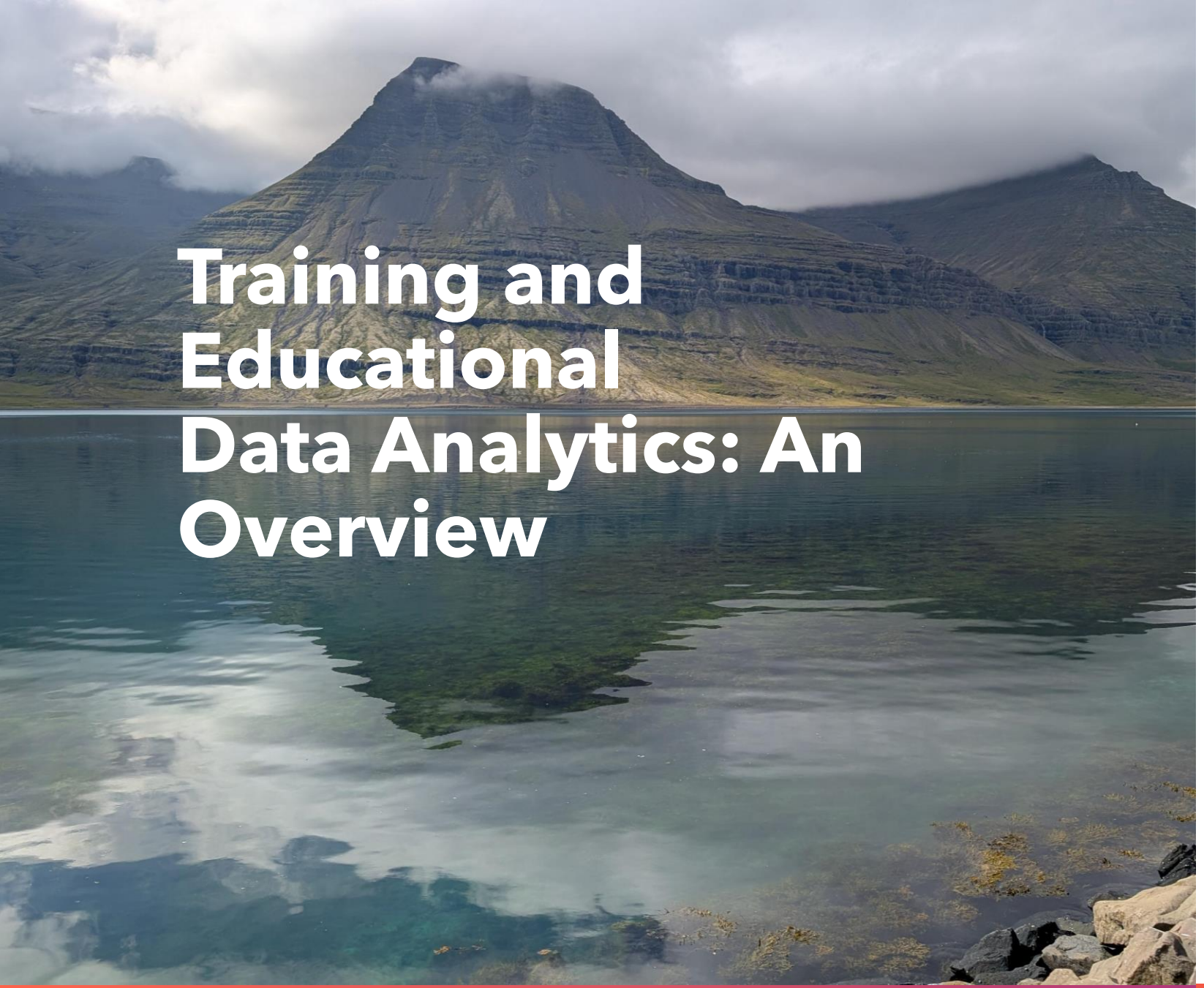


Training and Educational Data Analytics: An Overview

Stephen Downes

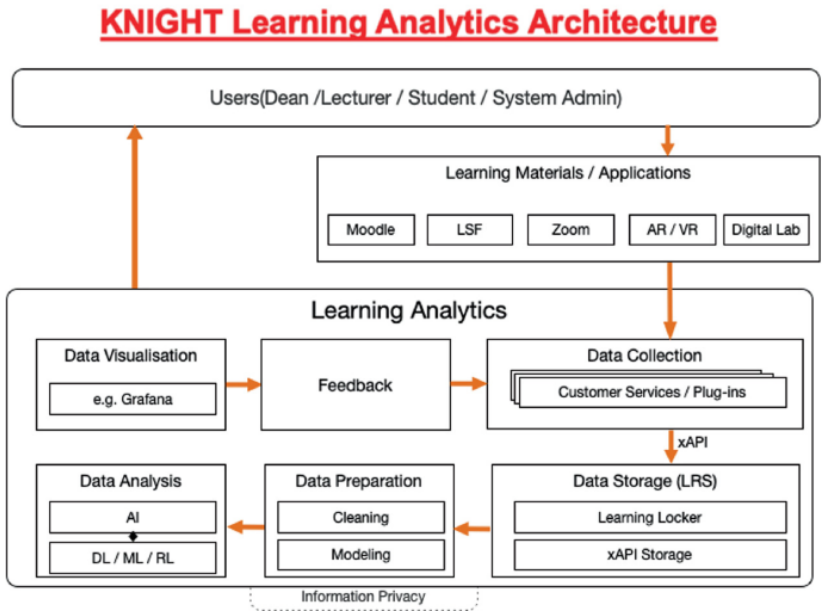
National Research Council Canada

November 6, 2025

1. Education and Training Data Standards
2. Analytics for Decision-Making
3. Issues and Considerations

