A Computer Science Perspective on Learning and Knowledge Building

H. Ulrich Hoppe

Universität Duisburg-Essen / COLLIDE

http:// www.collide.info


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University of Duisburg-Essen (UDE)

founded by merger in 2013
11 Faculties

- Humanities
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- Educational Sciences
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- Chemistry
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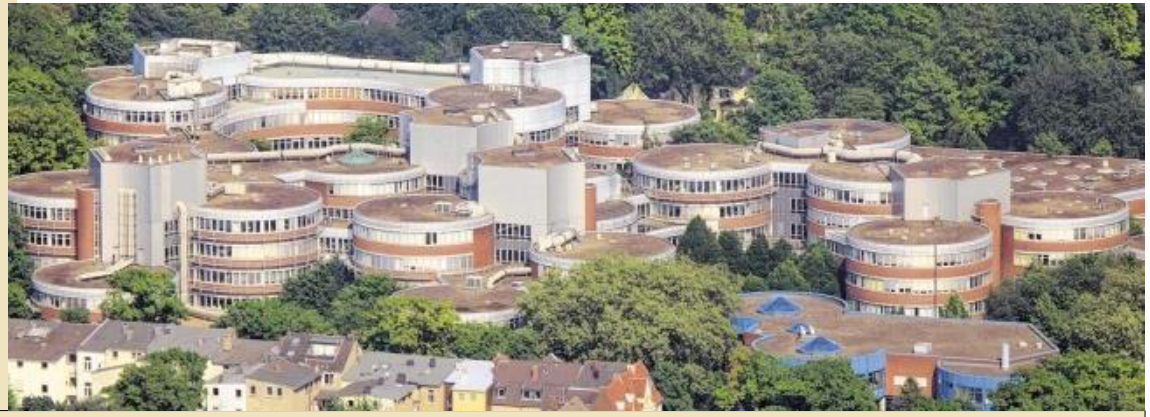

39,343	students
442	professors
2,691	academic staff
1,375	employees technical support and administrative services (excluding Faculty of Medicine)

Our Department

… of Computer Science and Applied Cognitive Science in the Engineering Faculty (Duisburg)

17 professorships / groups (13 in CompSci)

Focus on Interactive Media and "Human-oriented Computing"

3 B.Sc./M.Sc. Study Programmes with approx. 1500 students

Research Group COLLIDE

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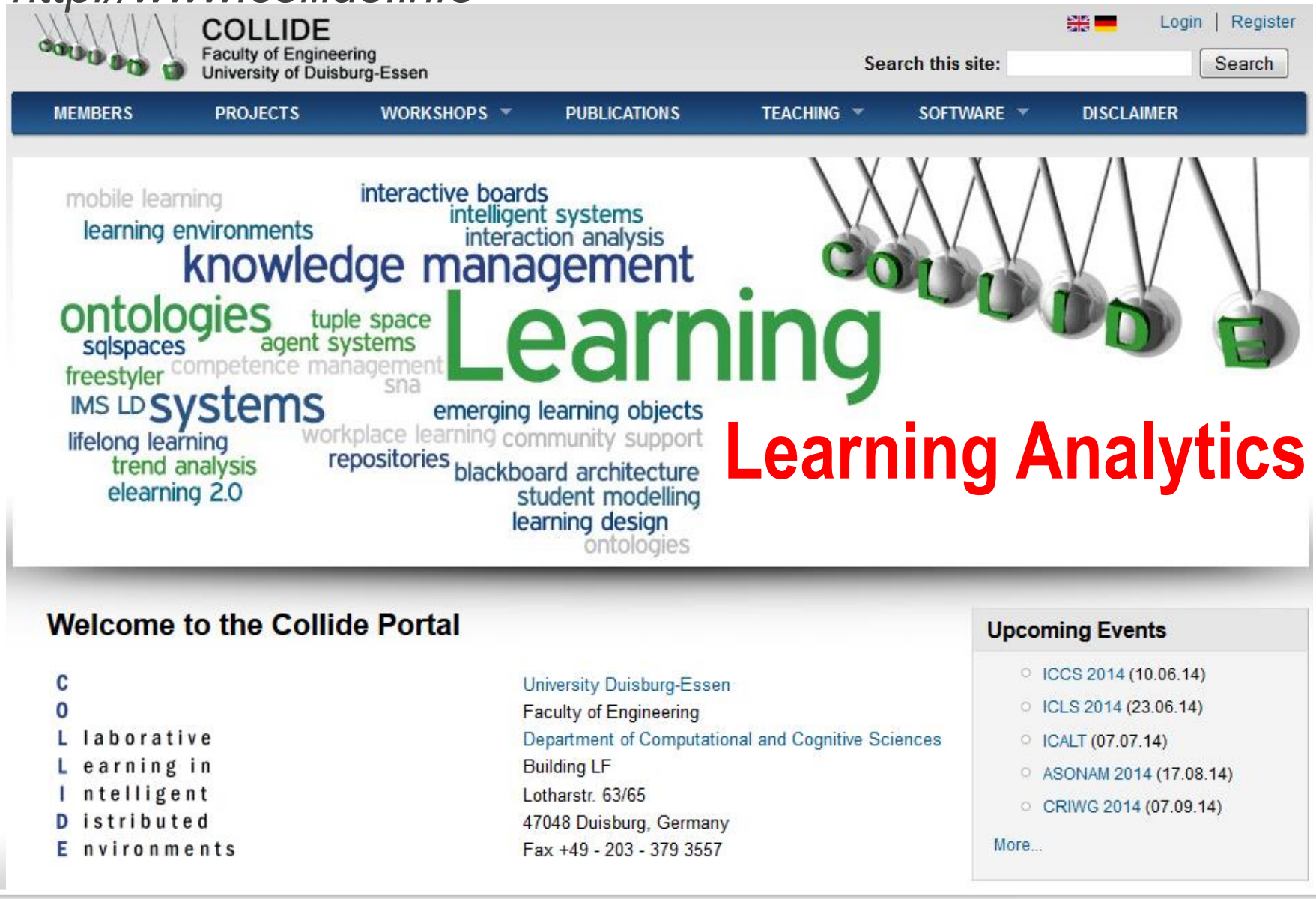


Project History I

- **COLDEX** ("Collaborative Learning and Distributed Experimentation", 2002-05, coord. by Collide): collaborative modelling tools for various areas of science learning; creation of a globally accessible repository of learner-created models ("emerging learning objects“).

- **SCY** ("Science Created by You", 2008-12, U. Twente): SCY-Lab environment facilitates learner experience through larger "missions" ; sharing of emerging learning objects.

Project History II

- **Go-Lab** (2012-16, U. Twente):
  uniform access to a variety of remote laboratories, both virtual and physical; customisable web-based learning environments and learning analytics components.

- **JuxtaLearn** (2012-15, Open Univ. Milton Keynes):
  fostering understanding of core science concepts through video creation on the part of the students; collaborative production and discussion around videos.

Project COLDEX

("Collaborative Learning and Distributed Experimentation", 2002-05)

The space planting scenario enables students to experiment with computer and robotic controlled plant growth chambers in the context of Advanced Life Support Systems

BioTube and Seismo Scenarios

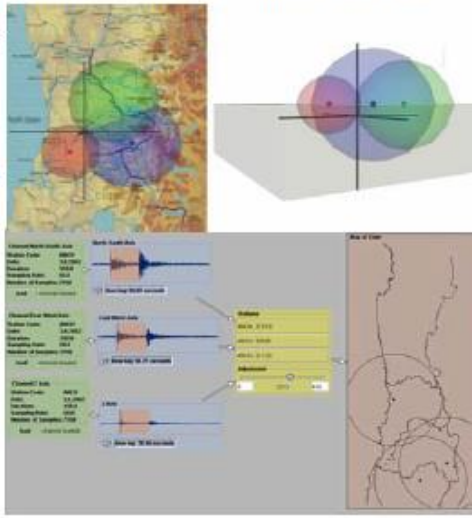
Collaborative Learning and Distributed Experimentation

Chemistry, biodiversity, seismology, astronomy … these are the scientific topics which are combined in the COLDEX project

Originating from the pedagogical idea of "challenge based learning", we support student groups – from face-to-face groups up to international learning communities; they can have a realistic look inside scientific work. Various "digital experimentation toolkits" containing virtual and physical tools enable open-ended learning activities.

By using a synchronised "learning object repository" (LOR) learners can find people with similar interests. The LOR supports retrieval in a big pool of models and data, re-use of learning objects and building of learning communities between Europe and South-America.

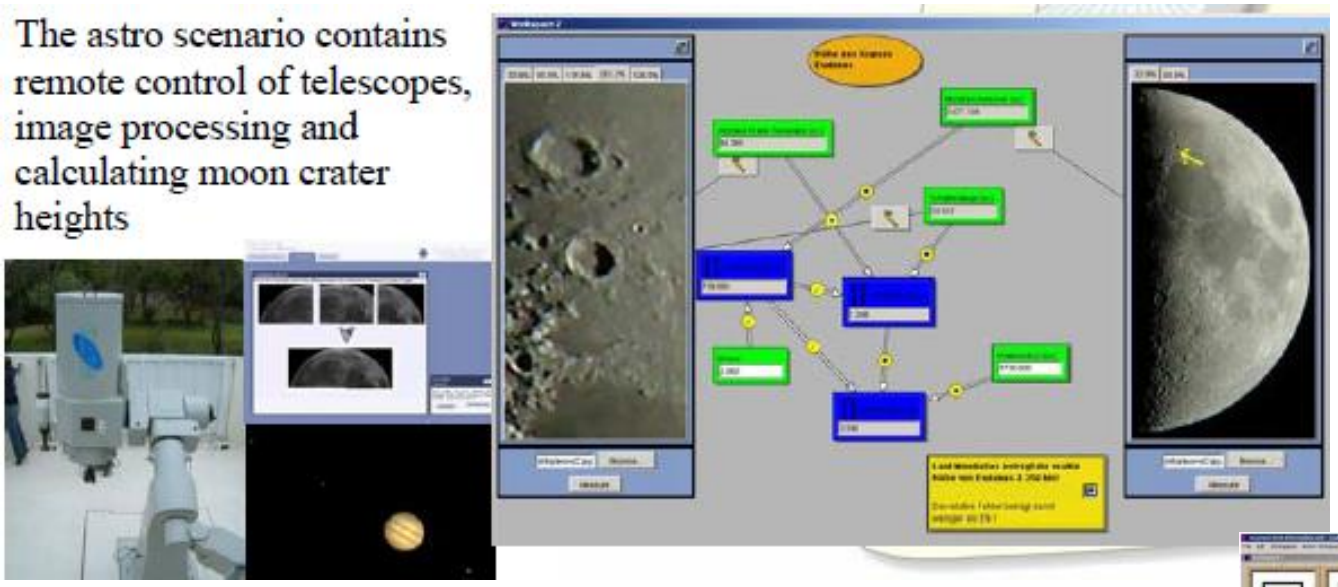
Finding epicenter and hypocenter of earthquakes is the main task in the seismo scenario



Project COLDEX

("Collaborative Learning and Distributed Experimentation", 2002-05)

The astro scenario contains remote control of telescopes, image processing and calculating moon crater heights

