Informatics Higher Education in Europe: Readiness and Core Skills

Andreas Bollin – University of Klagenfurt
Agustín Yagüe – Universidad Politécnica de Madrid
ECSS 2026, Porto

Welcome



Today's Program:

- **14:00–14:10** (10 min) **Opening & Framing**
- **14:10–14:50** (40 min) **Part A – Pathways into HE: Readiness vs. Early HE Reality**
  GECKO showcase, audience mapping and readiness gaps
- **14:50–15:30** (40 min) **Part B – Informatics Skills as a Foundation for Multiple Disciplines**
  TU Madrid input, group activity and common skills
- **15:30–16:00** (30 min) **Part C – Perspective & Wrap-Up**
  Expert perspectives, audience discussion and practical actions

Welcome

Andreas Bollin



- Head of Informatics Didactics Department / University of Klagenfurt
- Lead of Austrian “Informatics and AI” Curriculum
- (Deputy) Programme Director – Informatics & Informatics Education
- Head of “Informatik-Werkstatt” (approx. 3’000 pupils / year)

Agustín Yagüe



- Assoc. Prof. of Software Engineering / Universidad Politécnica de Madrid
- Former Dean of the School of Computer Systems Engineering (2017–2025)
- Research in Agile Software Development, Project Management, Software Quality, Software architecture and Software architecture in/by artificial intelligence

Why are we here? (1/4)

Three Questions we want to explore:

1. What informatics competencies do students bring into Higher Education?

2. What do universities expect – and where are the gaps?

3. Which informatics competencies are essential across disciplines?

➔ Informatics belongs to GENERAL EDUCATION

Why are we here? (2/4)

Part	Guiding Question	Expected Outcome
A - Readiness	What do students bring, and what do we expect?	3–5 readiness gaps
B - Skills	What is the common informatics core?	Common and discipline-specific competencies
C - Actions	What can we realistically improve?	3–5 practical actions

Wh

➔ Visit **gosocrative.com** and enter room name **"bollin1549"**

Live Poll 1 – Getting to know our audience:

Multiple Choice:

1. Higher Education – Informatics
2. Higher Education – Other Disciplines
3. School Education / Outreach
4. Education Research / Curriculum
5. Policy / Industry / Other

➔ Visit **gosocrative.com** and enter room name **"bollin1549"**

Why are we here? (4/4)

How Can We Make Competencies Comparable?