EDUCATION AND TRAINING DATA STANDARDS

Some Analytics Architectures



https://link.springer.com/chapter/10.1007/978-981-99-7947-9_4

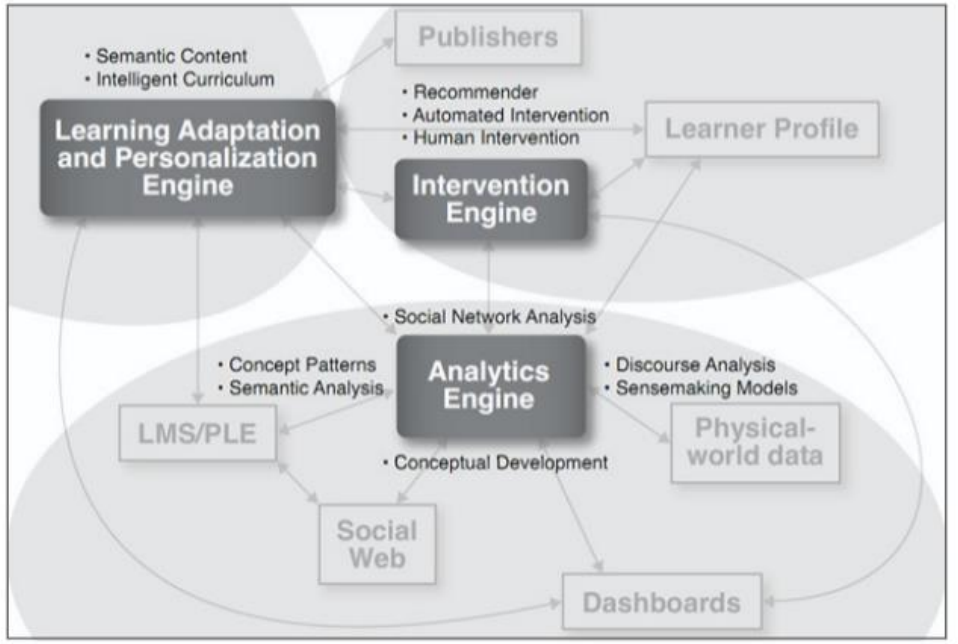
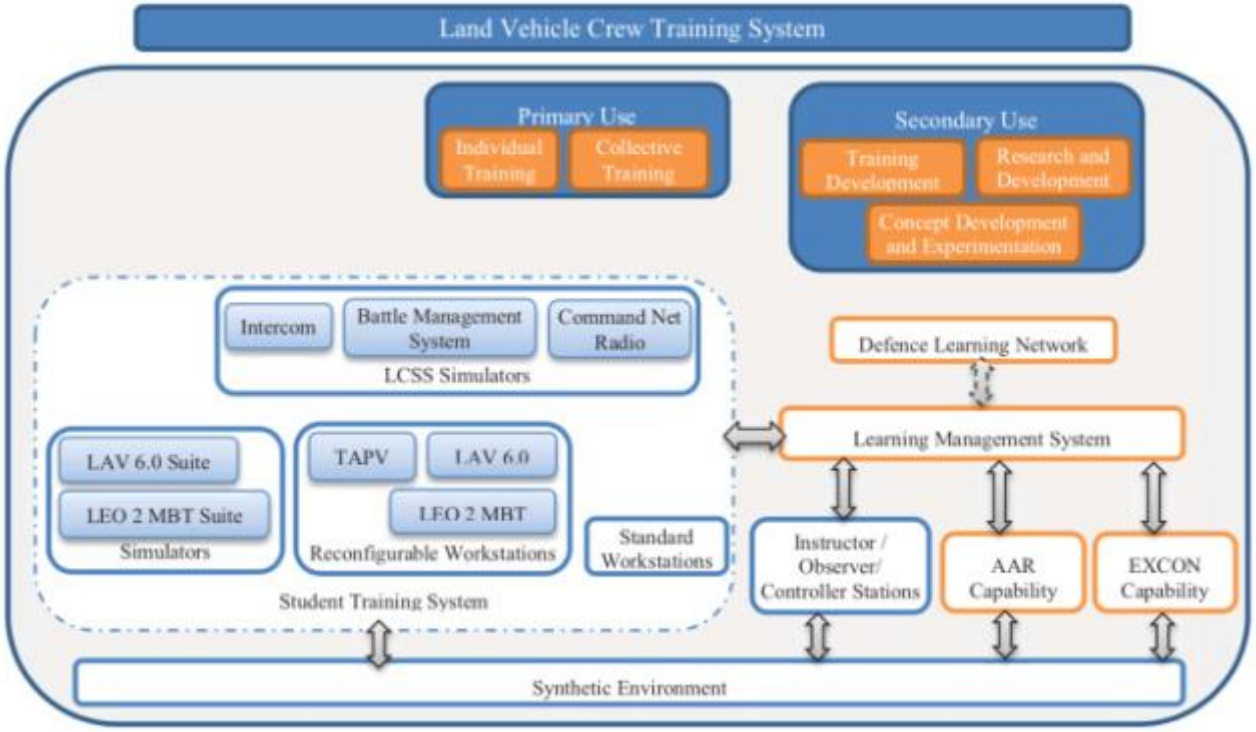


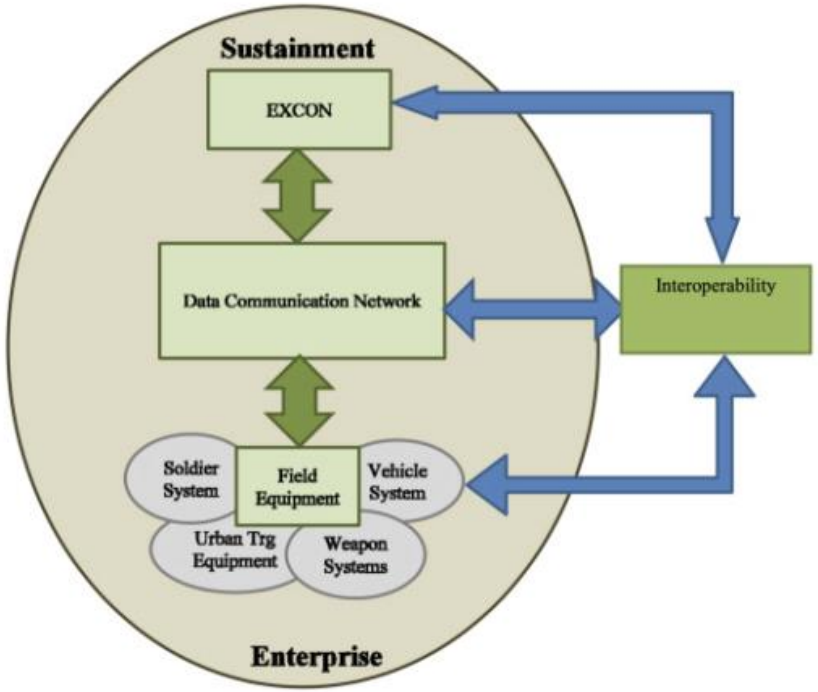
Image 4: Sample techniques for the analytics engine