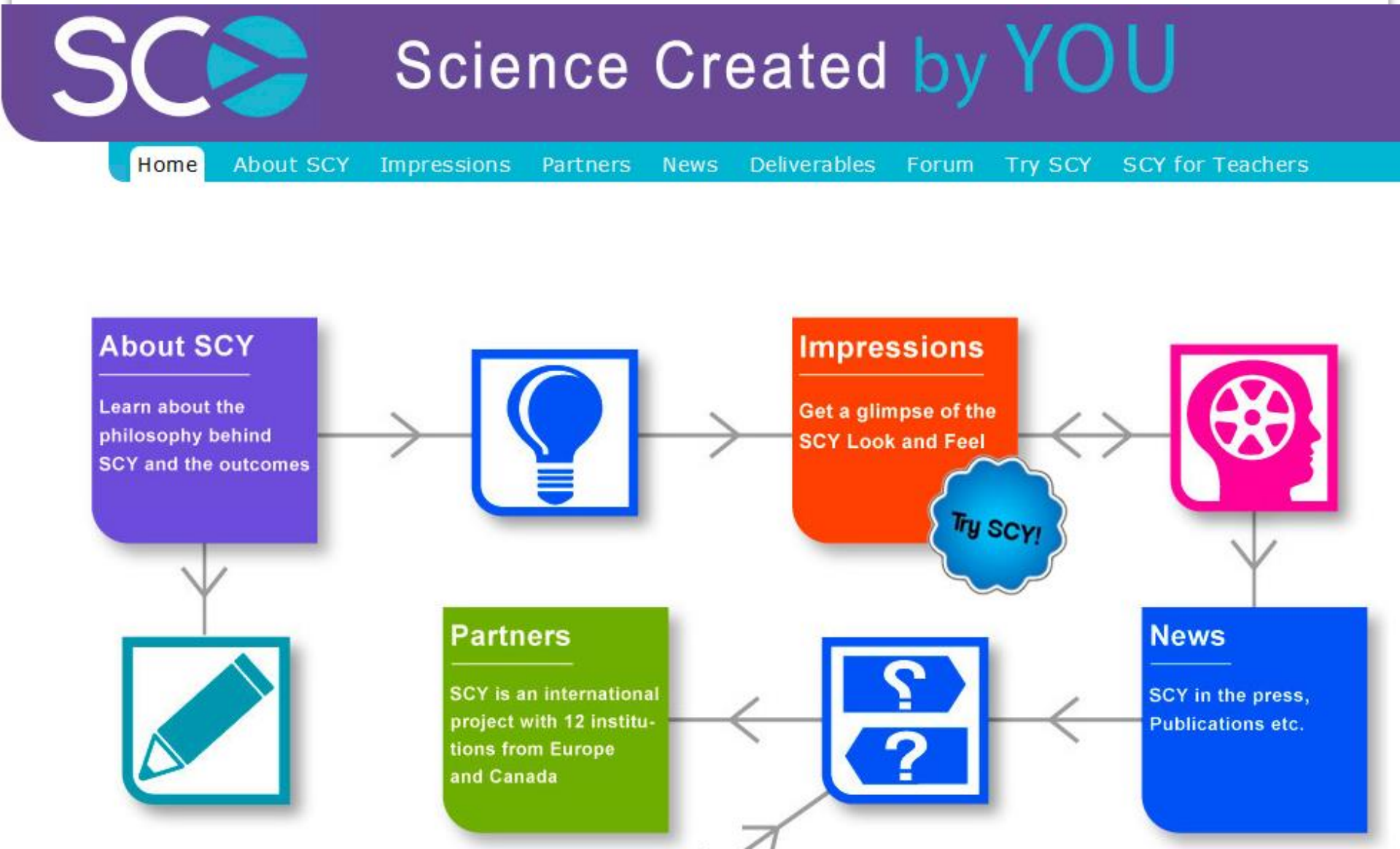


Astro and Maze Scenarios

COLDEX – Results and „Lessons Learned“

- Notion of „emerging learning objects“ (ELOs)
- Provision of a general purpose modelling environment (*CoolModes / FreeStyler*) with different „palettes“ for various modelling languages (e.g., *System Dynamics*, *Petri Nets*) and special applications
- Support for sharing ELOs in larger communities through similarity based search
- Resistance of teachers against „open production“

Project SCY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SCY is an international project with 12 institutions from Europe and Canada
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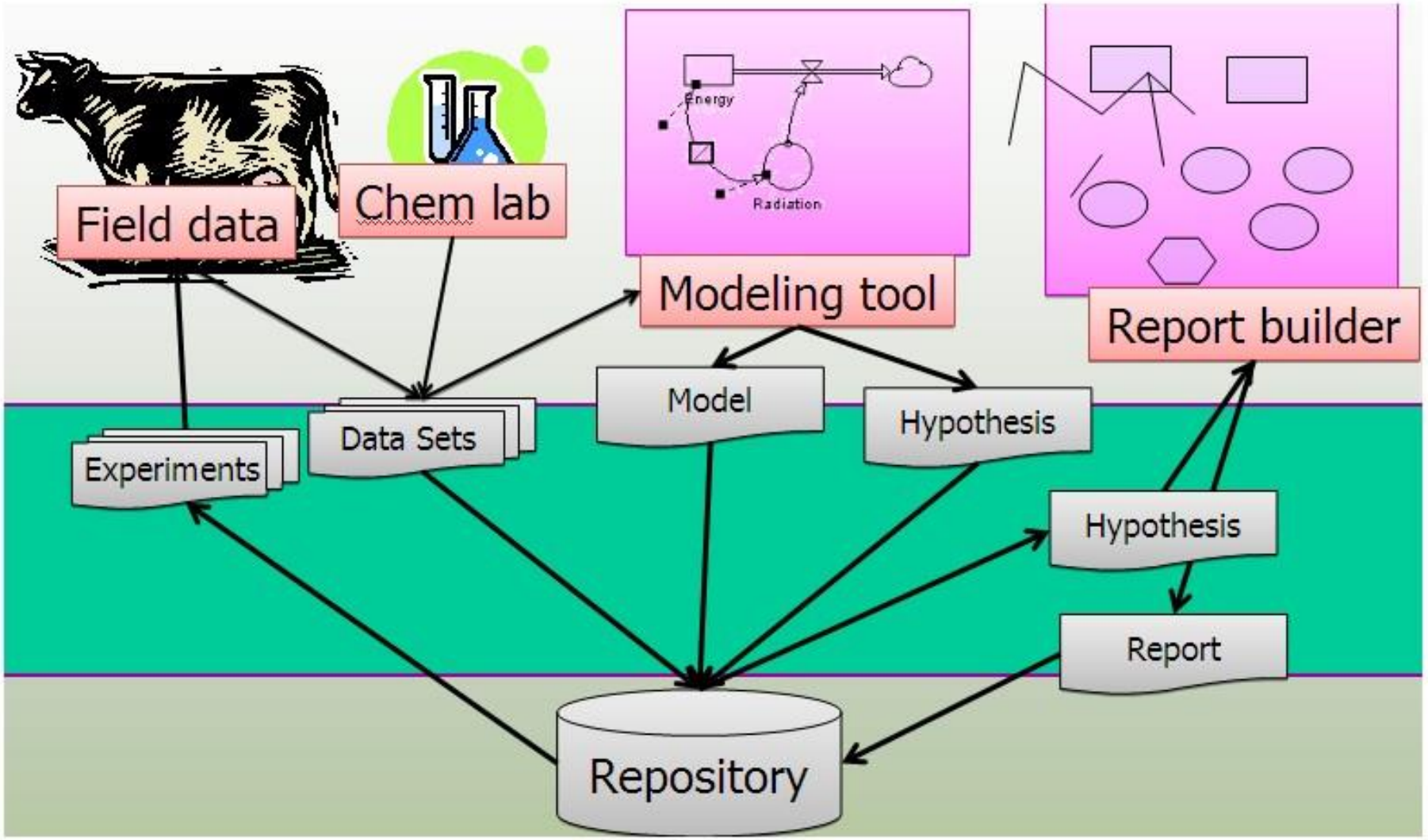
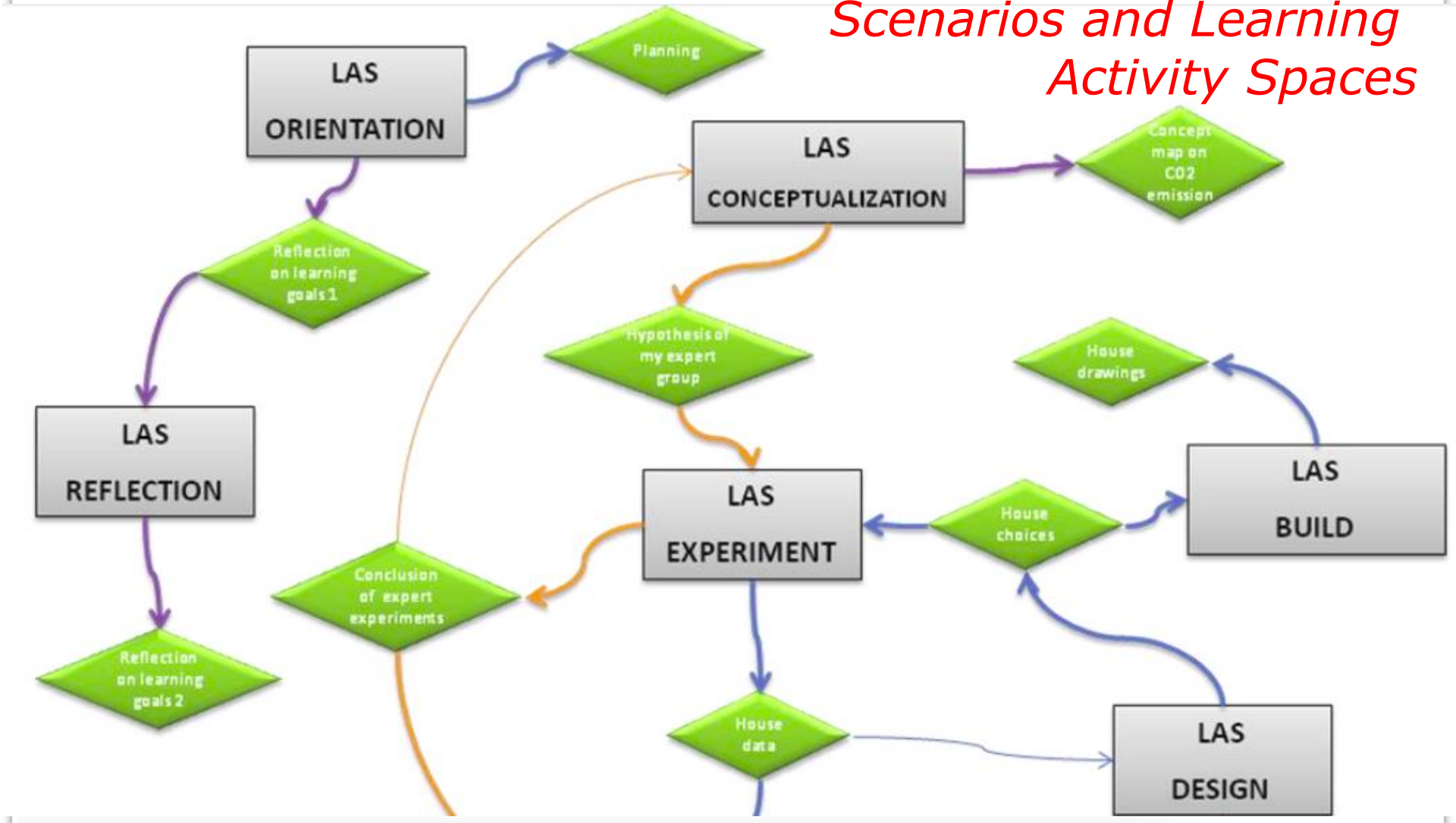
SCY – Tools and Architecture

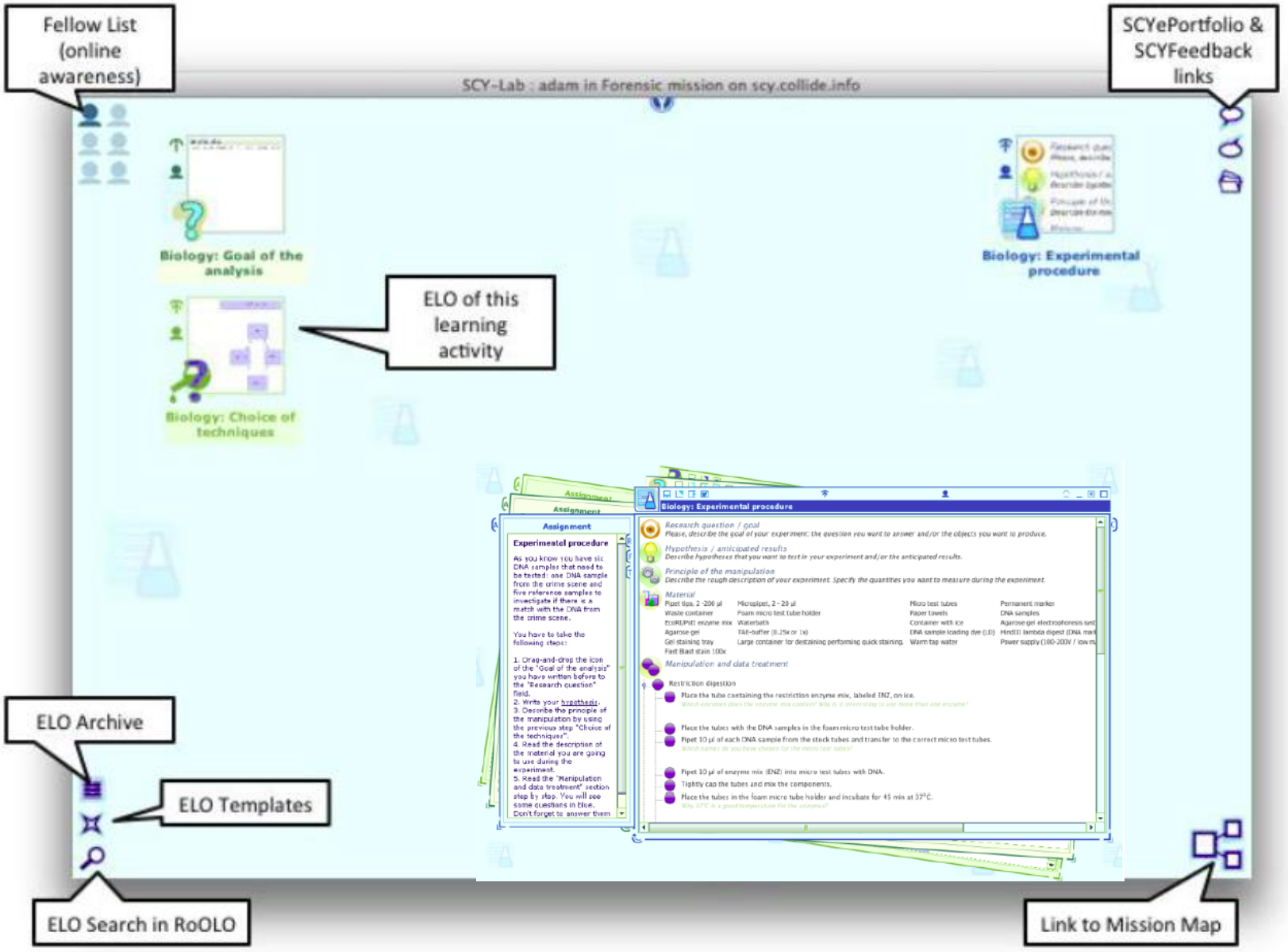


Mission “CO2-Friendly House”