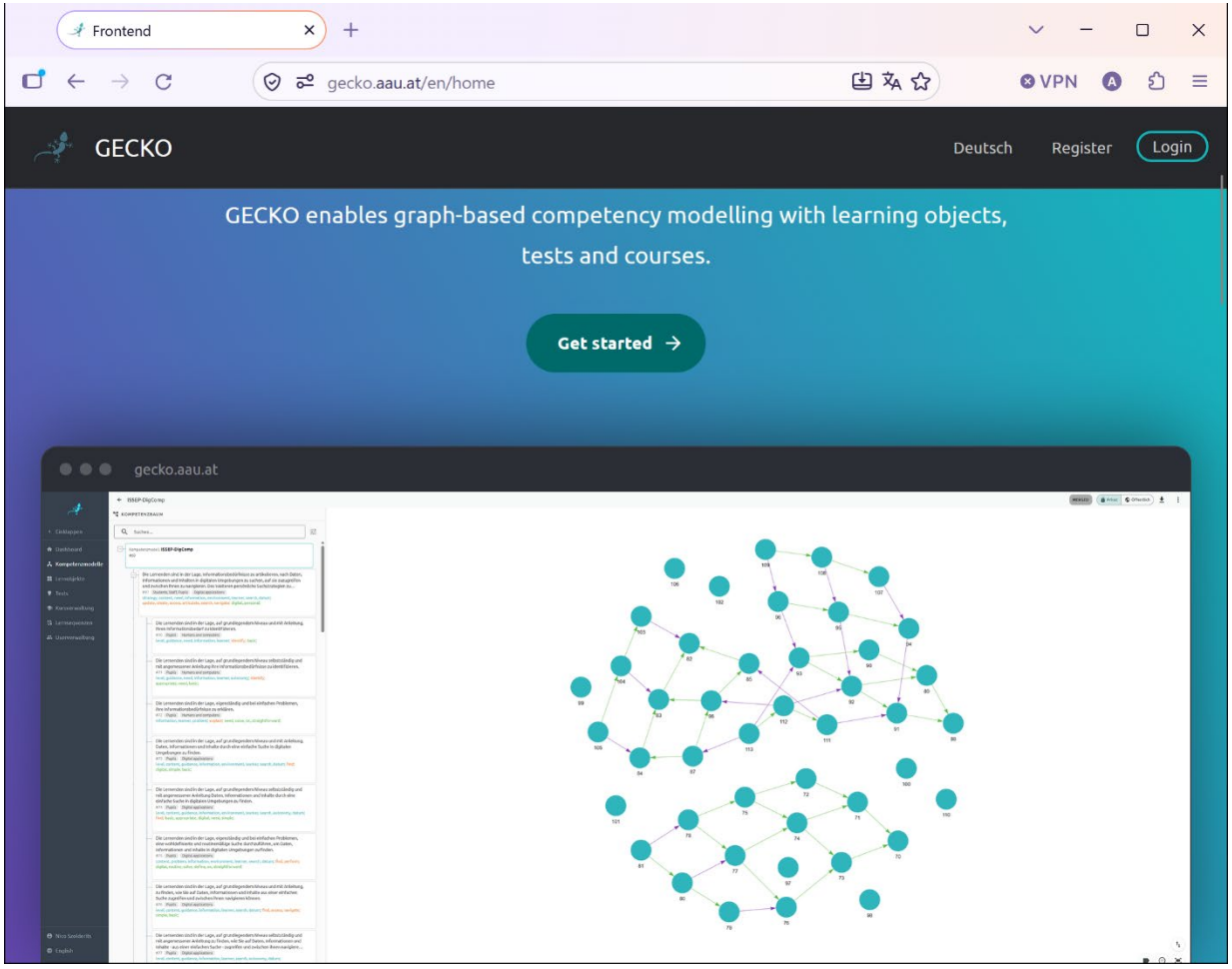
Challenges are …

- Different national curricula
- Different educational pathways
- Different competency descriptions
- Different HE entry expectations

A - GECKO Showcase

Andreas Bollin

https://gecko.aau.at



A – Readiness Gaps (1/3)

Life-Poll 2: Where do you observe the **largest gaps** between expected and actual entry competencies?

- Algorithmic thinking and problem solving
- Programming and debugging
- Abstraction and modelling
- Mathematical and logical reasoning
- Data and AI fundamentals
- Computer systems and networks
- Self-directed learning and persistence

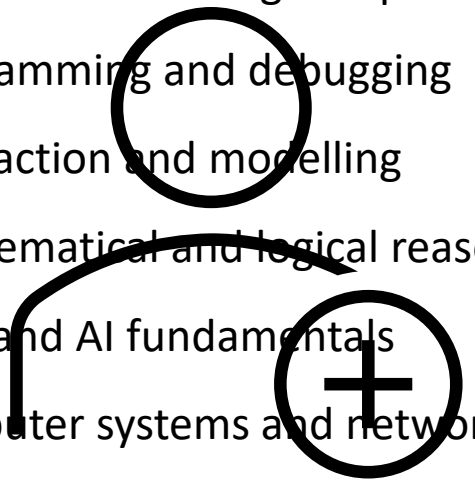


➔ Visit **gosocrative.com** and enter room name **"bollin1549"**

A – Readiness Gaps (2/3)

Life-Poll 2(contd.): Which informatics competencies should students **already have** when entering HE?