https://solaresearch.org/wp-content/uploads/2011/12/OpenLearningAnalytics.pdf

Analytics Architectures

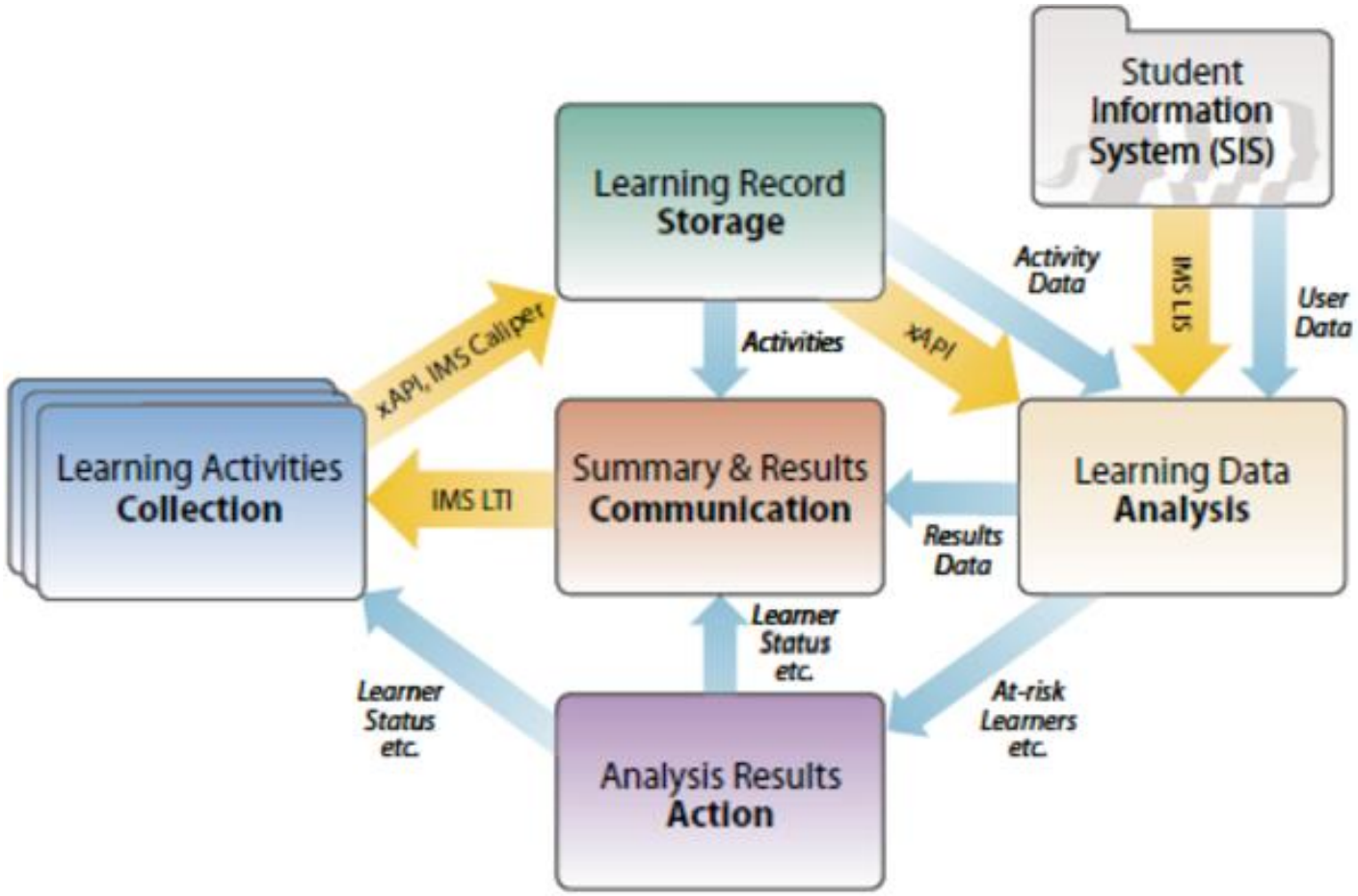


Public Services and Procurement Canada. (2017). Land vehicle crew training system (w8476-175579/b). https://buyandsell.gc.ca/procurement-data/tender-notice/PW-QF-111-26143



Public Services and Procurement Canada. (2021). Wesm - rfi/loi (w8476-216429/a). https://buyandsell.gc.ca/procurement-data/tender-notice/PW-QT-011-28148

A Learning Analytics Architecture



https://www.semanticscholar.org/paper/Privacy-in-Learning-Analytics-%E2%80%93-Implications-for-Hoel-Chen/46f32e1193d2cbe4a2b049bfa40c28cd252160ef/figure/1

Network Communications Standards

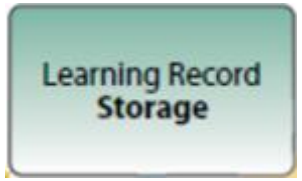
- Signals level:
  - WiFi, 4G, LTE, etc.
- Protocols level:
  - HTTP, FTP, SMTP, etc.
- Data level:
  - REST, JSONLD, etc.
- Authentication:
  - SAML, OAuth2, OIDC, etc.
- Application Level:
  - WSDL, HTML, docx

Military Scenario Definition Language (MSDL) and the Coalition Battle Management Language (C-BML)

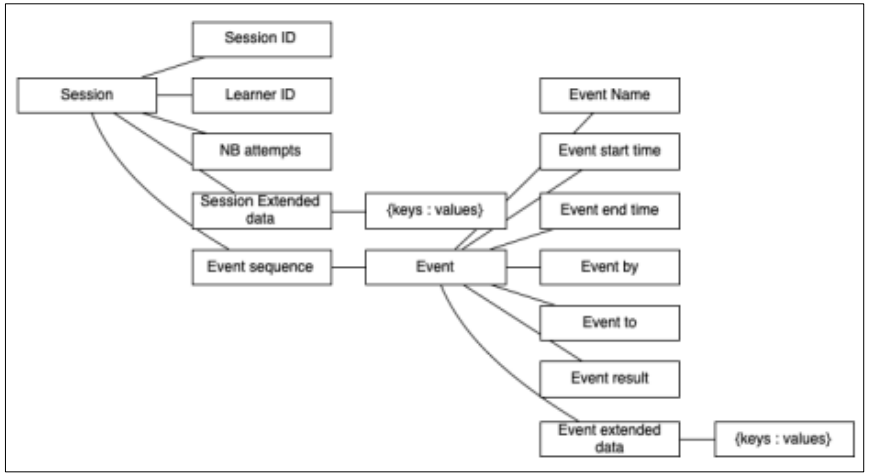
Learning Activities

- Standards and Examples
  - Readings, exercises, simulations, templates
  - IEEE 1484.12.1-2020 – Standard for Learning Object Metadata
  - **Distributed Simulation Engineering and Execution Process (DSEEP)** is a standardized process for building federations of computer simulations. DSEEP is maintained by SISO and the standard is published as IEEE Std 1730-2010.
- Input
  - From content authoring systems: SCORM packages
  - From simulation systems: battle plan templates
  - **Competency definitions – e.g.** IEEE Data Model for Reusable Competency Definitions (DM-RCD) 1484.20.1-2007 – see also ADL Competencies and Skill Systems (CASS)
  - **Task Standards** and Qualification Levels (QL), **Learning Design**, etc

Learning Record Store (LRS)

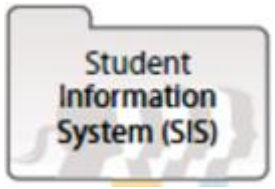


- Standards and Examples
  - Evidence Trace File (ETF)