Scenarios and Learning Activity Spaces



SCY-Lab Environment



SCY – Results and „Lessons Learned“

- SCY-Lab as a powerful environment
  (yet – might be better delivered as a web application)
- Integration of feedback/scaffolding facilitated through multi-agent architecture
- „Mission Maps“ as navigation aids guide learners through complex inquiry processes
- „Complexity overkill“ with big socially relevant learning challenges

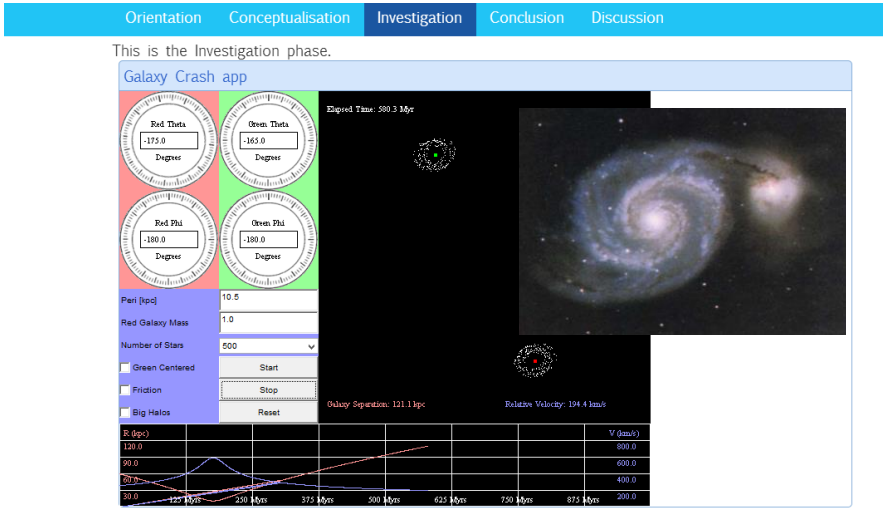
The Go-Lab Project

http://www.go-lab-project.eu/

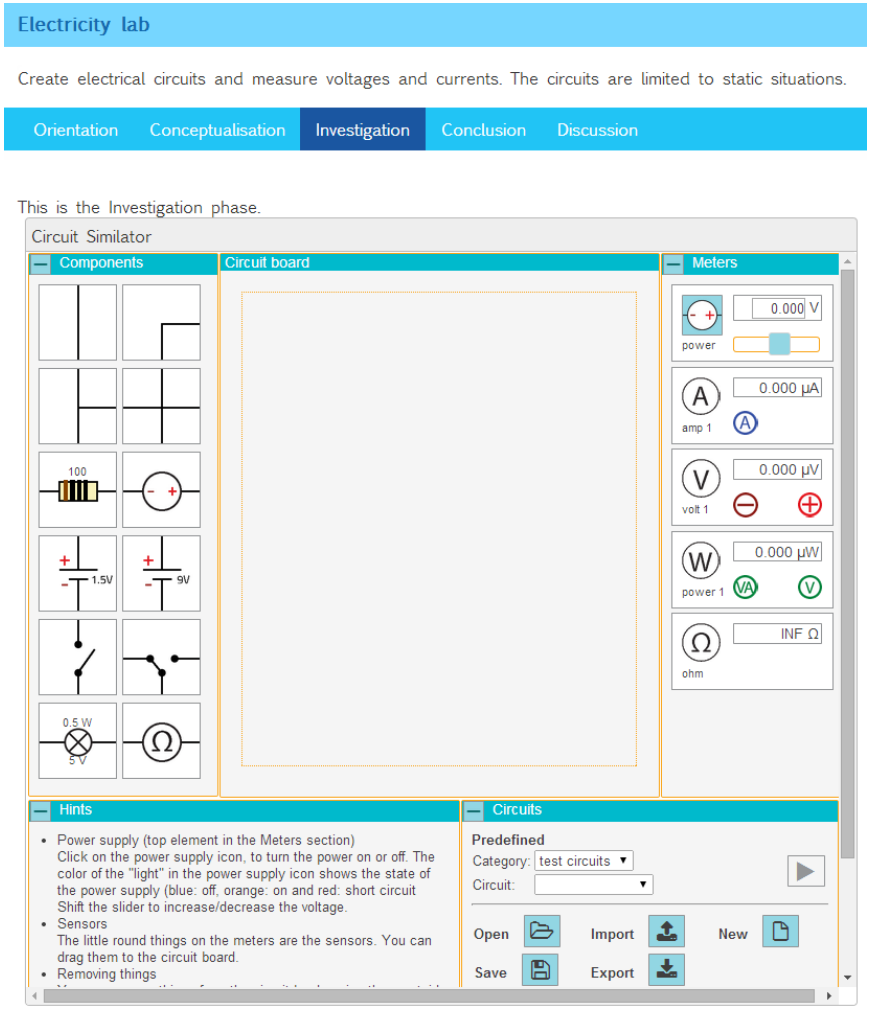
GO-LAB

- Large scale use of online labs in education.
- The Go-Lab Portal offers students the opportunity to perform personalized scientific experiments.
- Teachers enhance their classroom activities with a personalized web-based environment.

Experimentation with Remote and Virtual Laboratories



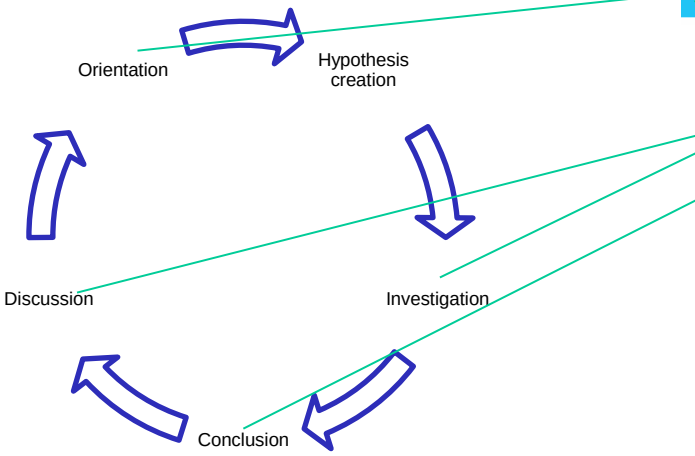
Remote lab: Students control real physical laboratories using a web-interface.

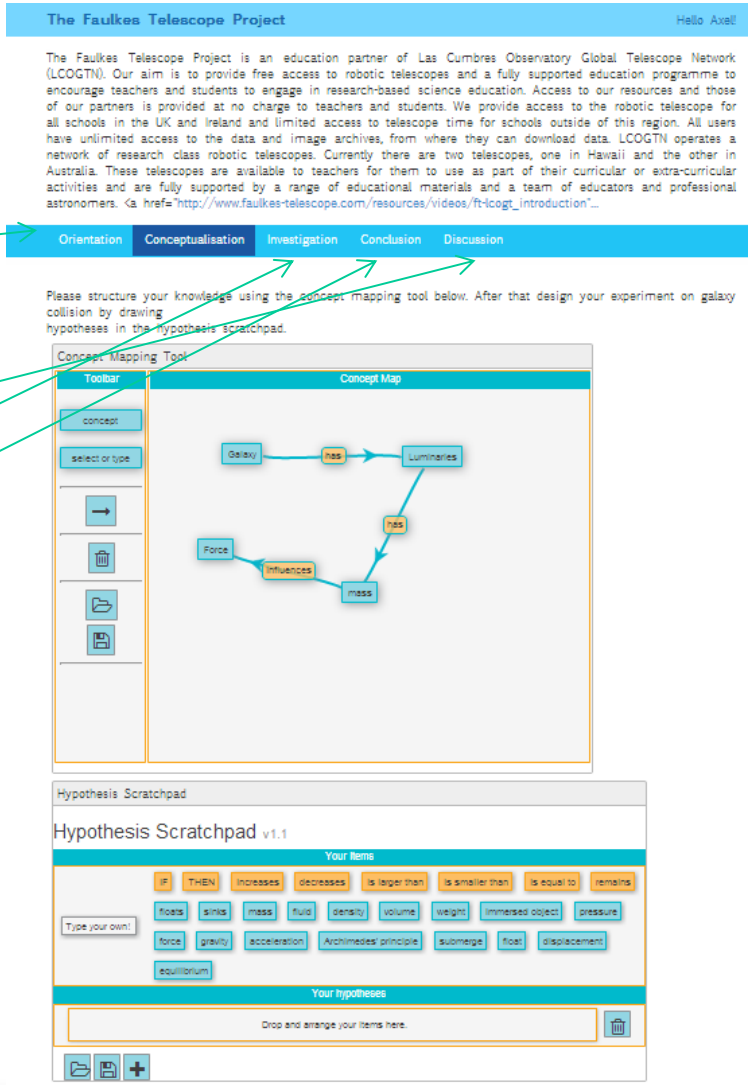


Virtual lab: Simulation of real-world processes.

Inquiry Learning at School

- Mapping of the inquiry cycle to virtual inquiry learning spaces.





- Open Social Apps support the activities in different phases.

Federation of Labs and Apps

Apps, Labs, templates

Teacher assembles inquiry learning spaces for certain scenarios in the **Go-Lab ILS platform**.

