START

Graz University of Technology

Advances in Behavioral Sciences in the Internet Age:
Selected Topics in Mathematical Psychology
Scientific Organizer: Xiangen Hu

Central China Normal University
Wuhan – China - June 27^{th} - 2013

Workshop on
‘Knowledge & Competence/Skill Spaces and their Applications’

Dietrich ALBERT & Reinhard SUCK & Xiangen Hu

Workshop on
‘Knowledge and Competence/Skill Spaces and their Applications’

Introduction and Overview (Dietrich Albert)

Basic Approaches of Knowledge Representation - Knowledge Space Theory (KST): Examples, Basic Concepts and Axioms - Competence-Based KST (CbKST): Example, Basic Concepts - Generation and Validation of Knowledge and Competence Structures - Adaptive Knowledge Assessment - Applications and Projects (List)

Mathematics of Knowledge and Competence/Skill Spaces (Reinhard Suck)

Bases, Entailment Relation, Surmise Functions, Fringes - Skills and Competences: CbKST and Set Representations - Special topics: Learning Spaces, Meshing Spaces, Related Concepts

Applications, Demonstrations & Resources in Education (Dietrich Albert; Xiangen Hu)

Web-courses - Books and Documents – Bibliography – Software – (Adaptive, Personalised) eLearning Systems and Investigations – Other Applications

Final Remarks and Discussion

Workshop on

'Knowledge and Competence/Skill Spaces

and their Applications'

Introduction and Overview

Dietrich A l b e r t

Cognitive Science Section - CSS

Knowledge Technologies Institute - Graz University of Technology

Department of Psychology - University of Graz

Austria - Europe

QUESTIONS

Some knowledge questions for you

Where is AUSTRIA?

- **AUSTRIA flag**

Where is AUSTRIA?