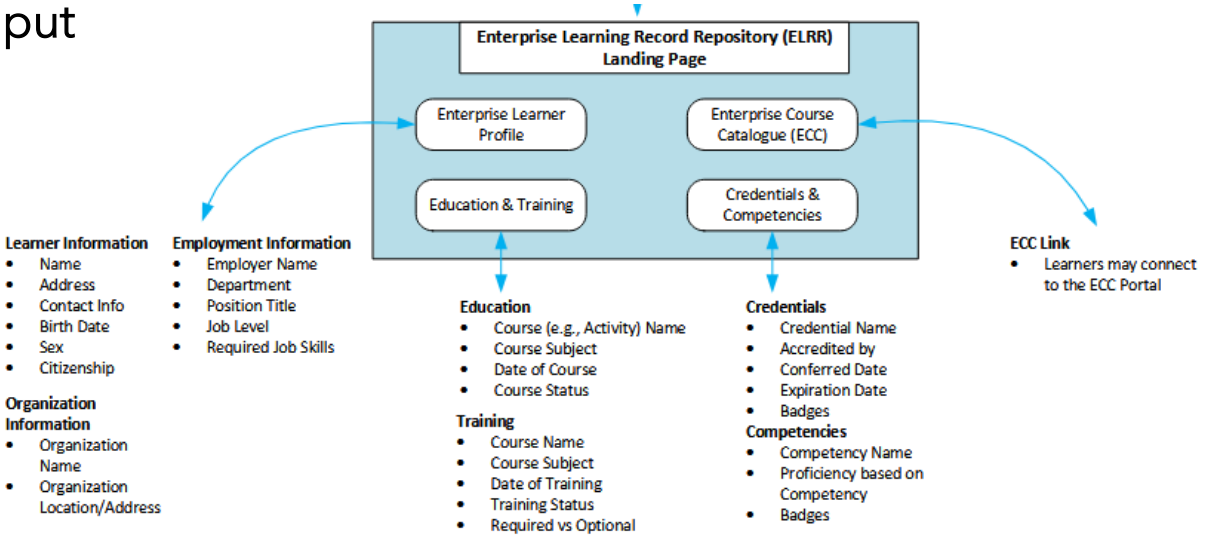


- Input
  - Experience API (xAPI) - IEEE 9274.1.1-2023" – also referred to as xAPI 2.0
  - IMS Caliper - https://www.imsglobal.org/spec/caliper/v1p2/
  - IEEE 2997 Enterprise Learning Record https://standards.ieee.org/ieee/2997/10632/

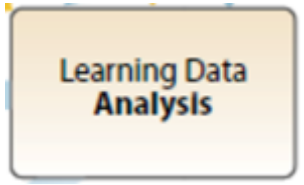
Student Information System



- Standards and Examples
  - Student records, company or group training records
  - IEEE P2997 Standard for Enterprise Learner Record https://standards.ieee.org/ieee/2997/10632/
  - ADL Enterprise Learner Record https://www.adlnet.gov/assets/uploads/ADL_ELRR_User_Flow_Diagrams_2021.pdf S
- Input

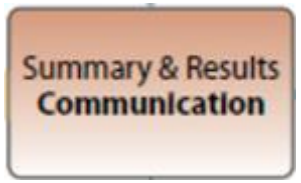


Learning Analytics



- Standards and Examples
  - Data management standards, e.g. DND/CAF Data Strategy, CDS/DM Joint Directive on Data Management, DND/CAF Data Governance Framework
  - ISO/IEC TS 20748-3:2020 Guidelines for data interoperability
  - Data standards e.g. https://www.solaresearch.org/wp-content/uploads/2020/09/SoLAR_Position-Paper_2020_09.pdf
  - **Tools:** R, PyTorch, etc.
- Input
  - **Learning data:** xAPI, Caliper, etc.
  - **Models:** ML algorithms, NN weights, e.g. ChatGPT 5, Claude, etc.
  - **Context**: Prompt engineering, Retrieval Augmented Generation
  - **Tools**: Model Context Protocol

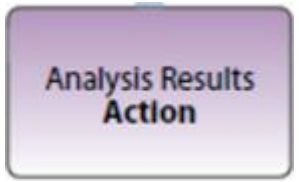
Dashboard



- Standards and Examples
  - **Tools:** e.g. Social Network Analysis & Pedagogical Practices (SNAPP), diagnostic instrument, Learning Object Context Ontologies (LOCO)
  - **Visualization types:** bar chart, bubble chart, etc. https://xdgov.github.io/data-design-standards/visualizations/
- Input
  - **Database** query and visualization standards: SQL, SPARQL, GQL

Guidebook on Learning Analytics Dashboards https://teach4edu4-project.eu/sites/default/files/2023-05/IO4%20Guidebook%20on%20Learning%20Analytics%20and%20Dashboards.pdf

Learning Tools Activation

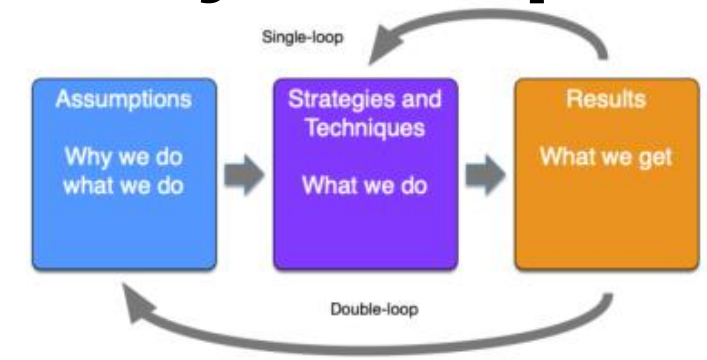


- Standards and Examples
  - IMS Learning Tools Interoperability (LTI) https://www.imsglobal.org/spec/lti/v1p3
  - IMS Security Framework and Learning Tools Interoperability version 1.3 based on OAuth2, OpenID Connect, and JWT.

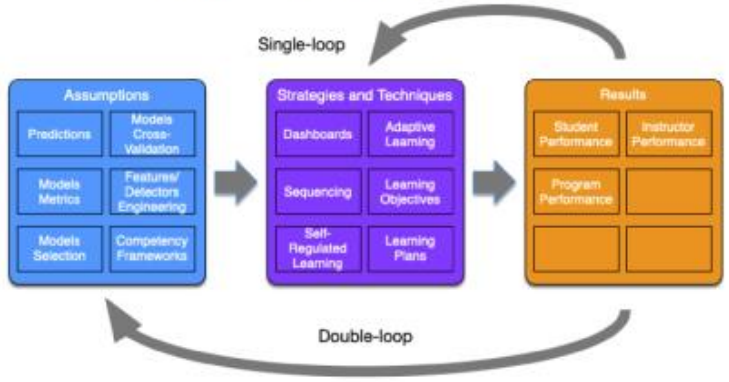
- Input
  - Automated activation
  - User or Instructor selected activation

ANALYTICS FOR DECISION-MAKING

Analysis Loops

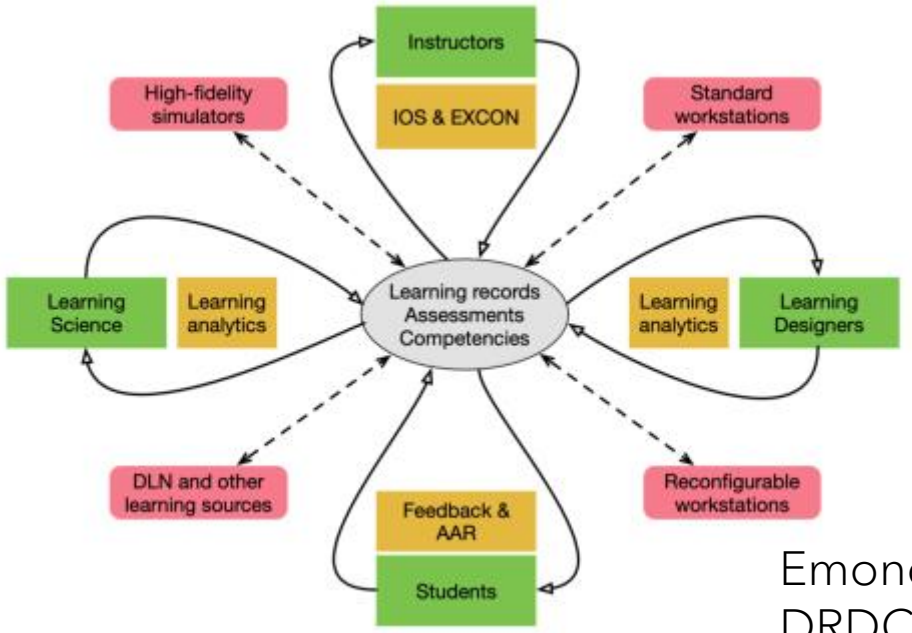


(a) Argyris's double loop learning.