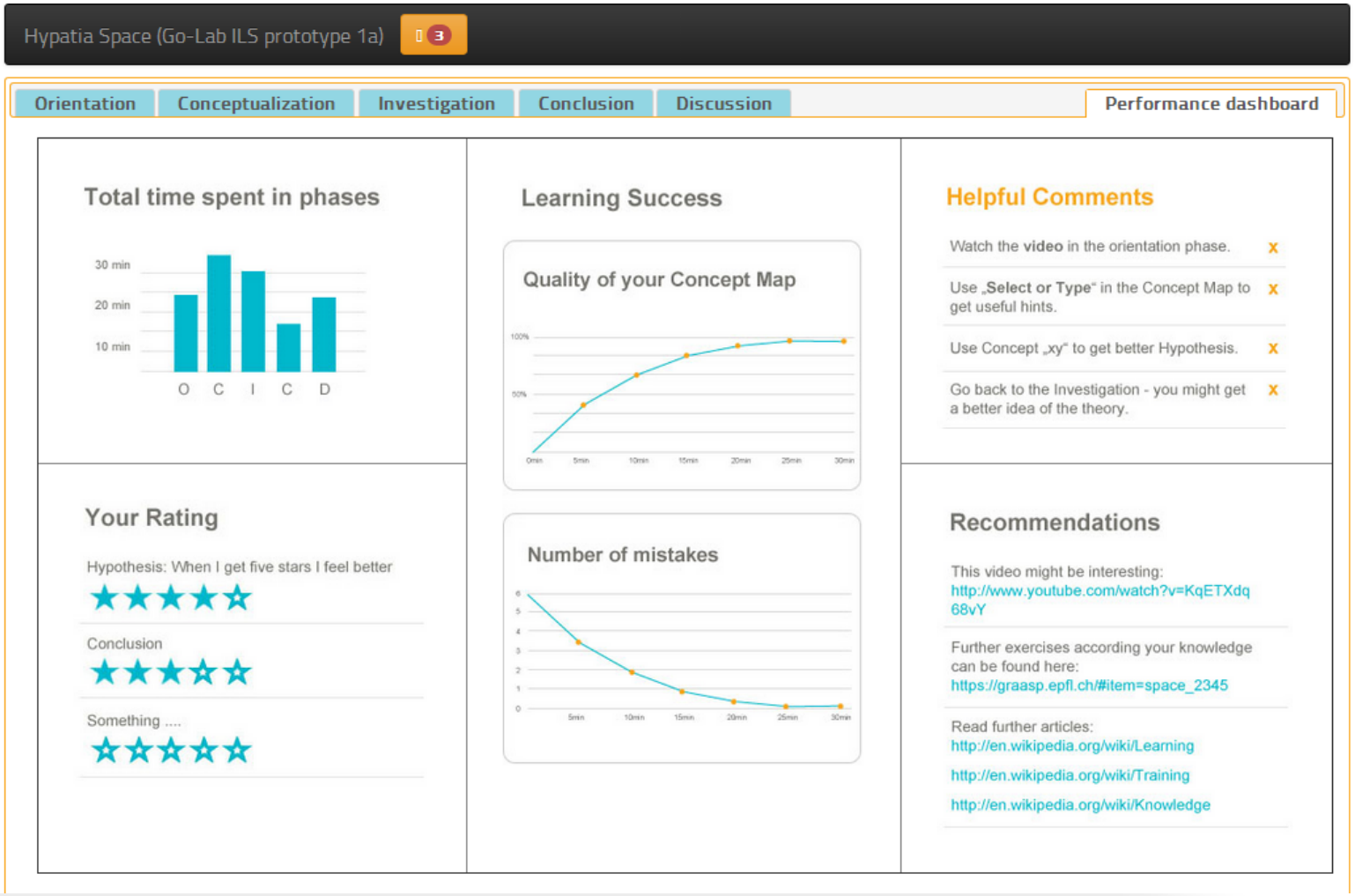
Create url

Student view distributed by url.

Sharing of predefined inquiry learning spaces, apps and online labs in a **lab repository**.

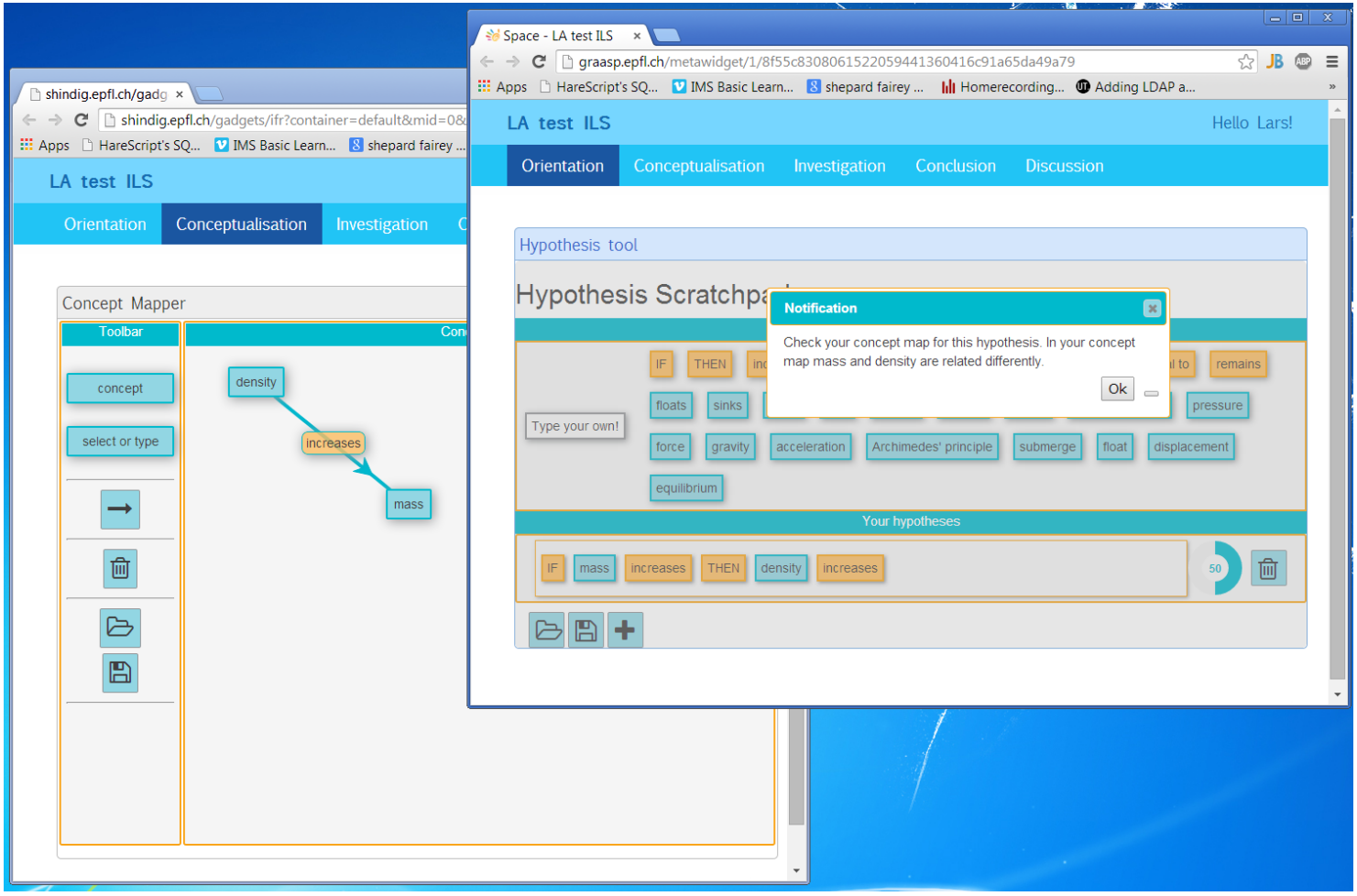
Intelligent Student Support

- Supporting self-reflection through student dashboards.



Intelligent Student Support

- Intelligent feedback mechanisms.



Learning Analytics

Learning Analytics - a common denominator for all types of measurement, collection, analysis and reporting of data about learners and their learning contexts with the aim of understanding and optimising learning and learning environments.

big data? (MOOCs?)

interest in algorithms & computational methods

relation to educational data mining?

Spectrum of Learning Analytics Topics and Applications

- Prediction of students at risk from academic records
- Monitoring of course participation on learning platforms (e.g. Moodle)
- „Open Learner Modeling“ as a tool for reflection support
- Discourse and argumentation analysis

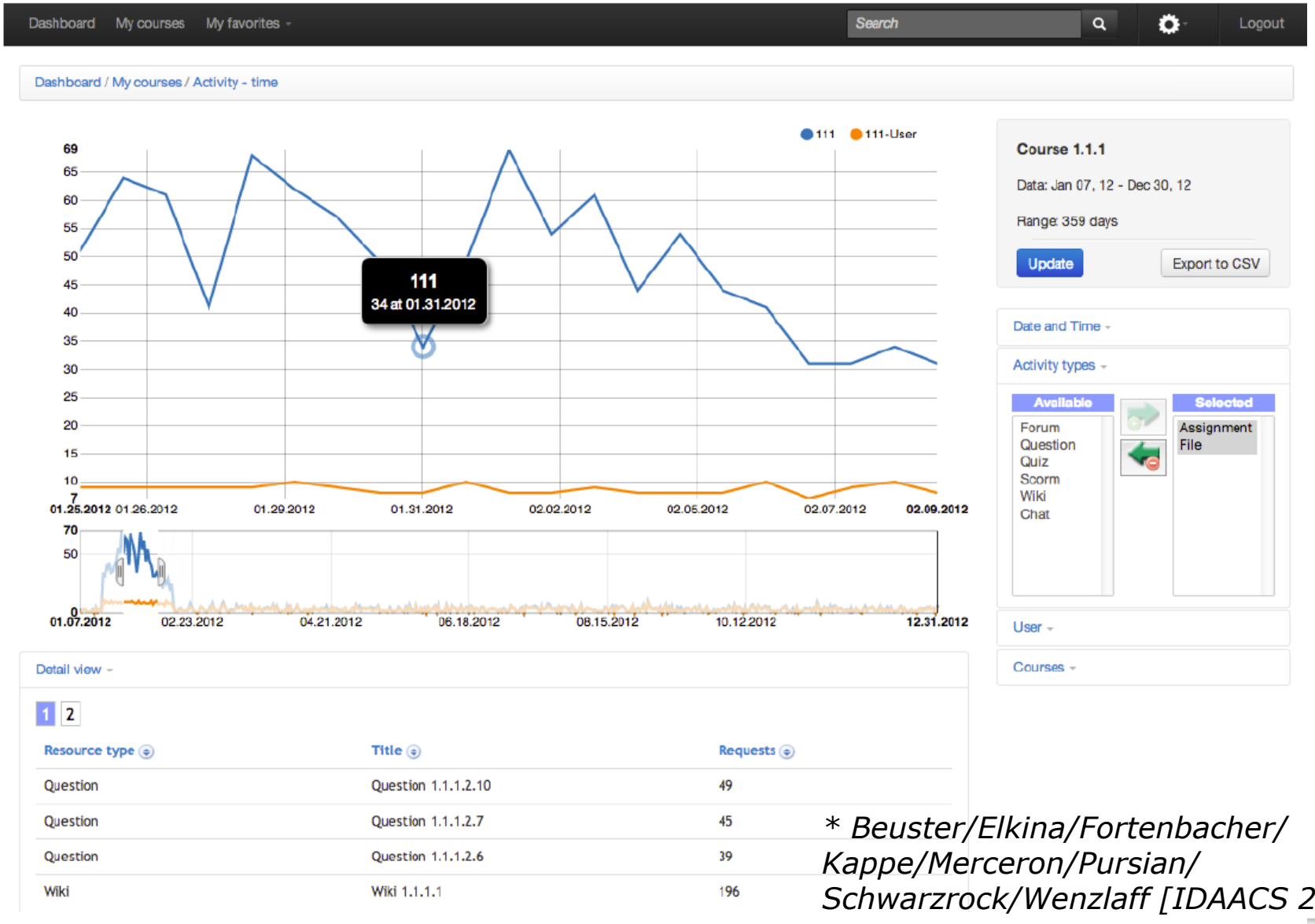
The Methodological „Trinity“ of LA

Activity analysis:
- process-oriented
- sequence analys
  (e.g. „proc
- action pat

Artefact analysis:
- product-oriented
- information / text mining
- „semantic richness“
  ysis

Network analysis:
- social or actor-artefact relations
- network measures (centrality, cohesion, …)
- no inherent time