- **AUSTRIA is located**

of course in **Europe** –

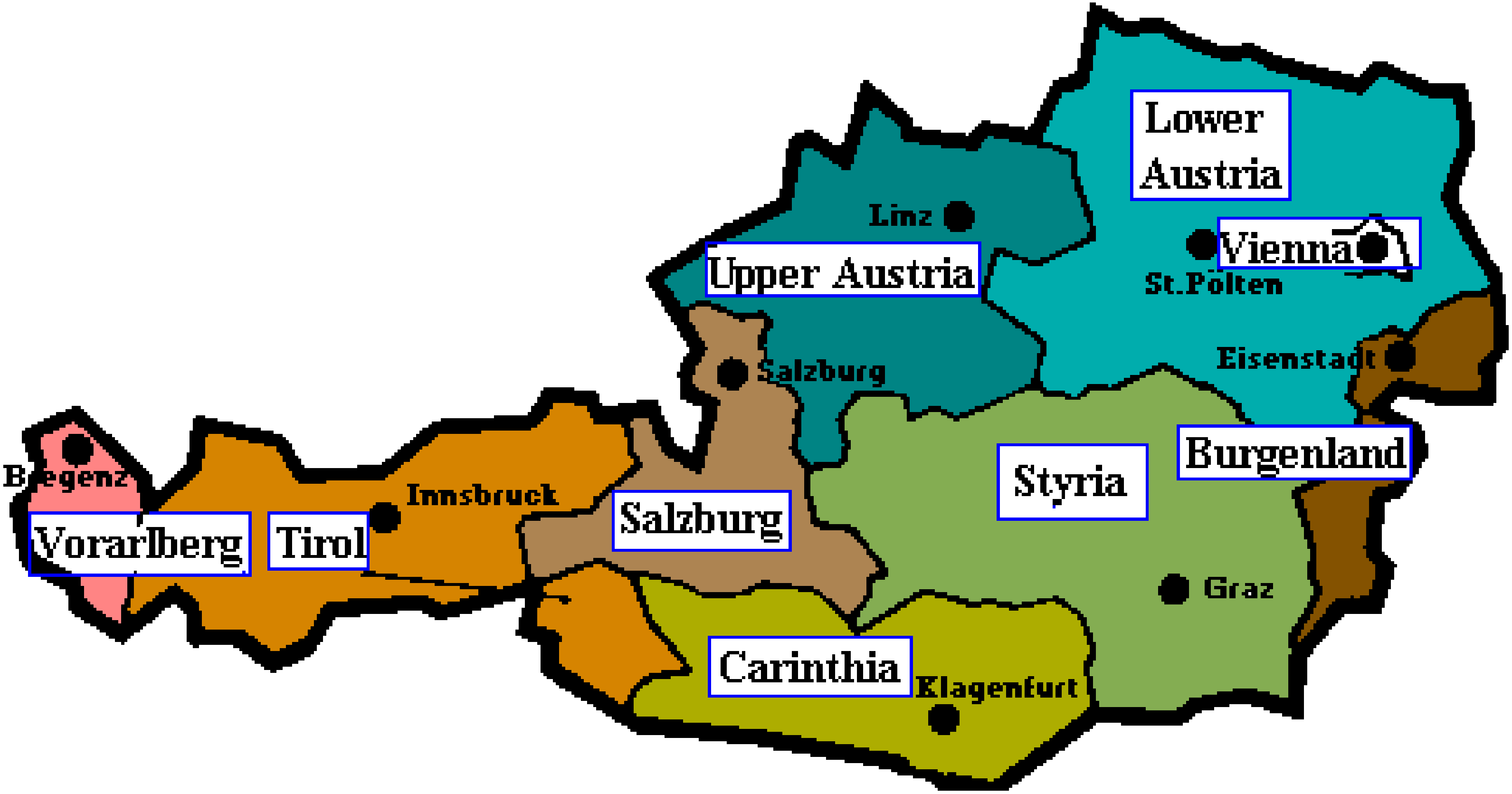
because it doesn't have kangaroos

Where is AUSTRIA in EUROPE?

- **AUSTRIA flag**

Where is STYRIA and It’s Capital GRAZ?

Where is STYRIA and It's Capital GRAZ?



How does GRAZ look like?

How does GRAZ look like?

TU Graz
Graz University of Technology

What's the Meaning of CSS?

What's the Meaning of CSS?

- **Cognitive Science Section (CSS)**
  - Principal scientist: Prof. Dietrich Albert
  - Interdisciplinary team of psychologists, computer scientists, mathematicians

  http://kti.tugraz.at/about-kti/team/

  CSS has been founded in 1993 - since 2010 CSS is located at
  - Knowledge Technologies Institute (KTI)

  http://kti.tugraz.at/
  - Head: Prof. Stefanie Lindstaedt
  - Graz University of Technology (TUGraz)

  http://portal.tugraz.at/portal/page/portal/TU_Graz

Our Experience & Expertise

Graz University of Technology

- European-wide collaboration with universities and business partners from various disciplines

- Long term experience in international and national projects
  - Cooperative EU-Projects since 2001 in the 5th Framework Programme