- Algorithmic thinking and problem solving
- Programming and debugging
- Abstraction and modelling
- Mathematical and logical reasoning
- Data and AI fundamentals
- Computer systems and networks
- Self-directed learning and persistence



➔ Visit **gosocrative.com** and enter room name **"bollin1549"**

A – Readiness Gaps (3/3)

Our Most Important Perceived Readiness Gaps (an attempt):

Opportunity Gap: Students never had the opportunity to develop a particular competency at school.

Competency Gap: Students were taught the relevant content but have not developed the expected level of competence.

Expectation Gap: Universities expect competencies that are not part of the intended school preparation.

Readiness Gap	Opportunity (O)	Competency (C)	Expectation (E)
1. Programming & Debugging	●	●	—
2. Algorithmic Thinking & Problem Solving	●	●	●
3. Abstraction & Modelling	○	●	◐
4. Mathematical & Logical Foundations	○	●	●
5. Computer Systems & Data Fundamentals	●	○	—
6. AI Foundations & Understanding	●	●	—
7. Self-directed Learning & Persistence	○	●	◐

● = primary/plausible cause or documented expectation; ◐ = partially documented expectation; ○ = possible cause; — = no sufficiently documented general entry expectation.

B – Traversal Skills (1/9)

Informatics skills to be analyzed

A taxonomy of 14 fields and 76 subfields frames every rating

1. **Mathematical and theoretical foundations** · 6 subfields
2. **Programming and algorithms** · 6 subfields
3. **Software engineering** · 6 subfields
4. **Computer engineering** · 6 subfields
5. **Operating systems and distributed computing** · 5 subfields
6. **Networks and communications** · 6 subfields
7. **Cybersecurity** · 5 subfields
8. **Data and information systems** · 6 subfields
9. **Artificial intelligence** · 7 subfields
10. **Graphics, multimedia and interaction** · 6 subfields
11. **Web and mobile technologies** · 4 subfields
12. **Applied computing** · 5 subfields
13. **Computing, business and society** · 3 subfields
14. **Digital skills applied to engineering** · 5 subfields

B – Traversal Skills (2/9)

Aligned with CS2023 and the ACM CCS

Field	Subfields
1 Mathematical and theoretical foundations	1.1 Discrete mathematics · 1.2 Logic · 1.3 Statistics and probability · 1.4 Numerical methods · 1.5 Theory of computation · 1.6 Formal languages and automata
2 Programming and algorithms	2.1 Programming fundamentals · 2.2 Data structures · 2.3 Algorithms and complexity · 2.4 Object-oriented programming · 2.5 Programming paradigms · 2.6 Language processors
3 Software engineering	3.1 Requirements engineering · 3.2 Software design and architecture · 3.3 Verification, validation and testing · 3.4 Software quality · 3.5 Project management · 3.6 Agile methodologies and DevOps
4 Computer engineering	4.1 Computer technology and structure · 4.2 Computer architecture · 4.3 Embedded systems · 4.4 Real-time systems · 4.5 Robotics · 4.6 Control and automation
5 Operating systems and distributed computing	5.1 Operating systems · 5.2 Concurrency · 5.3 Parallel and high-performance computing · 5.4 Distributed systems · 5.5 Cloud computing
6 Networks and communications	6.1 Computer networks · 6.2 Internet and protocols · 6.3 Mobile and wireless networks · 6.4 Internet of things · 6.5 Network and systems administration · 6.6 Quantum communications
7 Cybersecurity	7.1 Information security · 7.2 Cryptography · 7.3 Network and systems security · 7.4 Auditing and forensic analysis · 7.5 Post-quantum cryptography and cryptographic migration
8 Data and information systems	8.1 Databases · 8.2 Data warehouses and business intelligence · 8.3 Big data · 8.4 Data mining · 8.5 Enterprise information systems · 8.6 E-commerce
9 Artificial intelligence	9.1 Machine learning · 9.2 Knowledge representation and reasoning · 9.3 Agents and multi-agent systems · 9.4 Natural language processing · 9.5 Computer vision · 9.6 Bio-inspired computing · 9.7 Generative AI
10 Graphics, multimedia and interaction	10.1 Computer graphics · 10.2 Visualization · 10.3 Virtual and augmented reality · 10.4 Video games · 10.5 Multimedia · 10.6 Human-computer interaction
11 Web and mobile technologies	11.1 Web development · 11.2 Semantic web · 11.3 Web services · 11.4 Mobile applications
12 Applied computing	12.1 Geographic information systems and remote sensing · 12.2 Scientific computing · 12.3 Computer-aided design · 12.4 Bioinformatics · 12.5 Applied quantum computing
13 Computing, business and society	13.1 Ethics and legal aspects · 13.2 ICT business management · 13.3 History of and introduction to computing
14 Digital skills applied to engineering	14.1 Data analysis with Python, R or similar · 14.2 Professional use of generative AI tools · 14.3 Simulation, modelling and digital twins · 14.4 Task automation and scripting · 14.5 Cyber hygiene and personal data protection