(b) Learning analytics double loop.

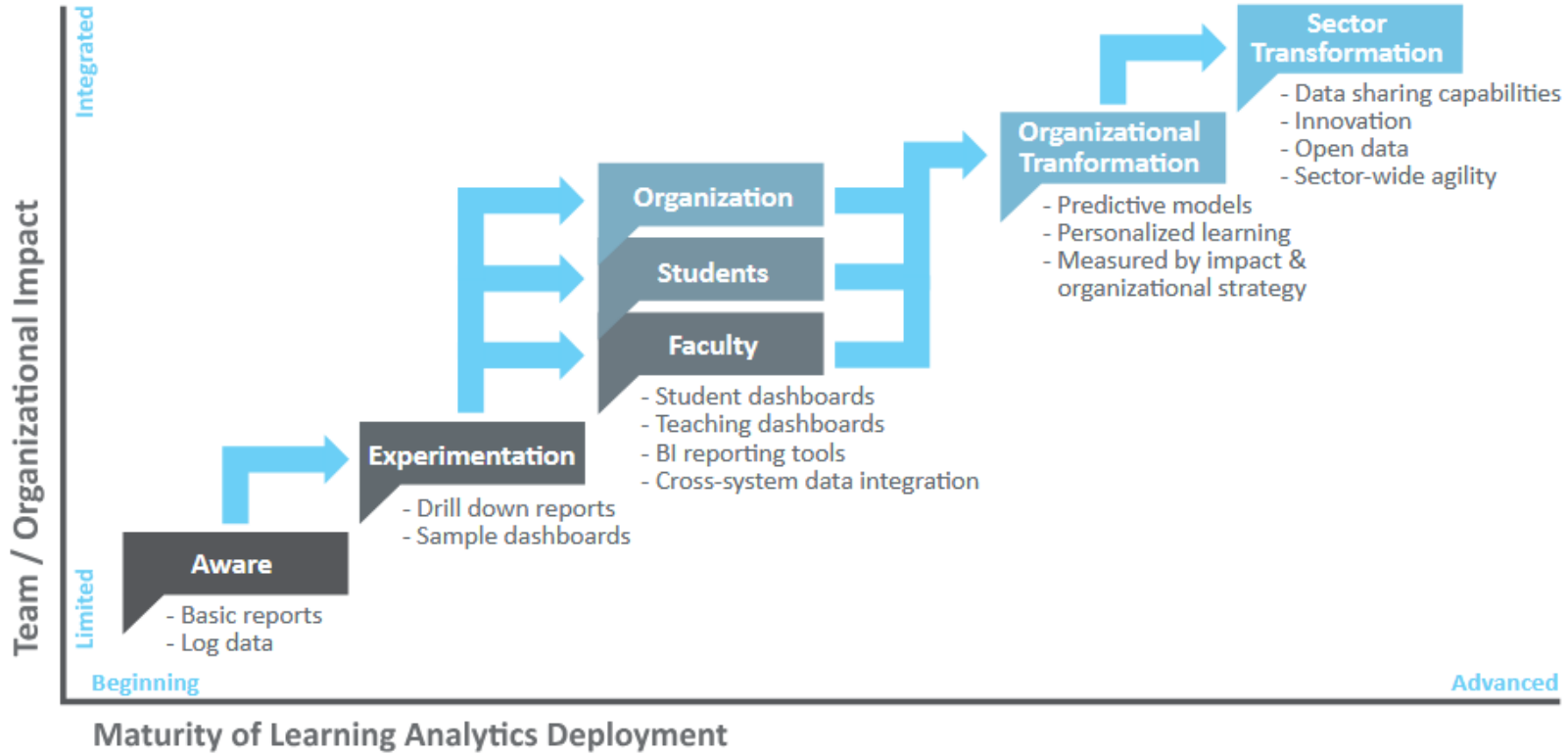
Argyris, C. (1976)



Emond, Durand, Downes
DRDC-RDDC-2022-C286

Illustrative example using LVCTS (Public Services and Procurement Canada, 2017) system architecture (DLN, standard and reconfigurable workstations, high-fidelity simulators), support components (IOS, AAR, EXCON)

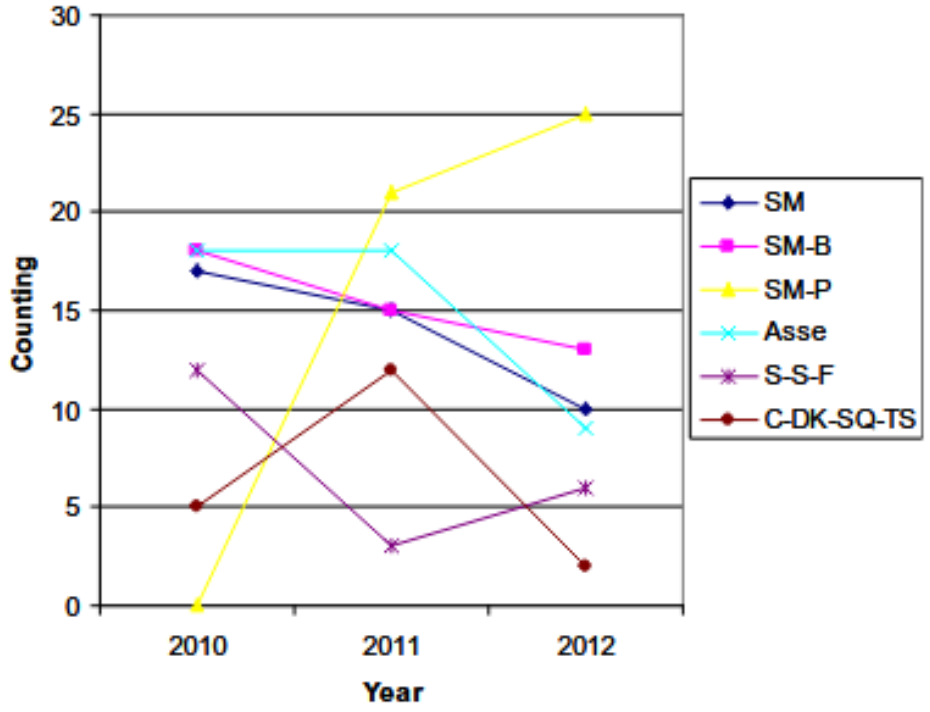
Evolution of Learning Analytics



https://solaresearch.org/wp-content/uploads/2017/06/SoLAR_Report_2014.pdf

Applications of Analytics (Modeling)

- Student behavior modeling
- Student performance modeling
- Assessment
- Student modeling
- Student support and feedback
- Curriculum
- Domain knowledge
- Sequencing
- Instructor support



Alejandro Peña-Ayala
https://www.sciencedirect.com/science/article/pii/S0957417413006635