Our R&D Projects since 2001

- weSPOT - Working Environment with Social and Personal Open Tools for Inquiry based Learning. (FP7 ICT STREP)
- INNOVRET - Innovative Online Vocational Training of Renewable Energy Technologies (FP7 – LLL Leonardo Da Vinci)
- RECOBIA - Reduction of the cognitive biases in intelligence analysis (FP7 SEC STREP)
- CULTURA - Cultivating Understanding and Research through Adaptive Learning (FP7 ICT STREP)
- ImREAL – Immersive Reflective Experience-based Adaptive Learning (FP7 ICT STREP)
- GaLA – Gaming and Learning Alliance (FP7 NoE)
- NEXT-TELL – Next Generation Teaching, Education and Learning for Life (FP7 ICT IP)
- ROLE - Responsive Open Learning Environments (FP7 ICT IP)
- TARGET – Transformative, Adaptive, Responsive and Engaging Environment (FP7 ICT IP)
- GRAPPLE – Generic Responsive Personalized Learning Environment (FP7 ICT STREP)
- 80Days - Around an inspiring virtual learning world in eighty days (FP7 ICT STREP)
- MedCAP - Competence Assessment for Spinal Anesthesia (FP7 – LLL Leonardo Da Vinci)
- Repeated Comprehensiosual Search (FWF)
- ELEKTRA - Enhanced Learning Experience and Knowledge Transfer (FP6 IST STREP)
- Graph Comprehension (FWF)
- Probabilistic Knowledge Space and Item Response Theories (FWF)
- ELeGI - European Learning Grid Infrastructure (FP6 IST IP)
- iCLASS - Intelligent Distributed Cognitive-based Open Learning System for Schools (FP6 IST IP)
- Kaleidoscope – TRAILS (FP6 IST NoE)
- LeGE-WG: Learning Grid of Excellence Working Group (FP5 Thematic Network)
- Efficient assessment of the organizational action (IHP Marie Curie Research Fellowship)
- EASEL: Educator Access to Services in the Electronic Landscape (FP5 IST IP)

Overview

- Introduction
- Knowledge Space Theory
    - Application: ALEKS
- Demand Component Approach
    - Application: RATH
- Competence-Performance Approach
    - Application: APeLS
- Ontology-based Skill Approach
    - Application: iClass

Introduction

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General Remarks

- ICT in Education needs basic **and** applied research: Policy of the European Commission (EC)
- ICT in Education needs research and development not only in technology but also in pedagogy, psychology, cognitive sciences, and social sciences: ICT-Calls of the EC regarding eLearning and Technology enhanced Learning (TEL)
- The gap between basic and applied research at one hand and good practices and applications at the other hand is rather small: We want to demonstrate this by our talks.
- This is the first aim of our talks

General Remarks

- Second aim is to demonstrate that real interesting and relevant problems can be solved by using mathematics. Once solved, the solutions can be applied in different settings by re-interpreting the formal model
- Third aim is to demonstrate – in terms of Prof. Batchelder – the usefulness of starting at the lowest non trivial level of modelling. The used mathematics have not yet been available while psychology started in 19th century as a modern science. The founders took physics as a model and did not know about discrete mathematics. That was and is a pity.

General Remarks

- Last but not least, the third aim of our talks is even more important:
  - to interest YOU in our approaches and
  - to invite YOU to spend some time at Graz University of Technology for collaborative research and development

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Classroom Teaching
Long Tradition

UNI GRAZ

COGNITIVE Science

Is this the Future of Classroom Teaching?

Classroom Teaching Advantages

- Well known and integrated into the educational system
- High potential for modernisation
- Face-to-face interaction
  - Students peers are models
    - Learning strategies
    - Exchanging Metacognitions
  - Social aspects / Social skills
  - Motivational aspects (e.g. through competing)

Private/Home Teaching
Even Longer Tradition

Private/Home Teaching Advantages

- Personalisation and individualisation
  - tailored
    - Instructions
    - Course content
    - Curriculum
    - Learning progress
    - Learning goal

Private/Home Teaching Advantages

- Intensive personal contact and tutor-learner interaction
  - Tutor supports learner in planning work
  - Discussion of course content
  - Tutor reacts on learners motivational and emotional states
- Flexibility
  - Individual times for learning
  - Individual places for learning
- etc.

Is Private/Home Teaching the Future of Education?

- Of course not this traditional type of private teaching - it is too expensive
- However, a modern type of private teaching may be realized and part of blended learning settings by ....