Own taxonomy, built from the topics of courses with computing content. Fields 1-13 follow the CS2023 knowledge areas (ACM, IEEE-CS, AAAI) and the ACM CCS 2012; field 14 covers applied use in engineering. In coral, the 3 quantum subfields added on 15-10-2026.

B – Traversal Skills (3/9)

Engineering fields to be analyzed

The analysis covers 11 engineering areas and 39 UPM degrees

2 Aeronautical UPM degrees
School of Aeronautical and Space Engineering

5 Agricultural UPM degrees
School of Agricultural, Food and Biosystems Engineering

2 Architecture UPM degrees
Schools of Architecture (ETSAM) and Building (ETSEM)

1 Sport sciences UPM degree
Faculty of Physical Activity and Sport Sciences (INEF)

3 Forestry UPM degrees
School of Forestry Engineering and Natural Environment

2 Geomatics UPM degrees
School of Surveying, Geodesy and Cartography Engineering

1 Civil UPM degree
School of Civil Engineering

5 Mining UPM degrees
School of Mining and Energy Engineering

8 Industrial UPM degrees
ETSII and ETSIDI schools

2 Naval UPM degrees
School of Naval Engineering

8 Telecommunication UPM degrees
ETSIT and ETSIST (telecommunication schools)

Other Universities
Analysis In progress

Each area has its own required-level profile (1-5) for the 76 computing subfields. Each degree is assigned to the closest area.

B – Traversal Skills (4/9)

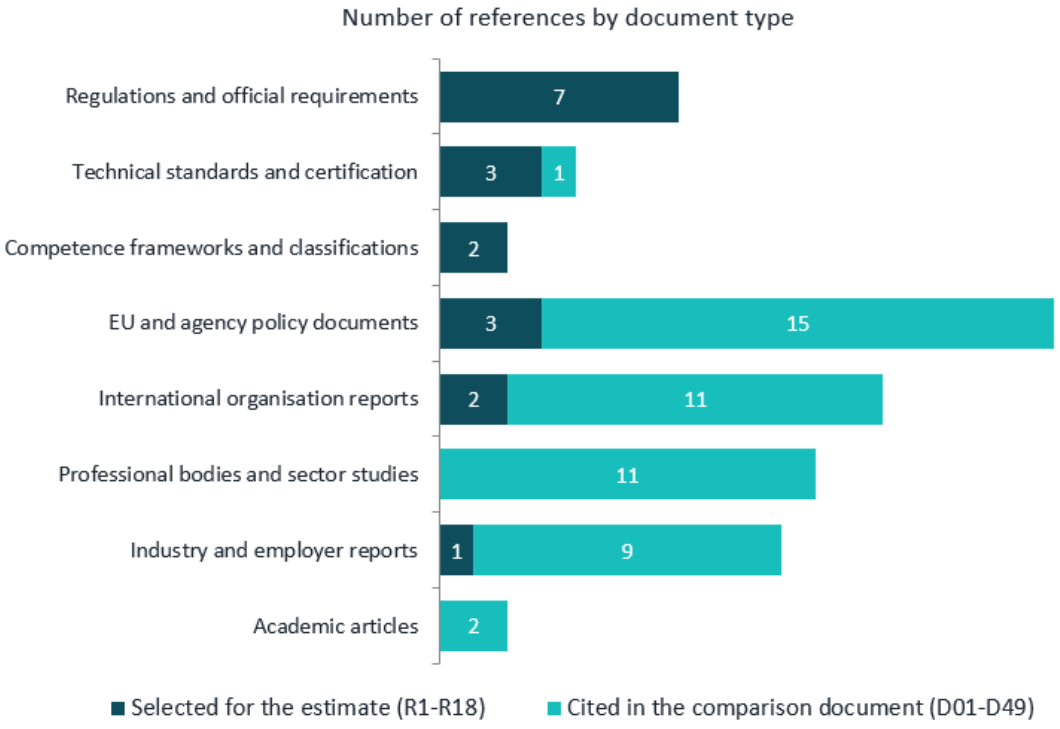
Each area needs a different profile; applied digital skills are common to all