Applications of Analytics (Methods)(1)

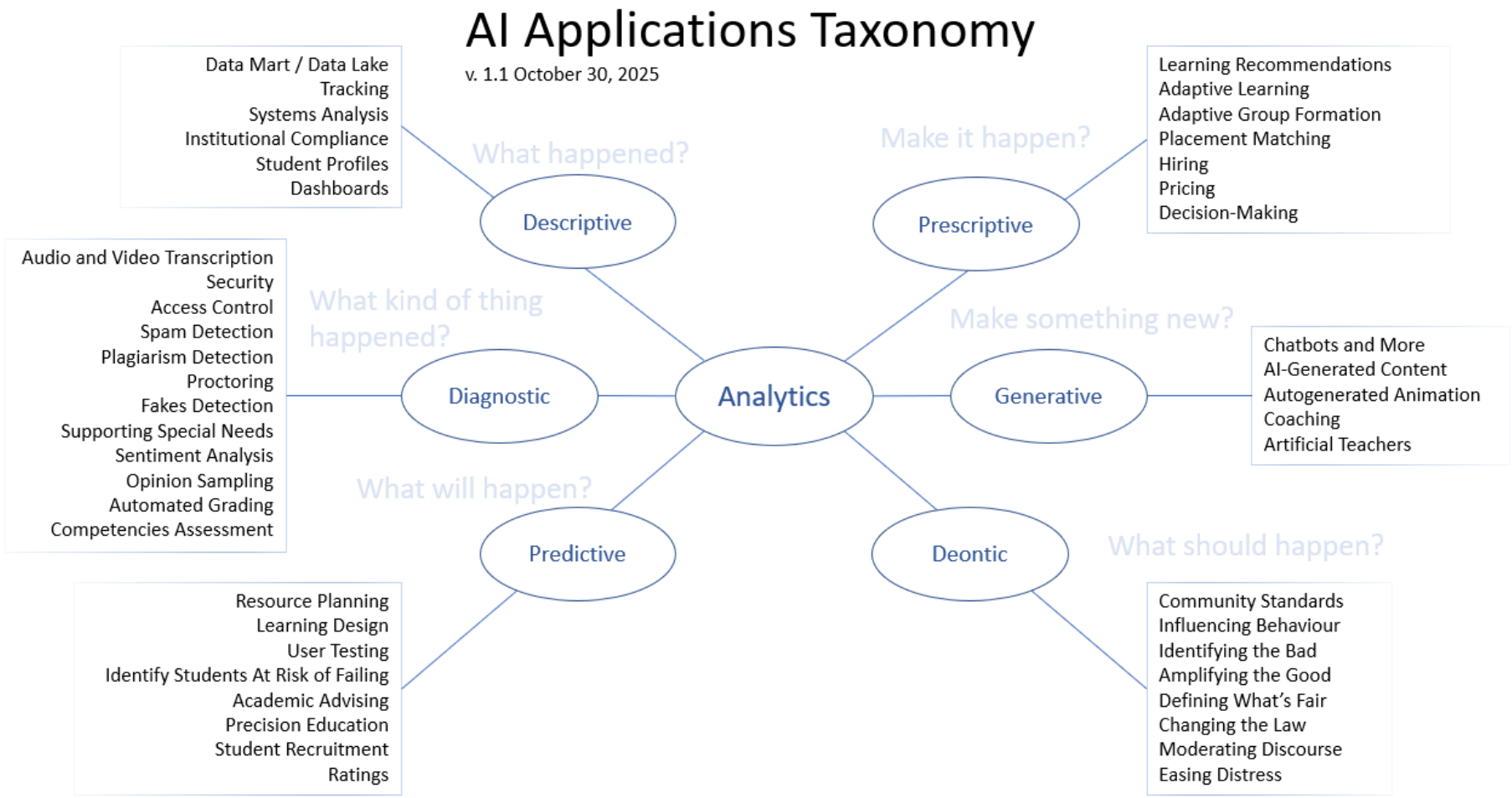
Method	Goal	Applications
Causal mining	Find causal relationships	Find causes of failing, dropouts
Clustering	Find similarities	Group materials or students
Discovery with models	Employ previously validated model	Identify relationships, characteristics, variables
Distillation of data	Represent data in intelligible ways	Help visualize and analyze
Knowledge tracing	Estimate mastery of skills	Monitor student knowledge
Outlier detection	Identify different individuals	Spot irregularities
Prediction	Infer target variable	Predict performance
Process mining	Analyze event logs	Spot behaviours

Applications of Analytics (Methods)(2)

Method	Goal	Applications
Recommendation	Predict ratings or preferences	Make recommendations
Relationship mining	Identify links and associations	Find learner behaviour patterns
Statistics	Find relationships among variables	Draw conclusions from correlations
Social network analysis	Identify social relationships	Describe collaboration
Text mining	Extract information from text	Analyze chats, web pages, etc
Visualization	Graphically represent data	Communicate results
Non-negative matrix factorization	Analyze student test data	Assessment of student skills

Romero & Ventura,
https://doi.org/https://doi.org/10.1002/widm.1355

Applications of Analytics (Outcomes)