Todays Hi-Tech Class Room

Graz University of Technology

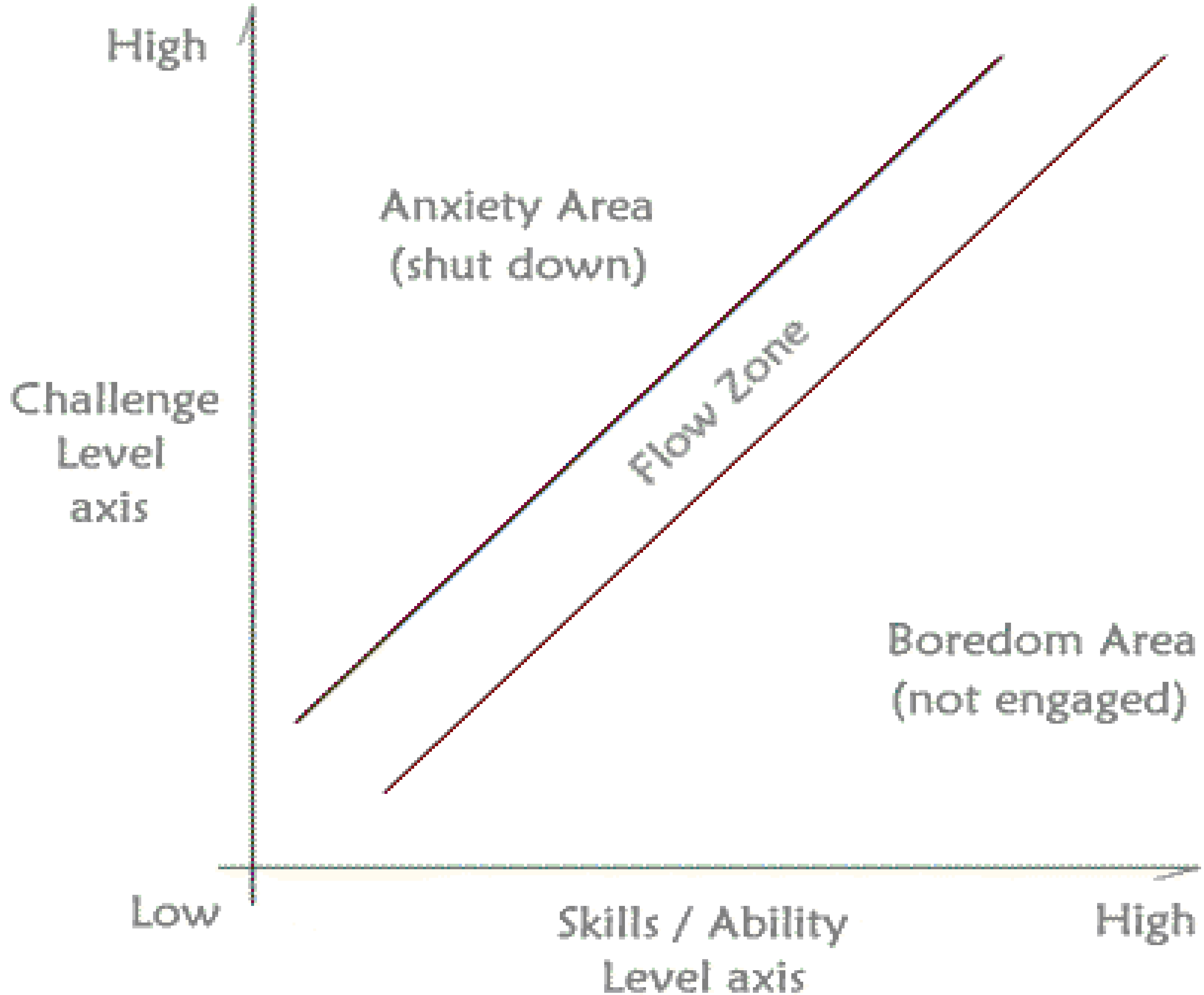
Main Questions of the Talk

- How to create adaptive, individualised eLearning systems based on psychology of learning which adapts to the individual student‘s knowledge, needs, decisions, self regulation skills …
- On the other hand, how to guide the student to follow a strict curriculum given by educational authorities, like the teachers, the Ministery of Education etc.
- **The (Competence-based) Knowledge Space Theory [CbKST] is used for supporting personalised eLearning !**