Field	Agri	Forestry	Civil	Archit.	Indust.	Aero	Naval	Mining	Telecom	Sport	Geomat.
1 Mathematical and theoretical foundations	2.3 (1/6)	2.3 (1/6)	2.5 (2/6)	2.0 (1/6)	3.0 (2/6)	3.0 (3/6)	2.7 (2/6)	2.7 (2/6)	3.7 (4/6)	1.8 (1/6)	2.5 (2/6)
2 Programming and algorithms	2.5 (1/6)	2.5 (1/6)	2.5 (1/6)	2.0 (0/6)	3.3 (3/6)	3.5 (4/6)	2.7 (1/6)	2.5 (1/6)	**4.2** (5/6)	1.5 (0/6)	3.2 (3/6)
3 Software engineering	2.5 (1/6)	2.5 (1/6)	3.0 (1/6)	2.8 (1/6)	3.8 (4/6)	**4.5** (5/6)	3.8 (4/6)	3.2 (2/6)	**5.0** (6/6)	1.5 (0/6)	3.2 (1/6)
4 Computer engineering	2.8 (2/6)	2.2 (0/6)	2.2 (0/6)	2.0 (0/6)	**4.3** (4/6)	**4.5** (6/6)	**4.0** (4/6)	3.5 (4/6)	**4.5** (5/6)	1.2 (0/6)	2.2 (0/6)
5 Operating systems and distributed computing	2.0 (0/5)	2.2 (0/5)	2.8 (2/5)	2.4 (1/5)	3.4 (2/5)	3.8 (3/5)	3.4 (2/5)	3.0 (2/5)	**4.6** (5/5)	1.2 (0/5)	2.8 (1/5)
6 Networks and communications	2.7 (2/6)	2.5 (2/6)	2.3 (1/6)	2.2 (1/6)	3.2 (2/6)	3.3 (2/6)	3.2 (2/6)	2.8 (2/6)	**4.5** (5/6)	1.8 (1/6)	3.0 (2/6)
7 Cybersecurity	2.4 (0/5)	2.2 (0/5)	2.4 (0/5)	2.4 (0/5)	3.6 (2/5)	3.8 (3/5)	3.6 (2/5)	3.0 (1/5)	**4.6** (5/5)	1.4 (0/5)	2.2 (0/5)
8 Data and information systems	3.7 (4/6)	3.3 (2/6)	3.0 (2/6)	2.8 (2/6)	**4.0** (5/6)	3.3 (4/6)	3.3 (3/6)	3.5 (4/6)	**4.2** (5/6)	2.5 (0/6)	3.2 (3/6)
9 Artificial intelligence	2.7 (2/7)	2.7 (2/7)	2.7 (2/7)	2.9 (1/7)	3.6 (3/7)	3.3 (2/7)	3.1 (2/7)	3.1 (2/7)	3.9 (5/7)	2.0 (0/7)	2.9 (2/7)
10 Graphics, multimedia and interaction	2.5 (1/6)	2.7 (1/6)	3.3 (3/6)	3.8 (4/6)	3.2 (3/6)	3.5 (4/6)	3.3 (4/6)	3.2 (3/6)	3.2 (2/6)	2.8 (1/6)	3.2 (3/6)
11 Web and mobile technologies	2.2 (0/4)	2.2 (0/4)	2.5 (0/4)	2.5 (0/4)	3.0 (1/4)	2.2 (0/4)	2.5 (0/4)	2.2 (0/4)	**4.2** (3/4)	2.0 (0/4)	**4.0** (3/4)
12 Applied computing	3.2 (2/5)	3.0 (2/5)	3.2 (3/5)	3.0 (3/5)	3.0 (2/5)	3.4 (3/5)	3.2 (2/5)	3.2 (3/5)	3.2 (2/5)	1.4 (0/5)	3.2 (3/5)
13 Computing, business and society	2.3 (1/3)	2.3 (1/3)	2.3 (1/3)	2.3 (1/3)	2.7 (1/3)	2.3 (1/3)	2.3 (1/3)	2.3 (1/3)	3.3 (2/3)	2.7 (1/3)	2.3 (1/3)
14 Digital skills applied to engineering	**4.2** (5/5)	**4.2** (5/5)	**4.2** (5/5)	3.8 (4/5)	**4.6** (5/5)	**4.6** (5/5)	**4.2** (5/5)	**4.6** (5/5)	**4.6** (5/5)	3.6 (3/5)	**4.4** (5/5)