Enhancing LMS with analytics: LeMo *

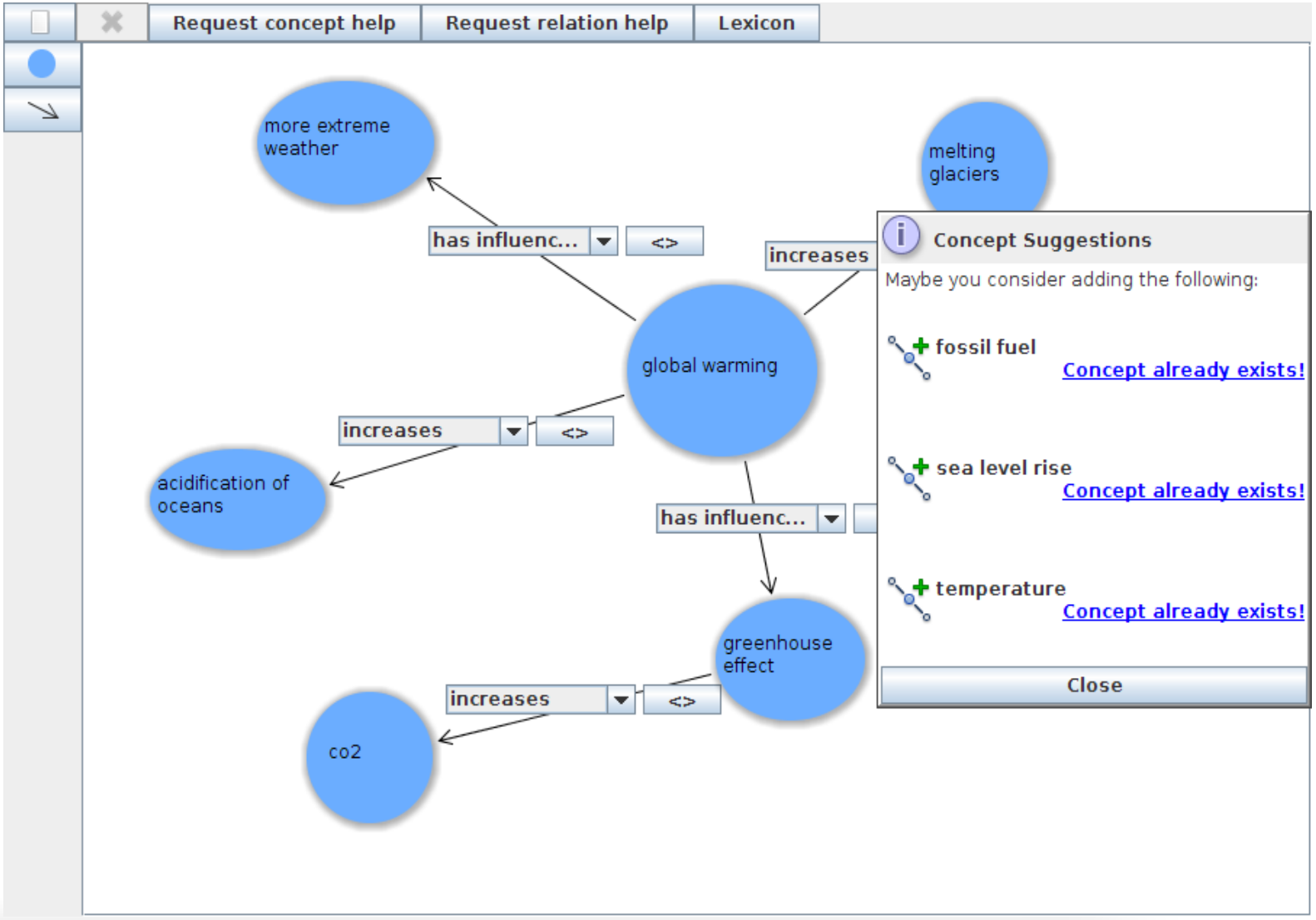


** Beuster/Elkina/Fortenbacher/ Kappe/Merceron/Pursian/ Schwarzrock/Wenzlaff [IDAACS 2013]*

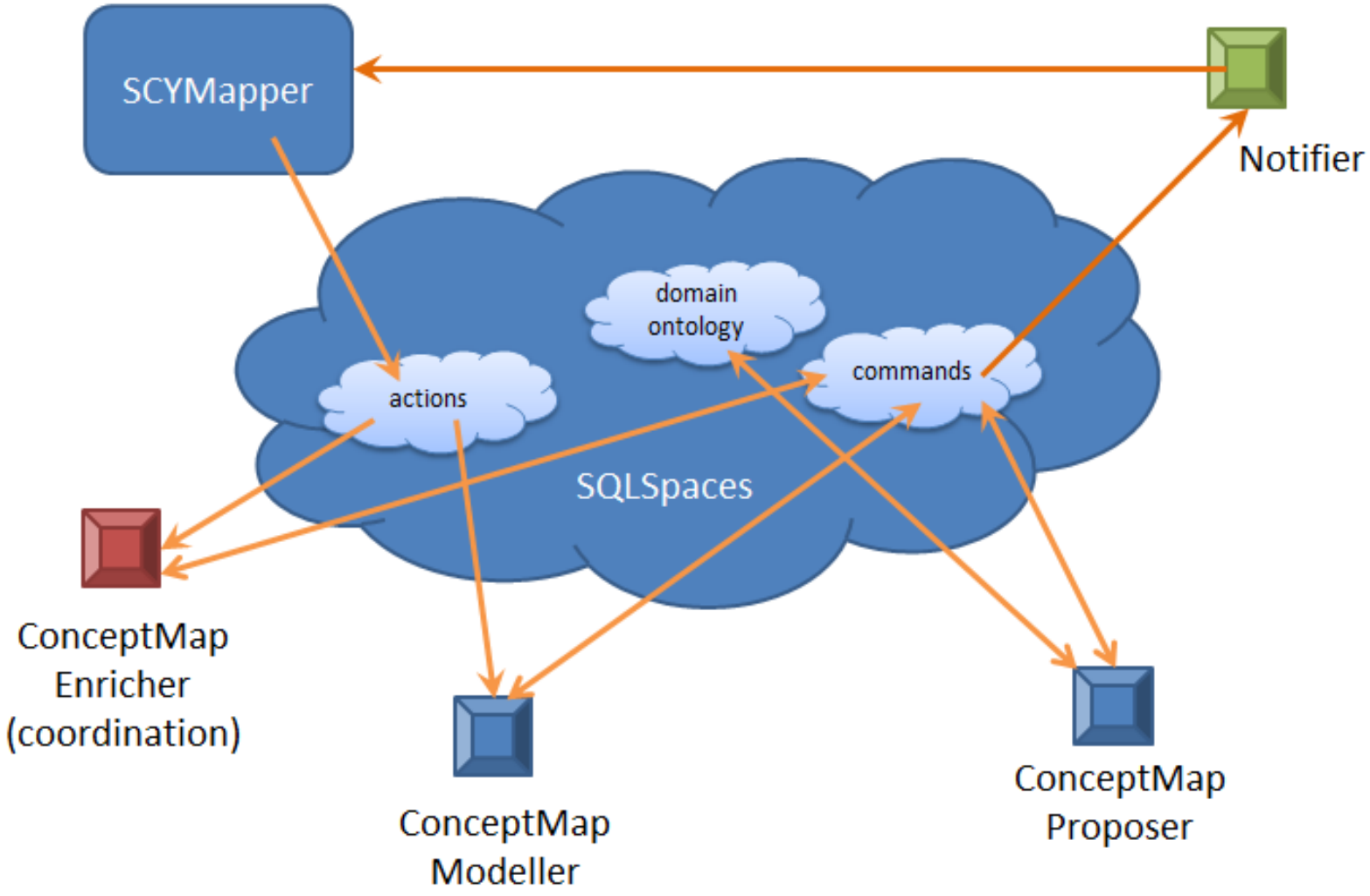
Example #1:

Analyzing student created concept maps (from project SCY)

Scaffolding of CM Construction

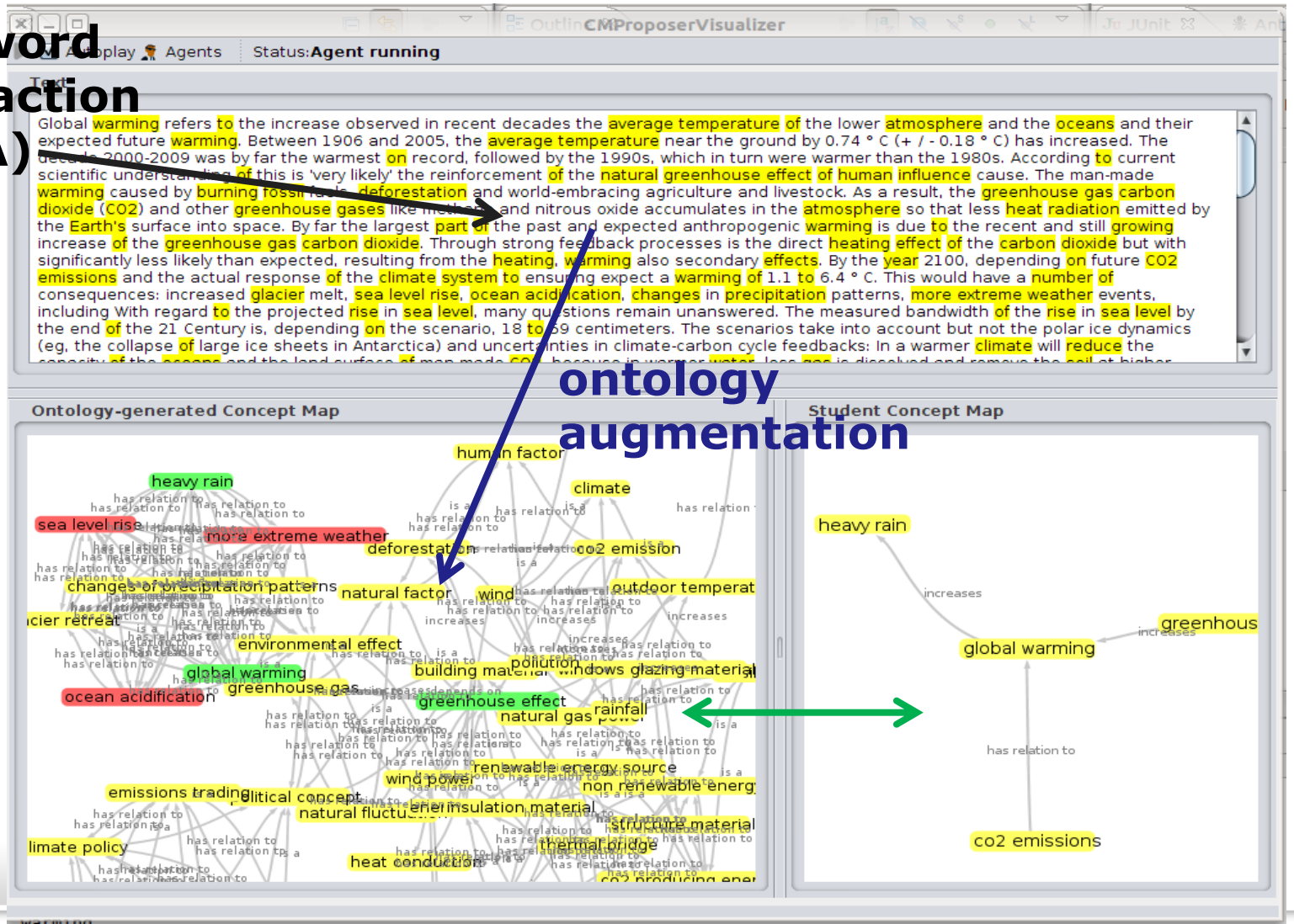


Agent Architecture



Ontology-based Support / Matching

keyword extraction (LDA)



Quality Assessment of CMs

Comparison to expert map(s)

Conlon, T.: 'Please argue, I could be wrong': a reasonable fallible analyser for student concept maps. Proc. of Ed-Media 2004.

Gouli, E., Gogoulou, A., Papanikolaou, K., Griggoriadou, M.: How to qualitatively + quantitatively assess concepts maps: the case of COMPASS. Proc. of AIED 2005.

Generic approach using *background knowledge* (a domain ontology) and *information extraction* (LDA) + *structural (graph-theoretical) measures*

Concept Mapping Study

Participants:

37 high school students aged between 16-18

Procedure:

45 min - introduction to concept mapping
(+ tool “SCY Mapper”)

45 min - reading/highlighting of a two page text on global warming followed by CM construction

experimental group received adaptive suggestions
control group could only access a dictionary

Expert Assessment

Four experts assessed the concept maps produced by the students …

based on two criteria (inspired by Marra, 2002):

- *completeness* regarding the concepts used
- *connectedness* regarding the relations introduced (adequacy, missing rel's)

First Results

No significant differences between scaffolded and non-scaffolded conditions.

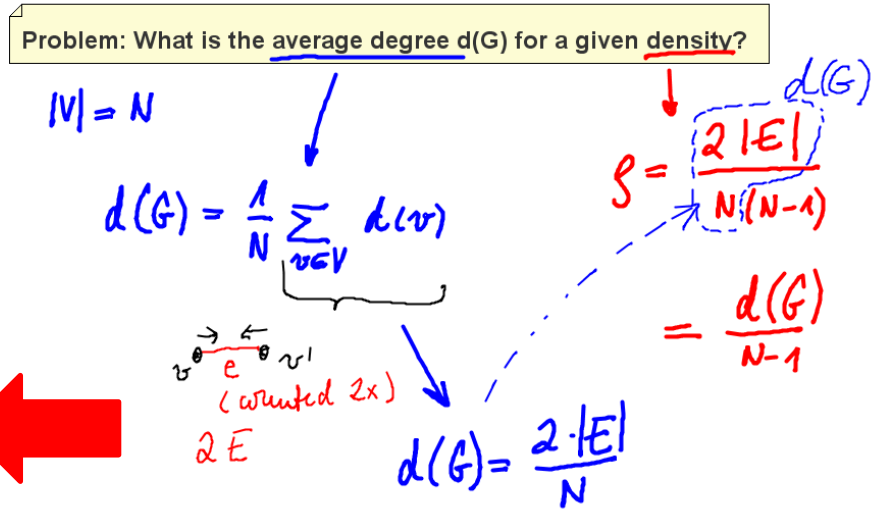
Predictive power of simple structural measures cannot be much improved by including of semantic features (ontology).