Balance →Flow

- The American psychologist Mihaly Csikszentmihalyi is the discoverer of a mental state that he calles ‘Flow ‘

- http://tonsoftime.com/2007/04/


High
Anxiety Area
(shut down)
Challenge
Level
axis
Flow Zone
Boredom Area
(not engaged)
Low
Skills / Ability
Level axis
High

A Simple, Wellknown Educational Principle

- The individual pupil/student has to be ready for what s/he is learning next
- Present the student with content and information for which s/he is ready for, that means
  - **You have to know the prerequisite content and whether the student has knowledge about this prerequisite knowledge or not, and**
  - **choose and present content according to the students current knowledge**

A far Reaching Consequence KST

- This well known simple rule has a less simple theoretical consequence:
- A mathematical-psychological theory founded by Falmagne and Doignon in 1985, developed by them further and extended by others (e.g. Albert, Held, Hockemeyer, Korossy, Lukas,,..): The **Knowledge Space Theory (KST)**
- KST and its CbKST-extensions are the basis for individualised eLearning – like private teaching

- Introduction
- **Knowledge Space Theory**
  - Application: ALEKS
- Demand Component Approach
  - Application: RATH
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Knowledge Space Theory
Basic Concepts

- Basic Concepts of KST
  - Knowledge domain
  - Surmise/prerequisite/precedence relation
  - Knowledge state
  - Knowledge structure, knowledge space
  - Learning path
  - Learning goal

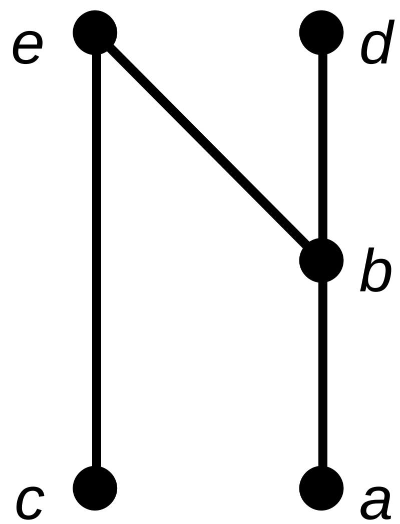
KST Basic Concepts Knowledge Domain

- In KST a knowledge domain is identified with a set of problems
  - Simple Example

a	378 x 605 = ?
b	58.7 x 0.94 = ?
c	1/2 x 5/6 = ?
d	What is 30% of 34?
e	Gwendolyn is 3/4 as old as Rebecca. Rebecca is 2/5 as old as Edwin. Edwin is 20 years old. How old is Gwendolyn?

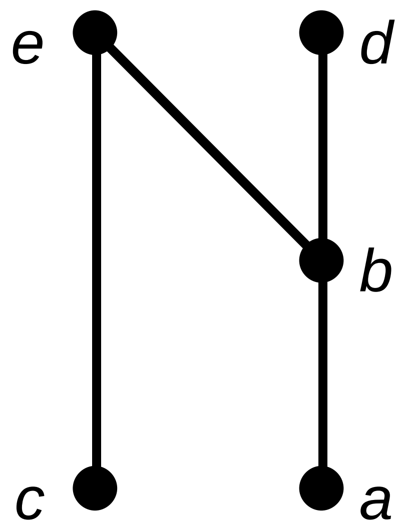
Surmise/Prerequisite Relation

- Surmise/Prerequisite/Precedence Relation
  - defined on the knowledge domain *Q* of the Example