Cell: mean required level of the field (1-5) and, in brackets, subfields with level ≥ 4 out of the total. Coral ≥ 4.5 · amber 4.0-4.4 · grey 3.0-3.9 · white < 3.

B – Traversal Skills (5/9)

Eight types of documents, 67 references, support the required-level matrix



1 Estimate

Level 1-5 per subfield and area, backed by 18 selected references

2 Contrast

Compared with NecesidadesInformaticaActuales: 8 rating blocks citing 49 references

3 Weigh

Confidence H when a regulation or standard requires it, M for reports, L for expert judgement

B – Traversal Skills (6/9)

Binding rules set the high-confidence levels; reports and studies set the rest

Document type	What it contributes	Examples	Refs
Regulations and official requirements	Competences a rule makes compulsory (confidence H)	CIN orders (BOE 2009), EU AI Act, NIS2, Machinery Regulation, EASA Part-IS, BIM procurement plan, EUDR	**7**
Technical standards and certification	Requirements for certified systems (confidence H)	DO-178C via FAA AC 20-115D, IACS UR E26/E27, NIST FIPS 203-205, IMO MASS Code	**4**
Competence frameworks and classifications	Common vocabulary of digital skills	DigComp 2.2 (JRC), ESCO (European Commission)	**2**
EU and agency policy documents	Direction of digital transformation by sector	Digital Decade, Quantum Europe Strategy, EU post-quantum roadmap, JRC construction, EASA AI Roadmap, IMO digitalisation	**18**
International organisation reports	Evidence of skills demand	WEF Future of Jobs 2025, OECD AI skills, FAO precision agriculture, ITU 5G	**13**
Professional bodies and sector studies	Skill gaps reported by each profession	AIAA, SERC, LeaderSHIP (shipbuilding), CECIMO, Lantra, Future Skills Centre	**11**
Industry and employer reports	What employers hire for	McKinsey (digital twins, IIoT), Autodesk/Dodge (BIM), STL Partners, EY, Michael Page	**10**
Academic articles	Peer-reviewed evidence	BIM uptake in AEC degrees (2026); geospatial technologies in plantation forestry	**2**

Plus the NecesidadesInformaticaActuales document itself: 8 rating blocks (Doc-A to Doc-H) used as a second, independent assessment. Full list in the References sheet.