Correlations

*Correlation of **structural measures** with expert judgments*

	Criterion 1 (completeness)	Criterion 2 (connectedness)
# nodes	r = 0.79, p = 0.000	-
# edges	r = 0.74, p = 0.000	r = 0.63, p = 0.000
density	**r = -0.53, p = 0.001**	r = -0.26, p = 0.11

A mathematical explanation ….

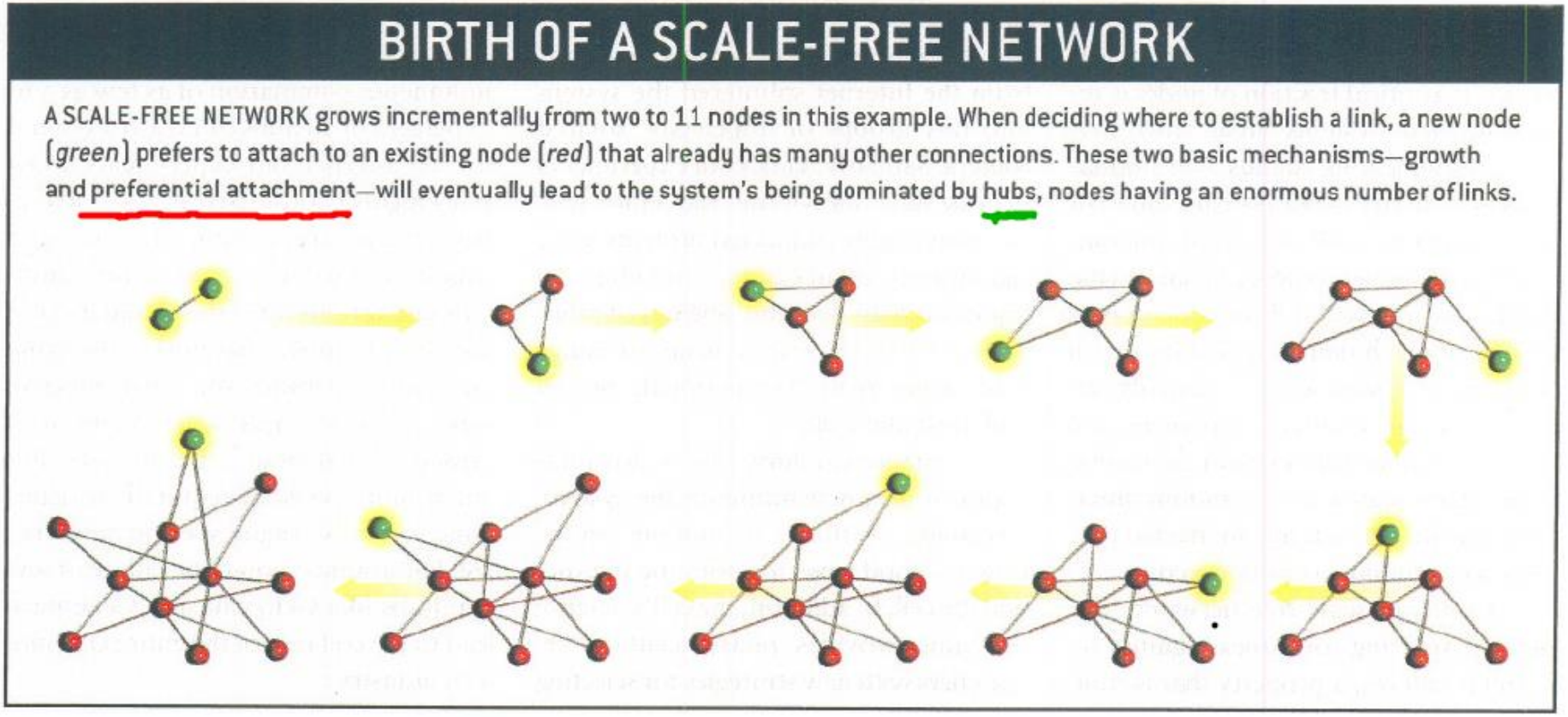


- In any graph *density* is *average degree* divided by #nodes.

- In „scale-free networks" the *average degree* tends to be stable.

- Hence: If CMs evolve like SFNs the density is highest for the ***smallest maps*** !

The Evolution of Scale-free Networks: *Preferential Attachment*



Barabási, Albert-László, Bonabeau, Eric (May 2003). "Scale-Free Networks". *Scientific American* **288** (5): 60–9.

A Network Perspective on Concept Maps

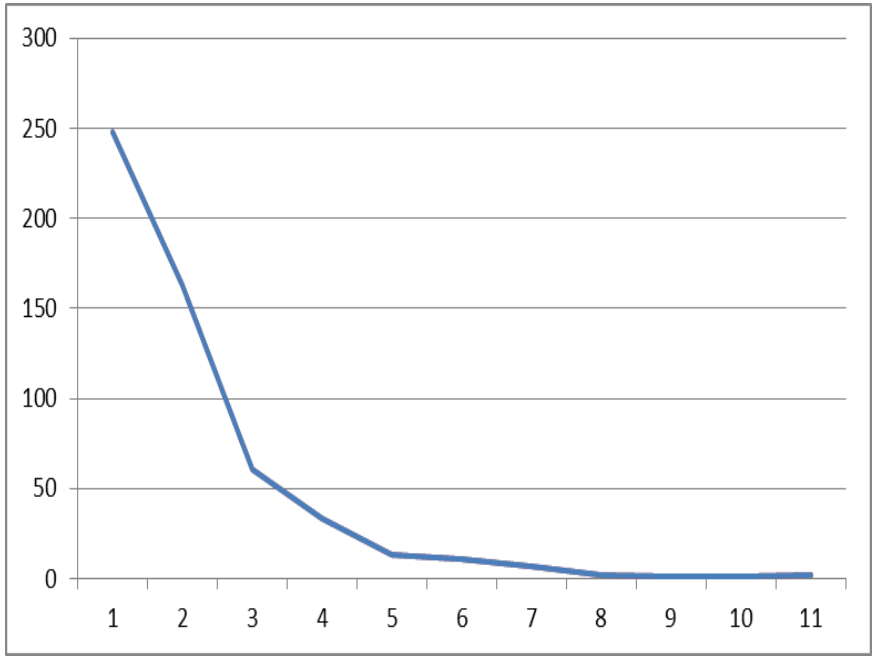
Concept maps are scale-free networks!

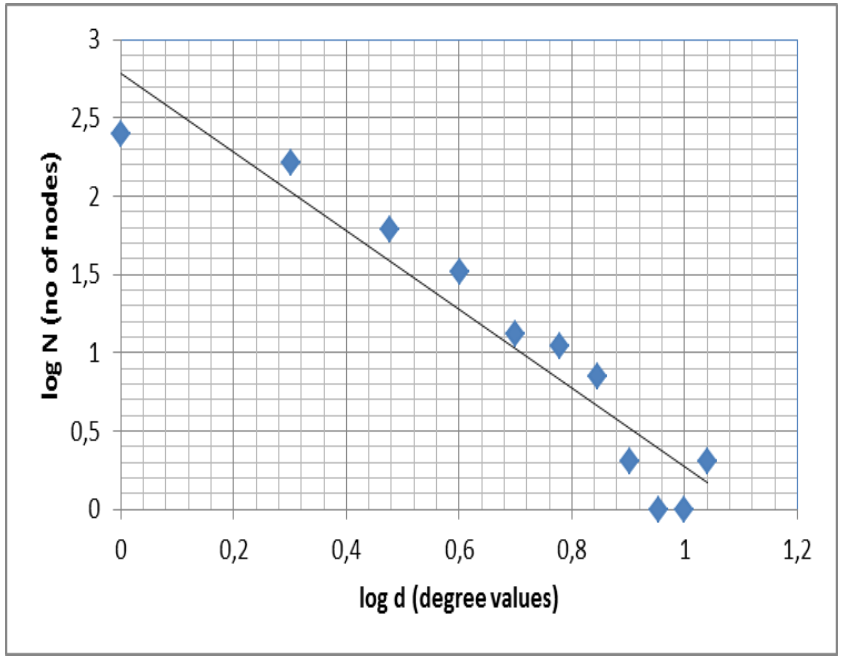
=> evolution of concept maps is governed by "preferential attachment";

density decreases with growing networks

M. Jacobson & M. Kapur (2010): "Ontologies as scale free networks – implications for theories of conceptual change" (panel paper at ICLS 2010)

The Litmus test





Aggregated degree distribution (from 37 maps)
left: number of nodes per degree value,
right: log-log graph

Related empirical work

Ifenthaler, Masduki and Seel (*Instructional Science, vol. 39, 2011*) compare a number of general graph theoretic measures to identify changes in cognitive structures using concept maps from five consecutive stages of a learning process

Table 4 Average scores (standard deviations in parenthesis) of graph theory based measures (organization) for measurement points 1–5 ($N = 25$)

		MP1	MP2	MP3	MP4	MP5
Surface structure	*M* (SD)	14.64 (7.99)	27.34 (14.13)	45.84 (23.85)	67.72 (48.94)	71.80 (46.71)
Graphical structure	*M* (SD)	5.52 (2.83)	7.62 (3.57)	9.48 (3.42)	12.08 (4.91)	11.72 (4.19)
Connectedness	*M* (SD)	.68 (.48)	.80 (.41)	.44 (.51)	.44 (.51)	.36 (.49)
Ruggedness	*M* (SD)	1.44 (.71)	1.32 (.74)	2.12 (1.42)	2.28 (1.49)	2.72 (2.01)
Average degree of vertices	*M* (SD)	1.93 (.43)	2.06 (.53)	2.12 (.39)	2.11 (.24)	2.09 (.26)
Number of cycles	*M* (SD)	2.52 (2.37)	3.38 (2.59)	4.12 (2.68)	4.76 (3.95)	4.48 (3.00)
Number of vertices	*M* (SD)	14.40 (6.69)	24.65 (11.76)	42.24 (22.60)	63.96 (45.85)	68.16 (44.33)

Example #2:

Extraction of semantic networks
from textual artefacts created by students
(from ongoing project JuxtaLearn)

Background:

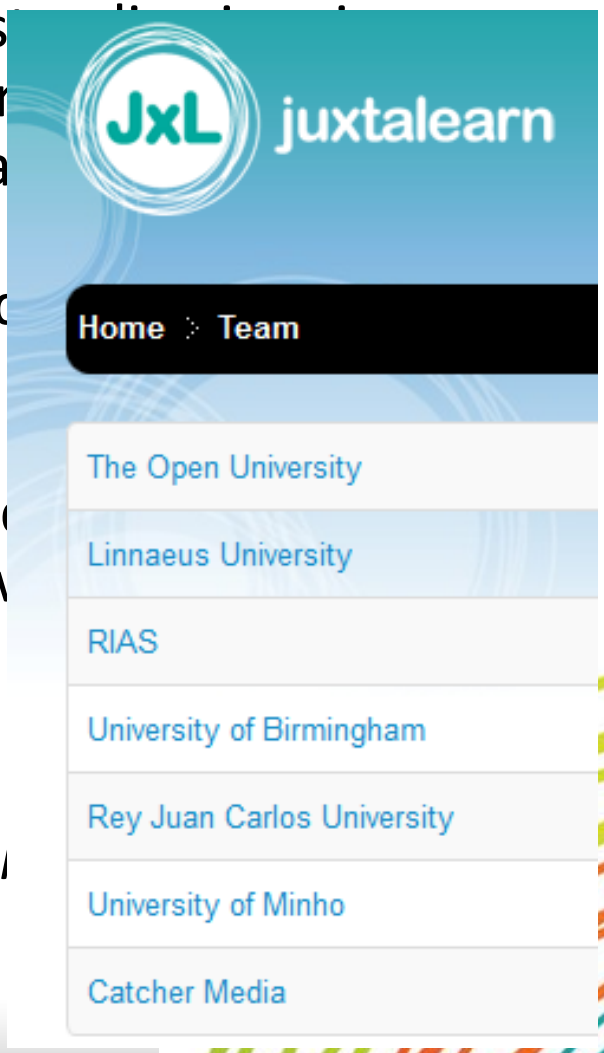
EU Project JuxtaLearn (2012-2015)