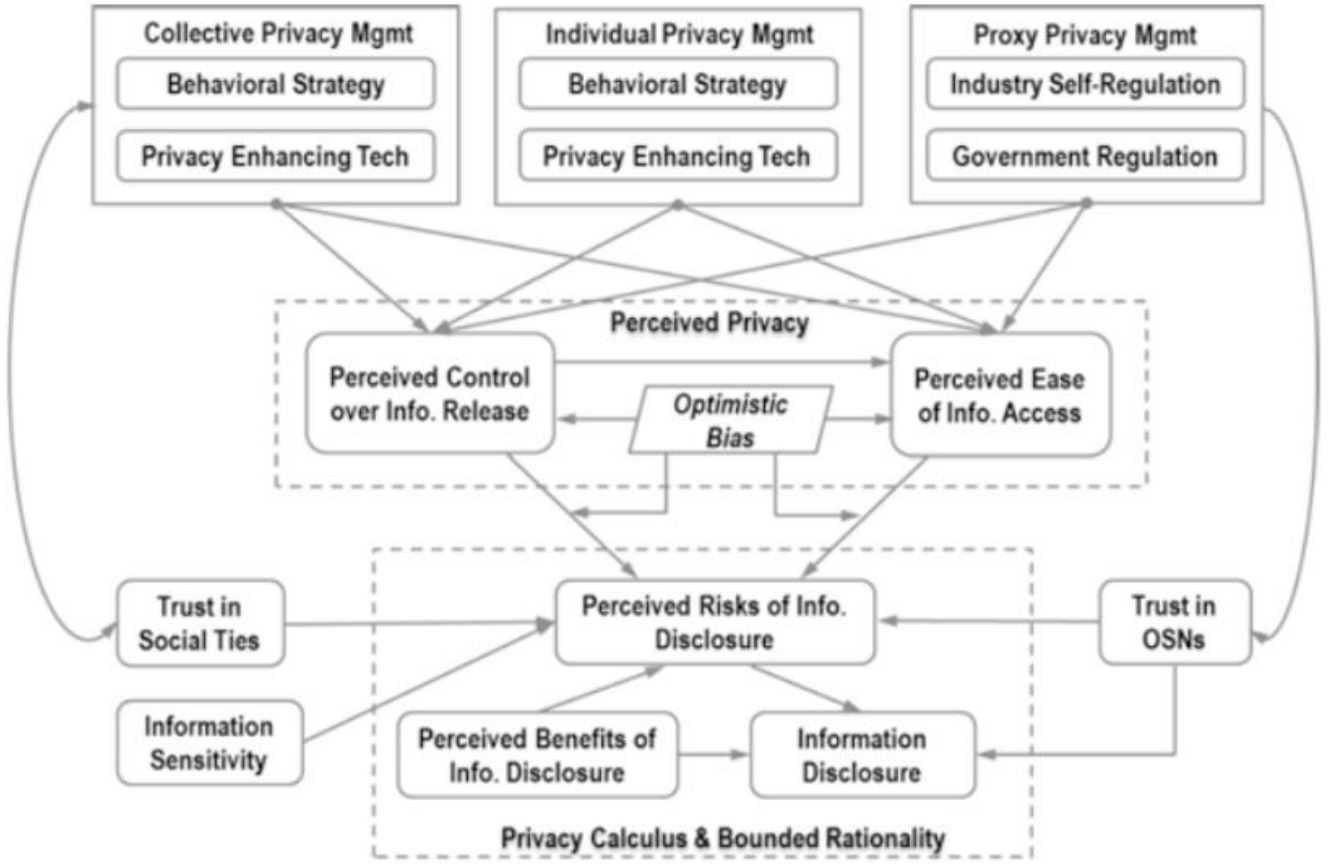


https://www.downes.ca/aitaxonomy.png

ISSUES AND CONSIDERATIONS

Privacy and Security

Implications for how individuals manage data and knowledge about themselves and their learning, highlighting issues of privacy, ownership of data, and consent to share and use data, as well as data security and analytic security



https://www.semanticscholar.org/paper/Privacy-in-Learning-Analytics-%E2%80%93-Implications-for-Hoel-Chen/46f32e1193d2cbe4a2b049bfa40c28cd252160ef/figure/1

Data Sources

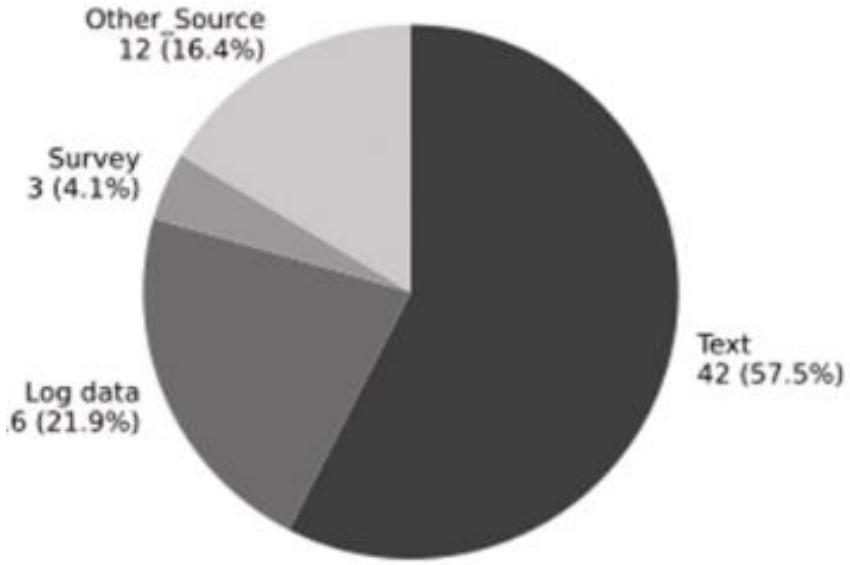


Fig. 2. Frequency of Data Sources.

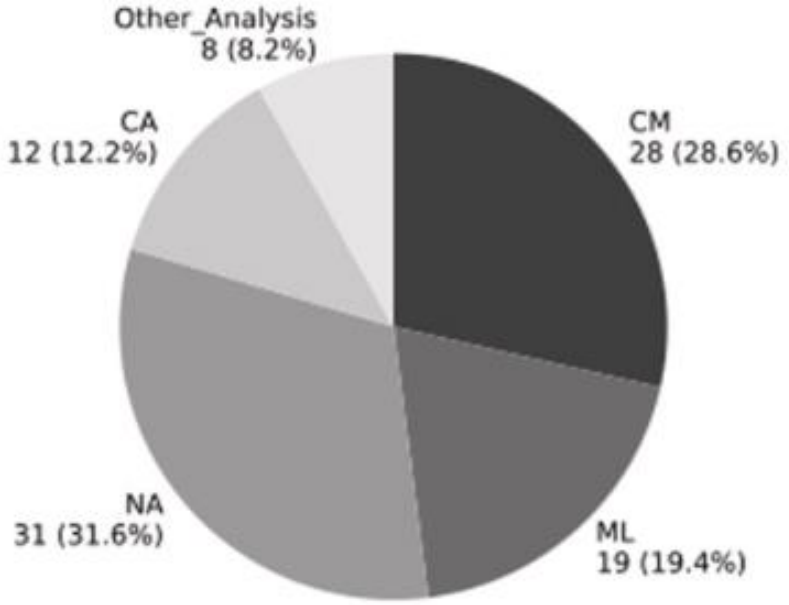


Fig. 3. Data Analysis Methods.

https://www.sciencedirect.com/science/article/pii/S266655732500048?via%3Dihub

Bias, Misrepresentation and Workflow

- Data Bias: inherent biases in data can transfer to the AI system.
- Algorithmic Bias: for example, prioritizing efficiency over fairness
- Operational Bias: interaction with existing institutional practices amplifying their effects.
- Feedback Loops: bias reinforced over time can compound.