B – Traversal Skills (7/9)

<u>What Informatics Competencies Does Your Discipline Need?</u>

Corner cafe format:

- Two (Three?) corners:
  - Corner 1: Engineering Disciplines (Based on the taxonomy proposed)
  - Corner 2: Sciences and other Disciplines (Economics, Social Sciences, etc)
- Each person should go through both corners
- Timebox settings: 7.5 minutes
- Wrap up: 5 minutes

Time: 20 minutes

B – Traversal Skills (8/9)

What Informatics Competencies Does Your Discipline Need?

On each corner, team members tasks:

1. Identify 3–4 essential informatics competencies for your cluster.
2. Which should be developed before HE, and which in early HE?
3. Identify one realistic improvement for the coming year.

Time: 20 minutes

B – Traversal Skills (9/9)

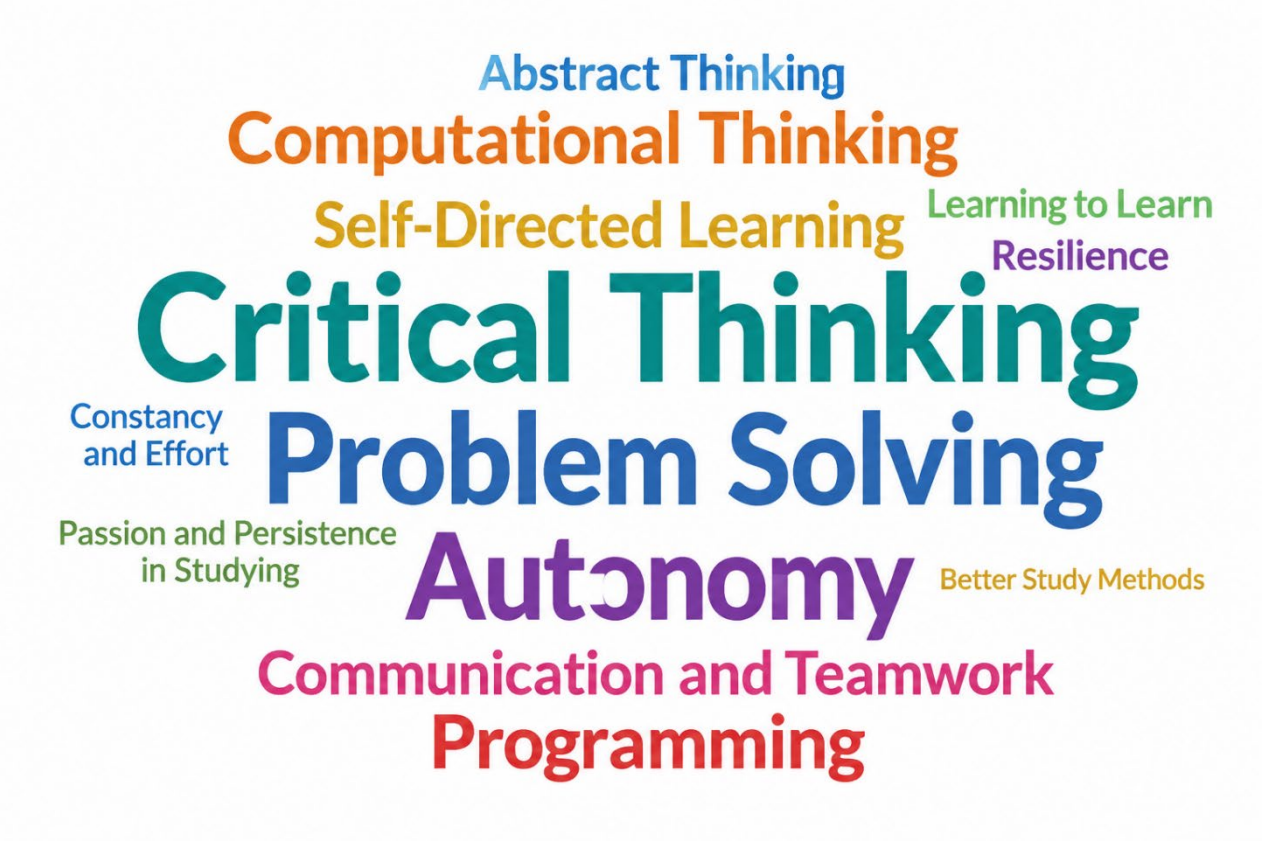
What Do Disciplines Share – and Where Do They Differ?