- Provoking student curiosity and unders
  and technology through creative perfor
  (concretely: film making – editing – sha

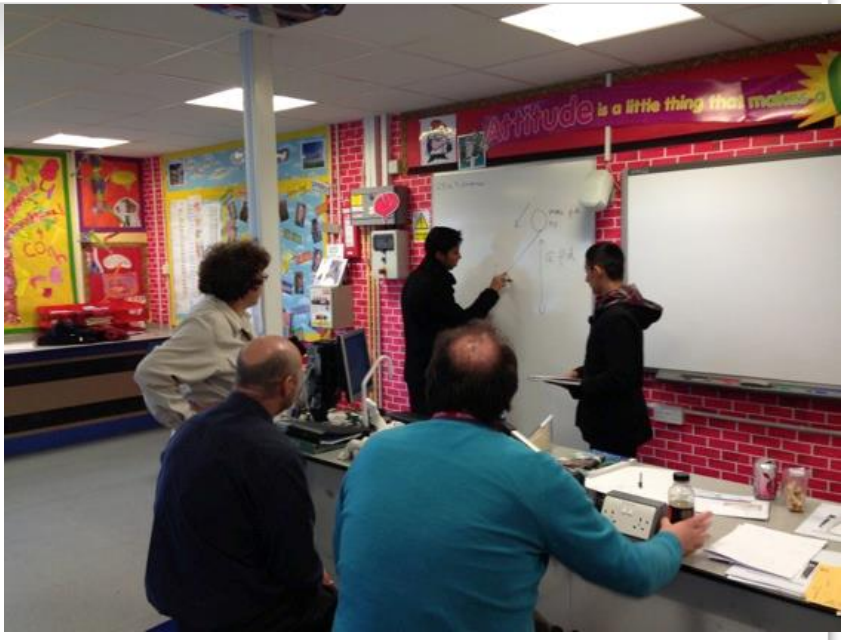
- Teaching and learning support is guide
  concepts

- First step: identifying such concepts an
  by conducting face-to-face workshops v
  students

  → *Learning Analytics techniques are*
  to extract representations of the u
  conceptual relations



Initial Workshops



- Teacher-student workshop

- Six A-level students

- Role reversal:
  students teach the teachers

- Topics: Chemistry - moles,
  Biology - alleles,
  Physics - potential energy

→ *transcripts and summaries analysed using the AutoMap/ORA toolset for Network Text Analysis*

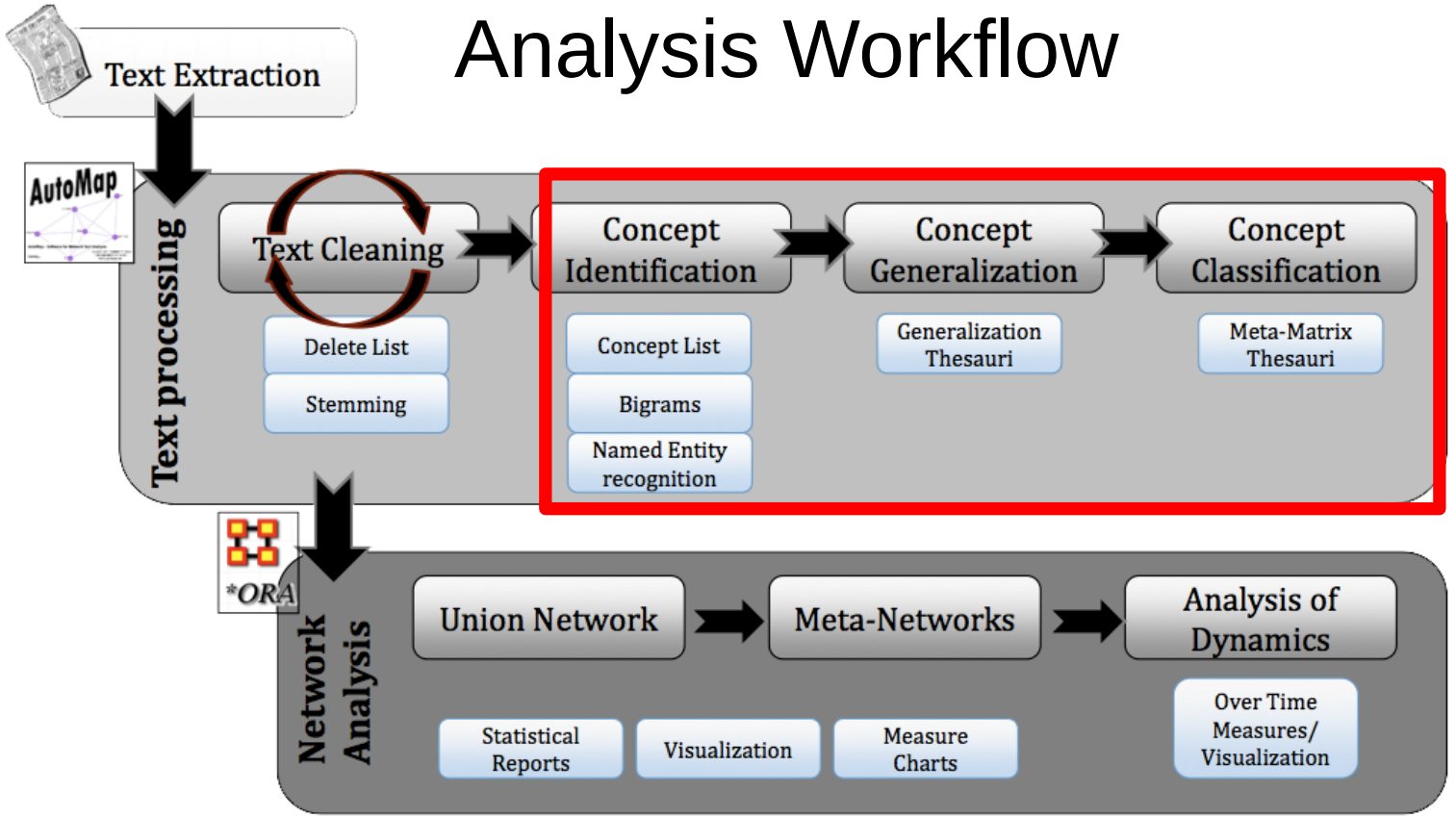
Network Text Analysis

- Use of the AutoMap and ORA software tools for „network text analysis“ developed by the CASOS group at CMU

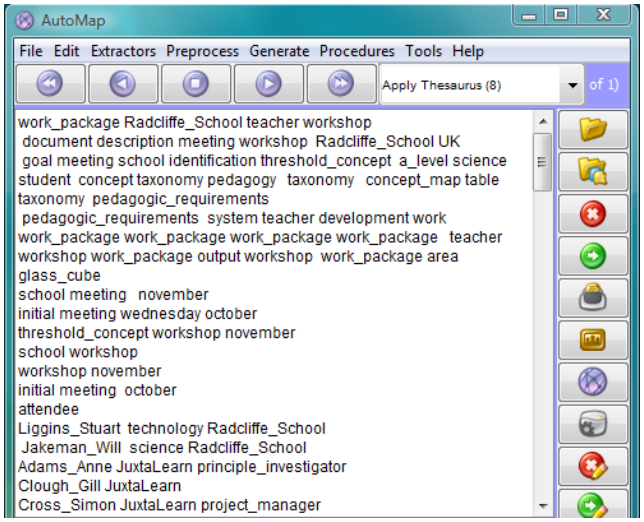
- Workflow:
  - collection of workshop transcripts (textual artefacts)
  - pre-processing and analysing with AutoMap[1]
  - visualization through ORA-Netscenes[2]

- Result:
  generation of multi-modal concept maps
  (with categories: actor, domain concepts, pedag. concepts …)

Network Text Analysis - Process



Concept generalization



Concept Generalization
-> Generalization Thesaurus

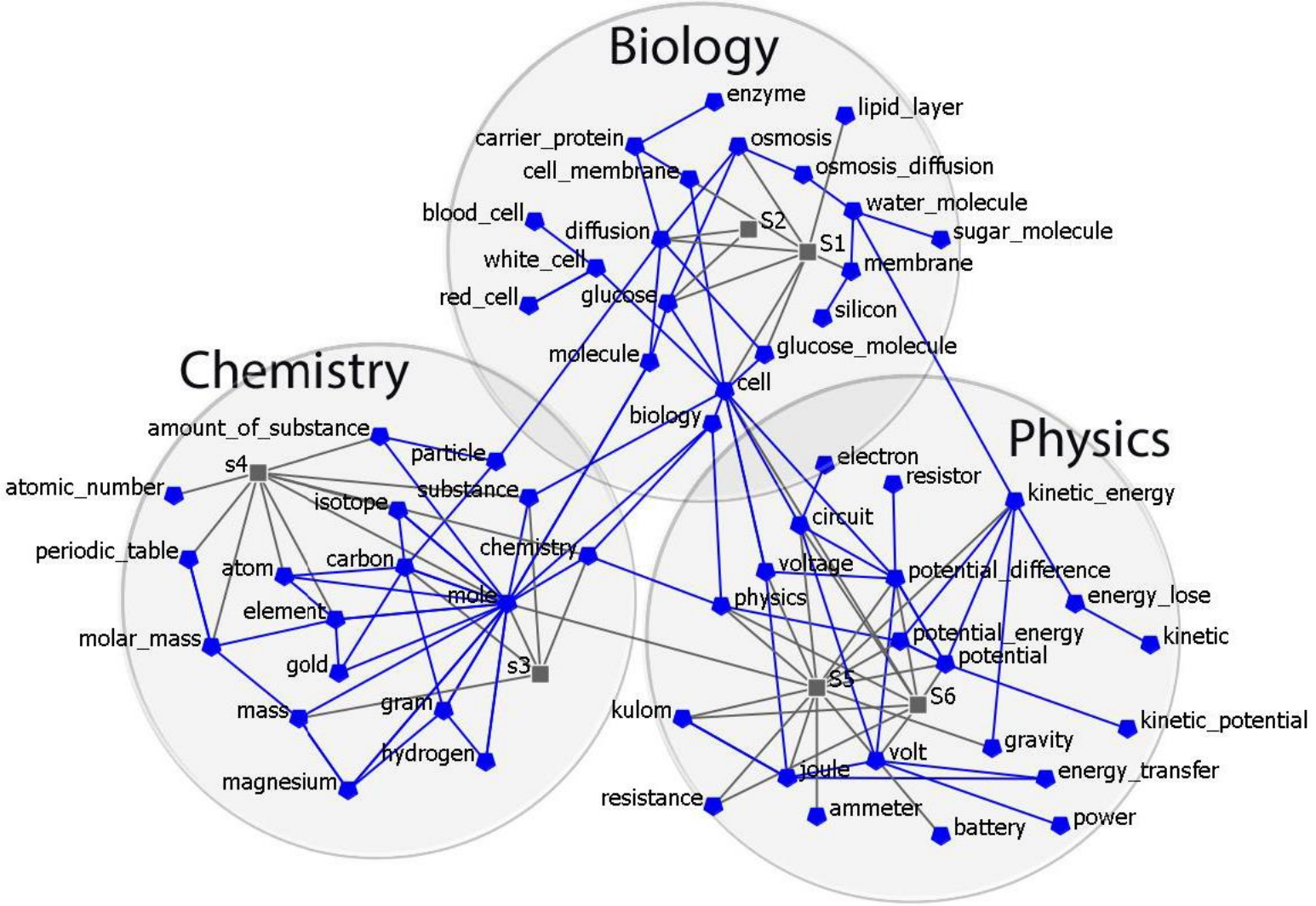
	A	B
2	Teachers	teacher
3	Teacher	teacher
4	teachers	teacher
5	teacher	teacher
6	Head of Technology	head_of_technology
7	Head of technology	head_of_technology
8	head of technology	head_of_technology
9	Head Technology	head_of_technology
10	Head technology	head_of_technology
11	head technology	head_of_technology
12	Head of science	head_of_science
13	Head of science	head_of_science
14	head of science	head_of_science
15	Head Science	head_of_science
16	Head science	head_of_science
17	head science	head_of_science

Concept Classification

- actor
- country
- general_concept
- (domain) knowledge
- pedagogical_concept
- role
- technical_concept
- tools _and_technologies