Surmise/Prerequisite Relation

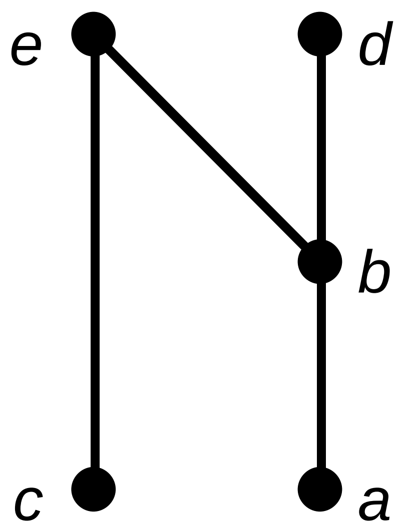
- Surmise/Prerequisite/Precedence Relation
  - defined on the knowledge domain *Q* of the Example



Attention please:

This is merely a simplified **visualisation** of a Surmise Relation S = {(a,b), (a,d), (a,e), (b,d), (b,e), (c,e)} !!!

KST Basic Concepts
Knowledge Structure



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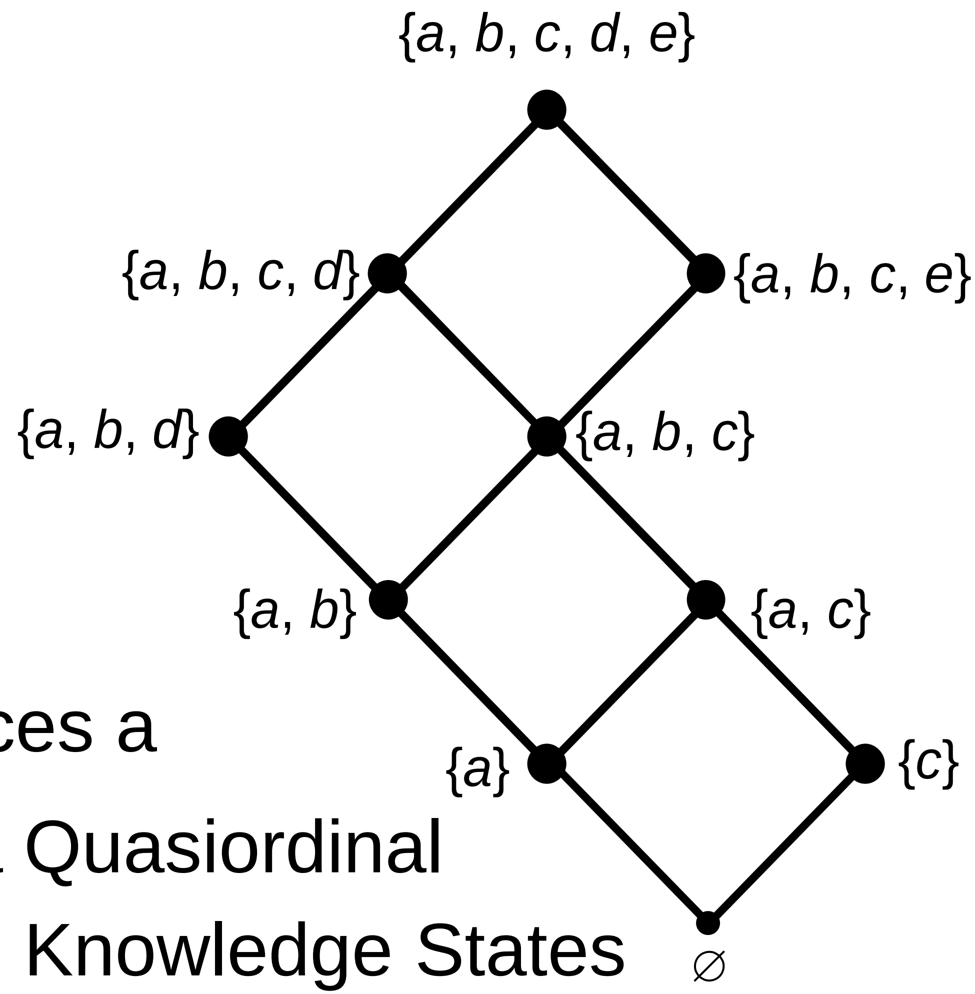
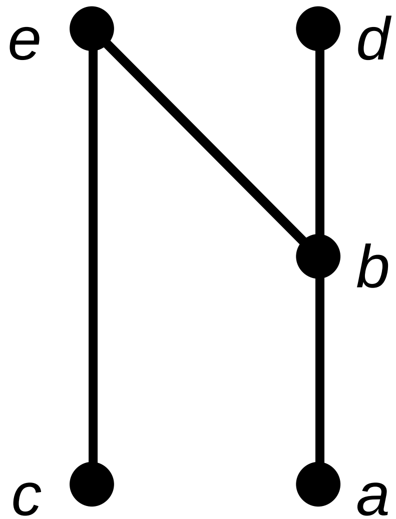