Some observations – do you agree?

Discipline	Discipline-Specific Needs	Common
Informatics	Formal methods, algorithms & complexity, software engineering, computer architecture & systems, applied informatics, AI development	• Algorithmic Thinking • Data Fundamentals • Programming & Automation • AI Foundations • Computing Systems & Security • Algorithmic Thinking
Engineering	Embedded AI, IoT, control systems	
Natural Sciences	Scientific computing, AI-based simulation	
Business & Economics	Predictive analytics, decision support	
Health & Life Sciences	Medical AI, sensitive data	
Humanities & Social Sciences	NLP, generative AI, algorithmic bias	

C – Where are we so far?

Life Poll 2: Which informatics competencies should students **already have** when entering HE?



C – Expectations and Reality (1/4)

Higher Education in Practice: A Case Perspective

Guests:

- Peter Puschner – TU Vienna
- Eduardo García Pardo – Universidad Rey Juan Carlos

Moderator: Agustín Yagüe

→ Objective: Reflecting on the findings from Parts A and B from the perspective of Higher Education practice.

C – Expectations and Reality (2/4)

Life-Poll 3: What can we **realistically** improve?

- Better communication of HE entry expectations
- Stronger school–university cooperation
- Shared competency frameworks
- Improved first-year support
- More targeted outreach initiatives



➔ Visit **gosocrative.com** and enter room name **"bollin1549"**

C – Expectations and Reality (3/4)

Conversation: Guiding Questions?

1. Where do you see the biggest mismatch between student preparation and HE expectations at your institution?

2. Which informatics foundations should schools provide, and which should universities teach?

3. What informatics skills are essential beyond Informatics programmes?

4. If you could change one thing to improve the transition into HE, what would it be?

C – Expectations and Reality (4/4)

Key Takeaways & Next Steps:

1. Part A (Readiness gaps):
   Programming, algorithmic thinking, mathematical foundations
   AI foundations: Data, models, training, inference & limitations
   Opportunity gaps vs. competency gaps vs. expectation gaps
   Better alignment of school preparation and HE expectations

2. Part B (Core and discipline-specific needs):
   Shared foundations: Algorithms, Data, Programming, AI, Systems
   AI increases the importance of informatics foundations
   Different applications and levels of depth across disciplines

3. Part C (3–5 realistic improvements):
   Communicate HE entry expectations more clearly
   Strengthen school–university collaboration → Werkstatt
   Develop shared competency maps → GECKO
   Provide targeted first-year bridging opportunities
   Exchange good practices across European institutions

Thank You – Let's Stay Connected

Thank You for Your Contributions!

Andreas Bollin – University of Klagenfurt

Agustín Yagüe – Universidad Politécnica de Madrid

Informatics Europe / NIAs

Contact information:
Andreas.Bollin@aau.at, agustin.yague@upm.es

Appendix - General Education

"Allgemeinbildung" ≠ vocational preparation

Humboldt (1793)

Self-formation through engagement with the world

Klafki (2000)

Self-determination, Co-determination, Solidarity

Biesta (2009)

Qualification, Socialization, Subjectification

Allgemeinbildung/General education for all enables

orientation, judgment, participation, and agency.