-> Meta Thesaurus

Teacher-Student Workshops - Results



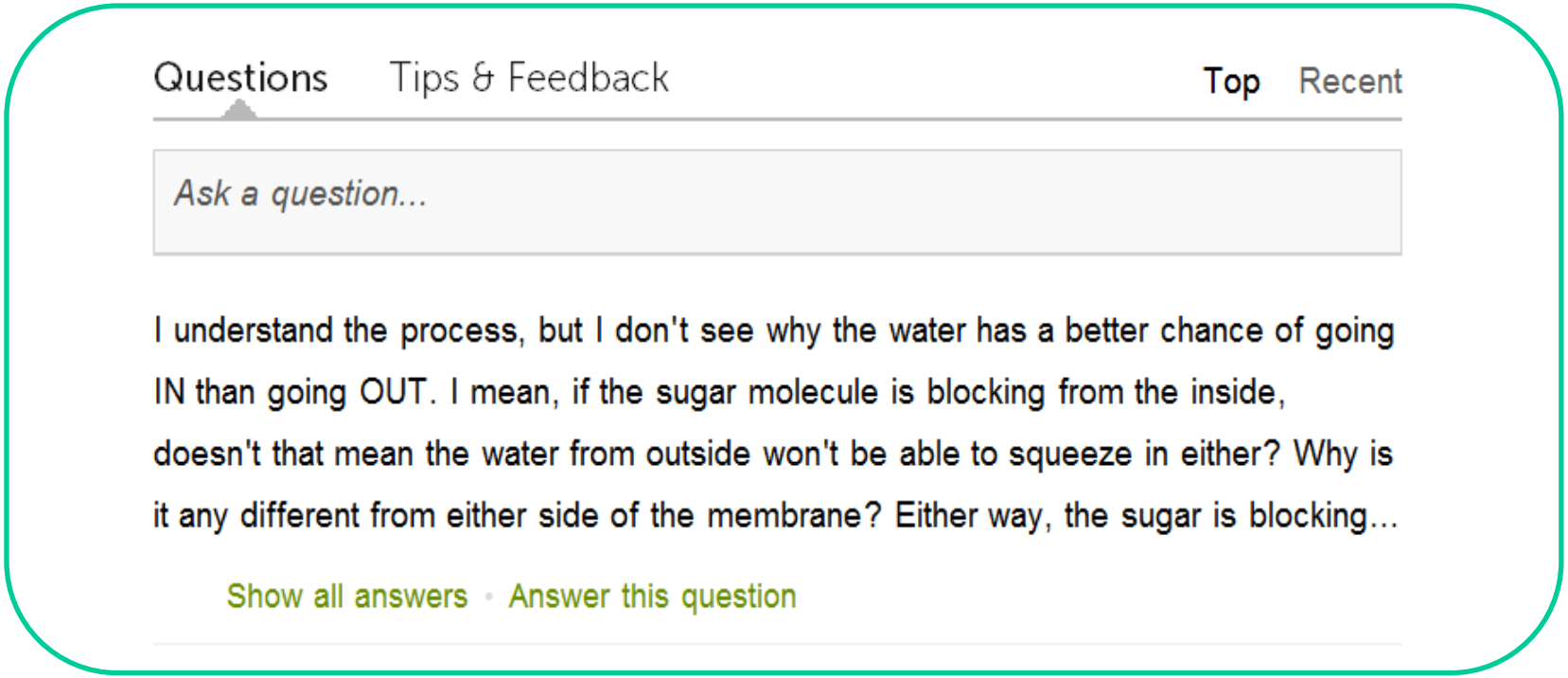
„External“ Learning Analytics in JuxtaLearn

Extraction of information from *video comments* about:

- associations of concepts
  (adequate or inadequate from a scientific point of view)
- identification of concepts that are frequently addressed in questions as indicators of possible origins of comprehension problems
- associations between concepts often used in answers as indicators for missing relations in students’ mental models (=> misconceptions or “stumbling blocks”)

Case study: Khan Academy

Scaffolded questions & answers



Artefact Analysis - the JxL Approach

- Textual annotations of videos as indicators for students' understanding and potential misconceptions
- In addition to domain concepts "signal concepts" (difference between X and Y, help on X needed, etc.) indicate special relations

- Benefits for…
  - Researchers: insight into patterns of learning
  - Teachers: monitoring learning processes around videos
  - Students: system recommends videos or peer helpers

Data Selection / Extraction

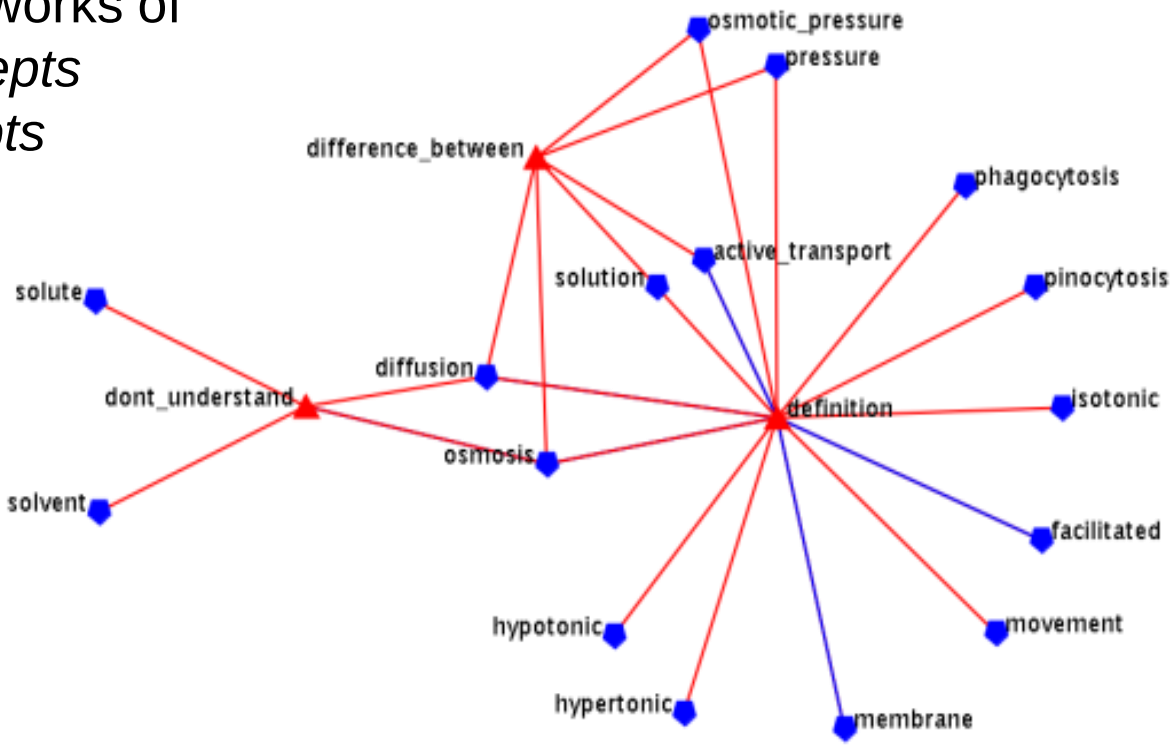
- 1.284 comments from educational videos

	chemistry	biology	physics
# users	328	309	86
# questions	279	184	70
# answers	362	312	77

- Video topics:
  - Chemistry: *Mole* and *Avogadro's Number*
  - Biology: *Diffusion* and *Osmosis*
  - Physics: *Voltage* and *Electrical Potential*

Resulting Multi-modal Network

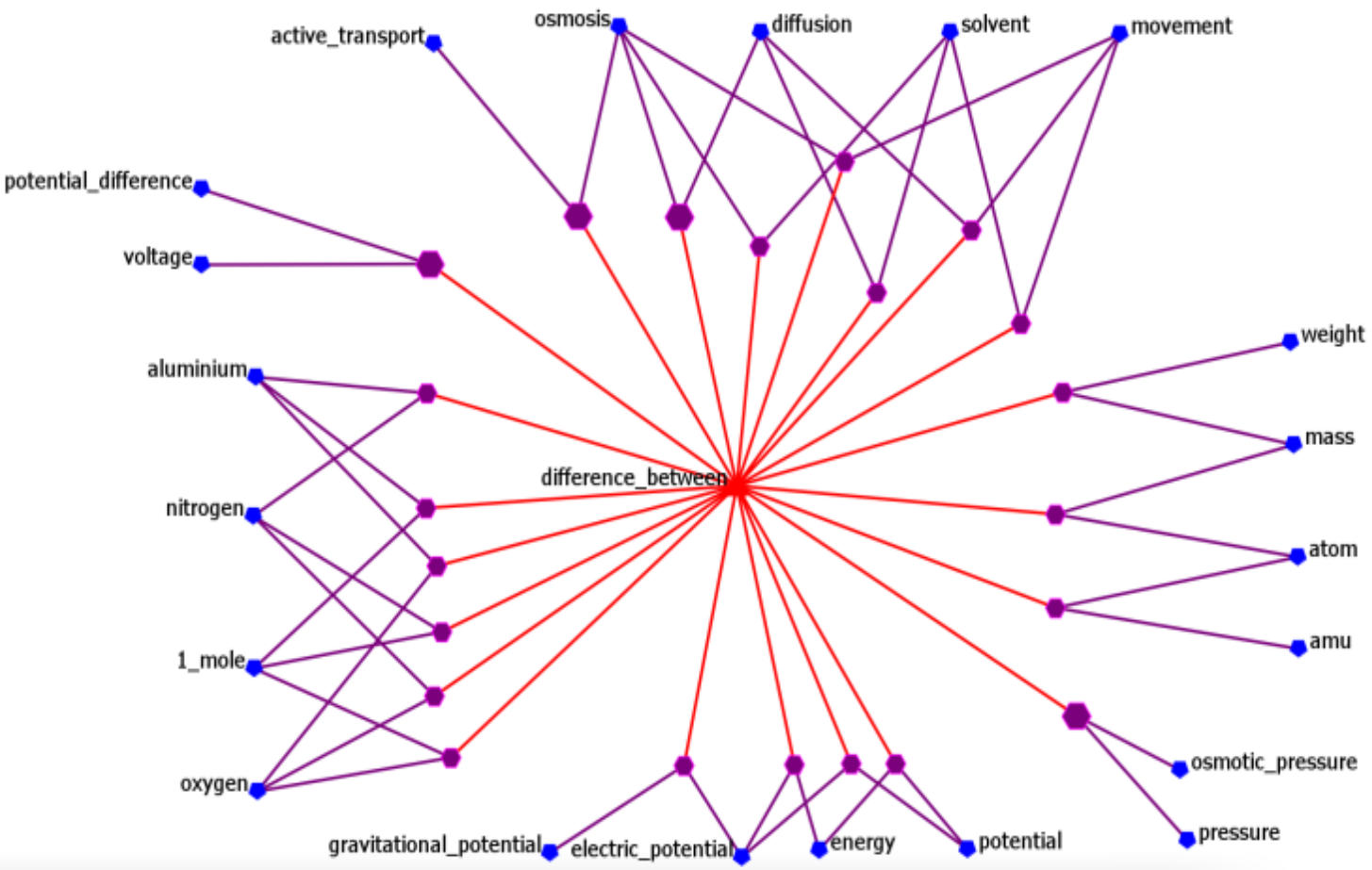
Multimodal networks of
- *domain concepts*
- *signal concepts*



Examples:
- *I don't_understand diffusion, but ….*
- *What's the difference_between osmotic_pressure and solution??*

Multimodal Analysis - disambiguated

Introduction of *combination nodes between domain concepts* and *signal concepts*



Highlighting Results in Context

I finally understand osmosis. Thanks Khan!!
1: do_understand osmosis thanks khan

how i know if the membrane will allow sugar to diffuse or not? plzany body reply.
1: explanation i_know if membrane be allow sugar diffusion not plzany body reply

KhanAcademy helped me to review a unit on OSMOSIS AND DIFFUSION in my BIOLOGY class!
1: khan_academy help review unit on osmosis_diffusion in biology class

hey is it possible for you to create a video explaining the pressure flow theory of phloem transport?
1: hey be possible creation video explanation pressure flow theory phloem transport

Still confused about osmotic pressure :/ wasted a bit of time..
1: still confusion about osmotic_pressure / waste bite time

how do the sugar molecules get out?
1: explanation sugar_molecule get out

Embedment into JxL Process

Stimulate and support reflection & feedback by

- providing awareness of one's own performance
- providing awareness about the learning process (students' progress, group structure)

Short Summary / Outlook

- *Artefact analysis* can help to identify problems of understanding and misconceptions
- Network perspective on knowledge artefacts facilitates new theoretical approaches
- For learning analytics combinations of the perspectives (*artefact – activity – network*) are needed!

QUESTIONS – COMMENTS ?