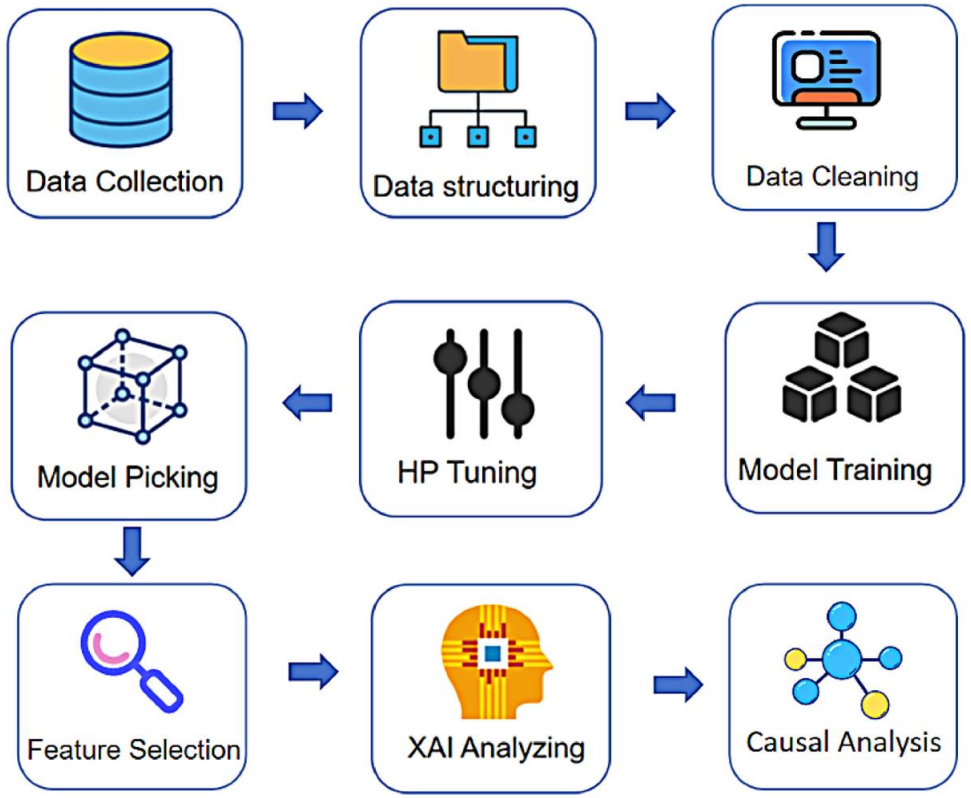
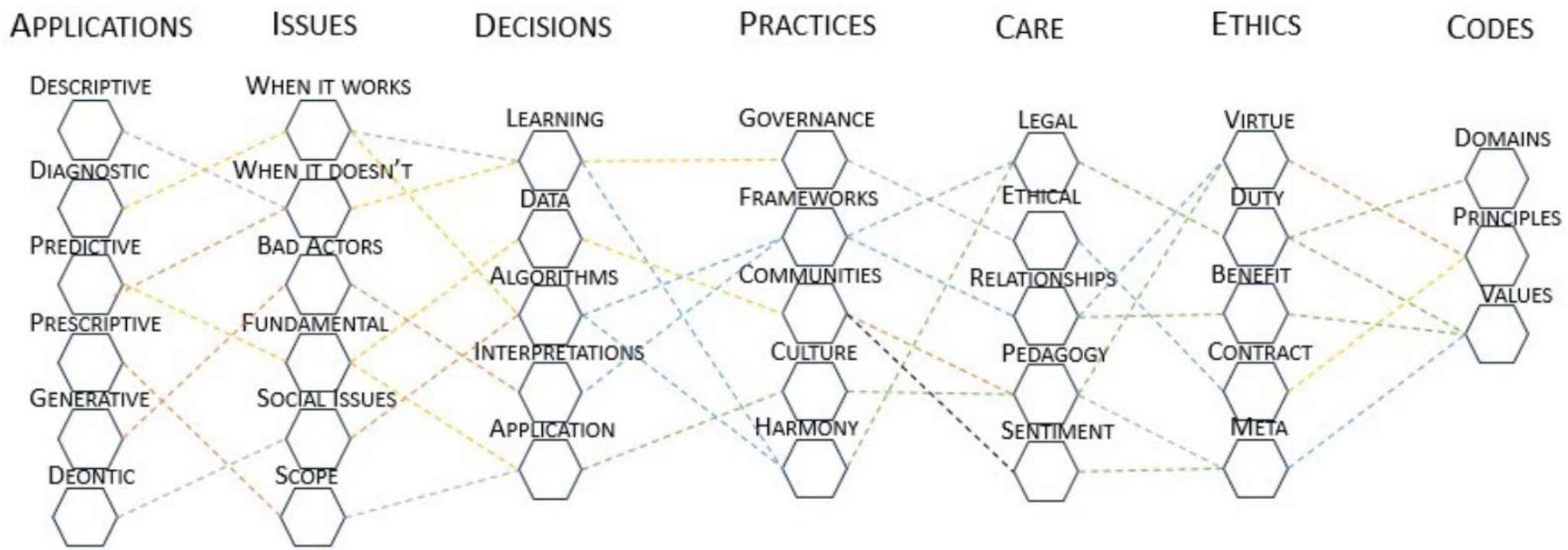


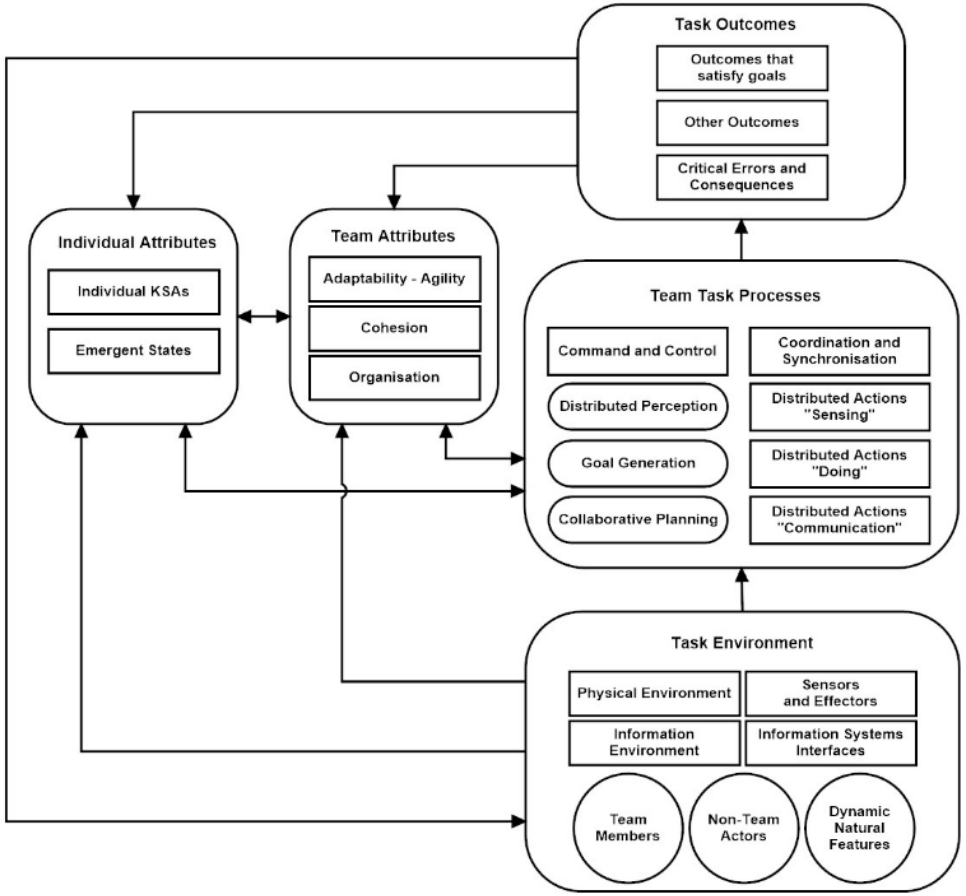
Image https://www.nature.com/articles/s41598-025-12514-5
https://techrseries.com/featured/bias-in-workflow-automation-identifying-and-mitigating-ai-induced-inequities/

Data Literacy



https://www.downes.ca/presentation/574

Individual vs Collective Analytics



- Communication
- Coordination
- Mutual performance monitoring
- Back-up behaviour
- Collaboration
- Conflict management

https://www.iitsec.org/-/media/sites/iitsec/workshops/iitsec-2018-team-and-collective-training-needs-analysis.ashx?la=en