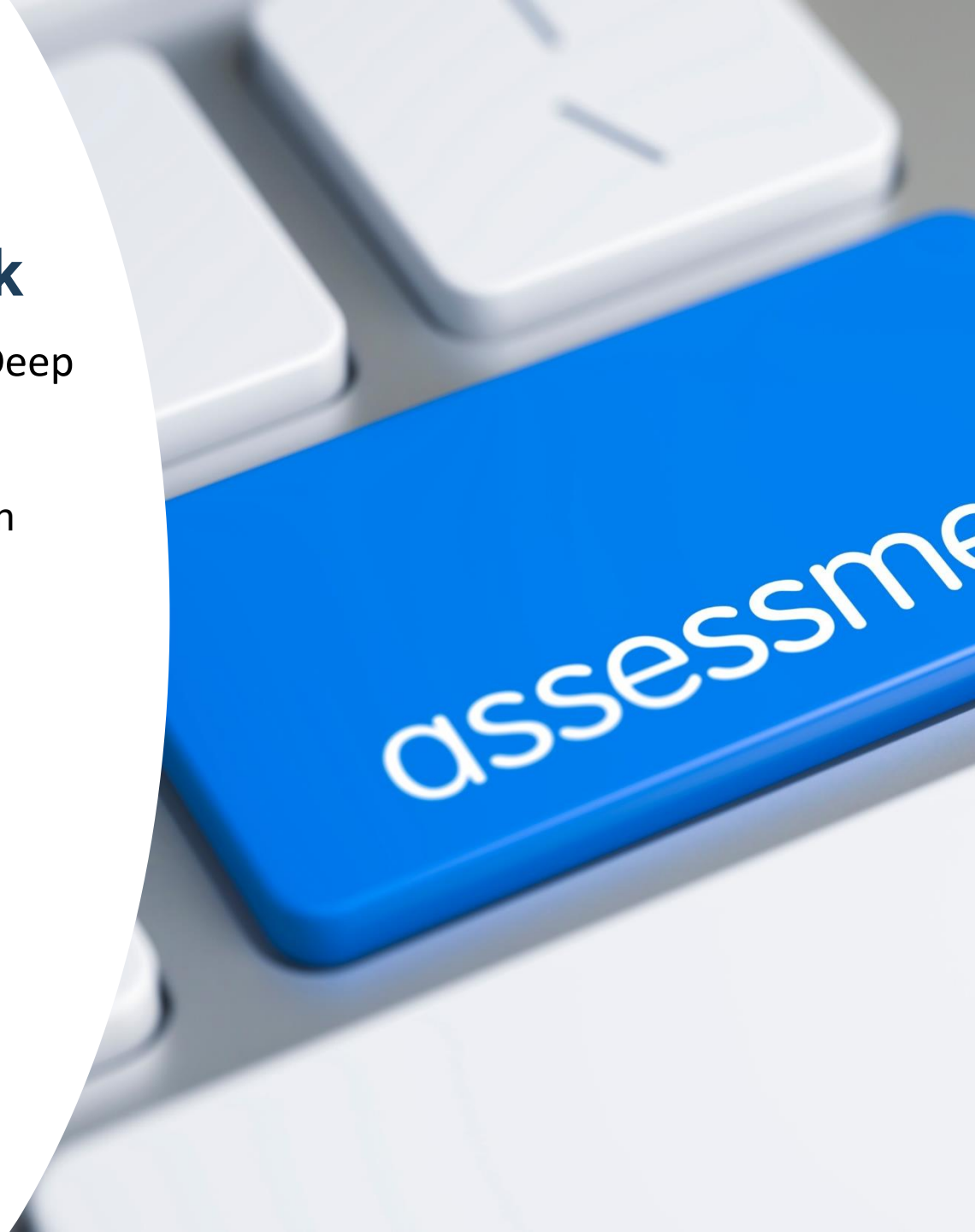
Relevant, **E**ssential, **A**uthentic, **D**eep

Less control
More fun
More time spent on preparation

Routine task

More control needed
Use of AI/LA
Bigger task banks





Practical implications for mathematics e-assessment

- LA can provide important **insights** for the development or **improvement of LD** in line with the intended course LOs
- LA can also contribute to the **development of databases of assessment tasks** aligned with course LOs, with **ensured validity and reliabality**, supporting sharing and reusing
- LA can support the development of **tailored educational interventions** corresponding with the needs of specific student groups
- Proposed LA can also contribute to the development of **recommendation systems**, as well as students' meta-cognition and self-regulated learning

References:

- S. Bennett, S. Agostinho and L. Lockyer, "Technology tools to support learning design: Implications derived from an investigation of university teachers' design practices", Computers & Education, 81, 211–220, 2015. Available: https://doi.org/10.1016/j.compedu.2014.10.016
- G. Conole, Designing for Learning in an Open World, Springer New York, 2013. Available: https://doi.org/10.1007/978-1-4419-8517-0
- Cox, W. (2003). A MATH-KIT for engineers. Teaching Mathematics and Its Applications: An International Journal of the IMA, 22(4), 193–198. https://doi.org/10.1093/TEAMAT/22.4.193
- B. Divjak, D. Grabar, B. Svetec, P. Vondra (2022) „Balanced Learning Design Planning: Concept and Tool." Journal of Information and Organizational Sciences. 2/2022. Available: https://www.researchgate.net/publication/359320864_Balanced_Learning_Design_Planning_Concept_and_Tool
- Divjak B., Kadoić N., Žugec B. The Use of Decision-Making Methods to Ensur Assessment Validity. 2021 *IEEE Technology & Engineering Management Conference – Europe*
- Divjak, B., Žugec, P., & Pažur Aničić K. (2022). E-assessment in mathematics in higher education: a student perspective. To be published in the International Journal of Mathematical Education in Science and Technology
- R. Koper and B. Olivier, "Representing the learning design of units of learning", Educational Technology & Society, 7(3), 97–111, 2004. Available: https://www.j-ets.net/collection/published-issues/7_3
- L. Lockyer and S. Dawson, "Learning designs and learning analytics", Proceedings of the 1st International Conference on Learning Analytics and Knowledge - LAK '11, 153, 2011. Available: https://doi.org/10.1145/2090116.2090140
- L. Lockyer, E. Heathcote and S. Dawson, S. "Informing Pedagogical Action: Aligning Learning Analytics with Learning Design", American Behavioral Scientist, 57(10), 2013. Available: https://doi.org/10.1177/0002764213479367
- D. Persico and F. Pozzi, F., "Informing learning design with learning analytics to improve teacher inquiry", British Journal of Educational Technology, 46(2), pp. 230–248, 2015. https://doi.org/10.1111/bjet.12207
- B. Rienties and L. Toetenel, "The impact of learning design on student behaviour, satisfaction and performance: A cross-institutional comparison across 151 modules", Computers in Human Behavior, 60, pp. 333–341, 2016. Available: https://doi.org/10.1016/j.chb.2016.02.074
- van der Vleuten, C. P. M. (1996). The assessment of professional competence: Developments, research and practical implications. Advances in Health Sciences Education, 1(1), 41–67. https://doi.org/10.1007/BF00596229

Thank you

Q & A