- Surmise Relation induces a
- Knowledge Structure/a Quasiordinal Knowledge Space with Knowledge States

KST Basic Concepts
Learning Path and Goal



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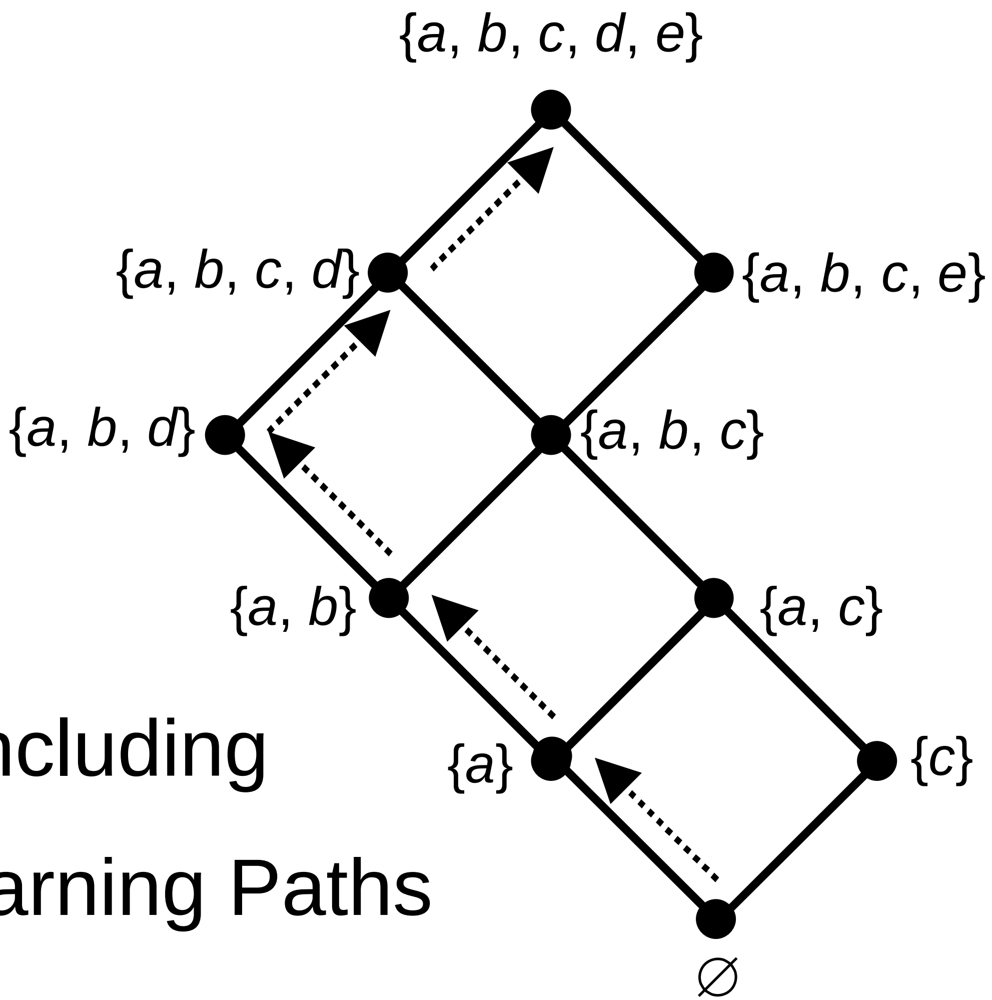
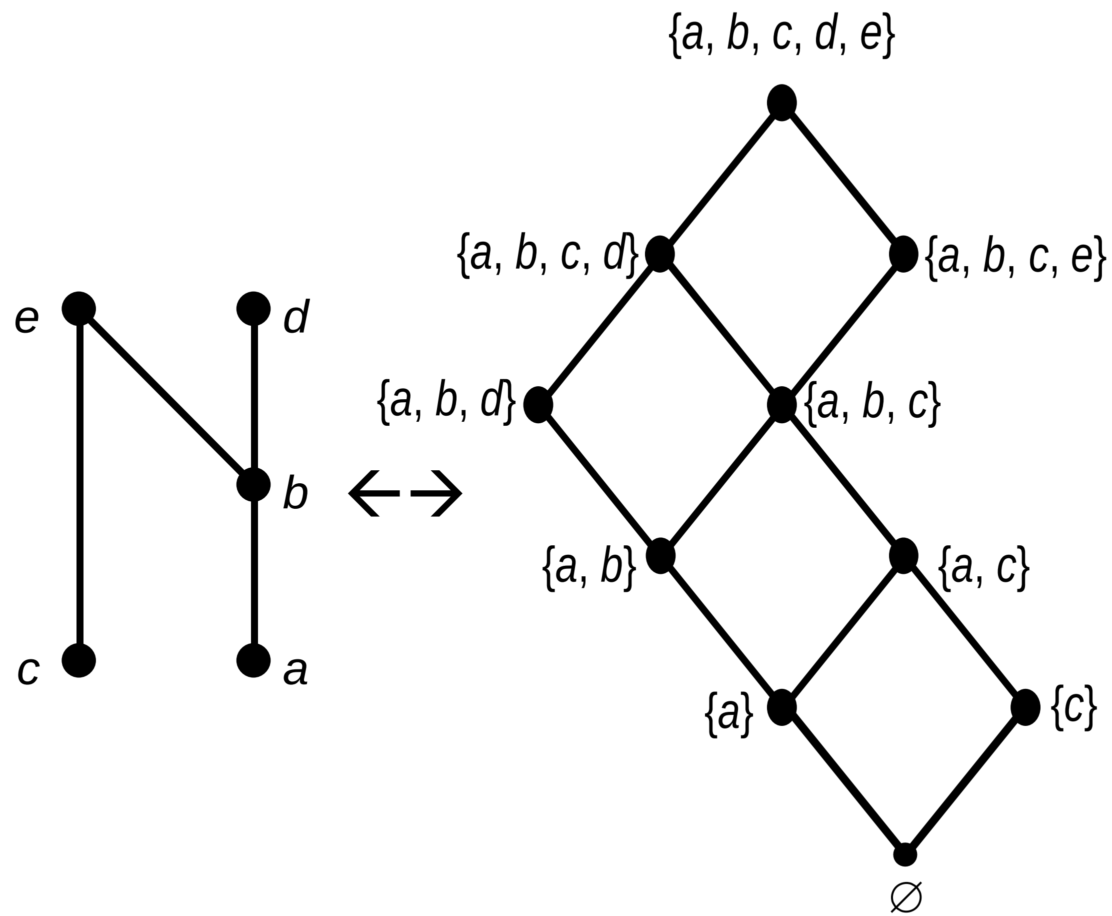


- Knowledge structure including
- one of the possible Learning Paths

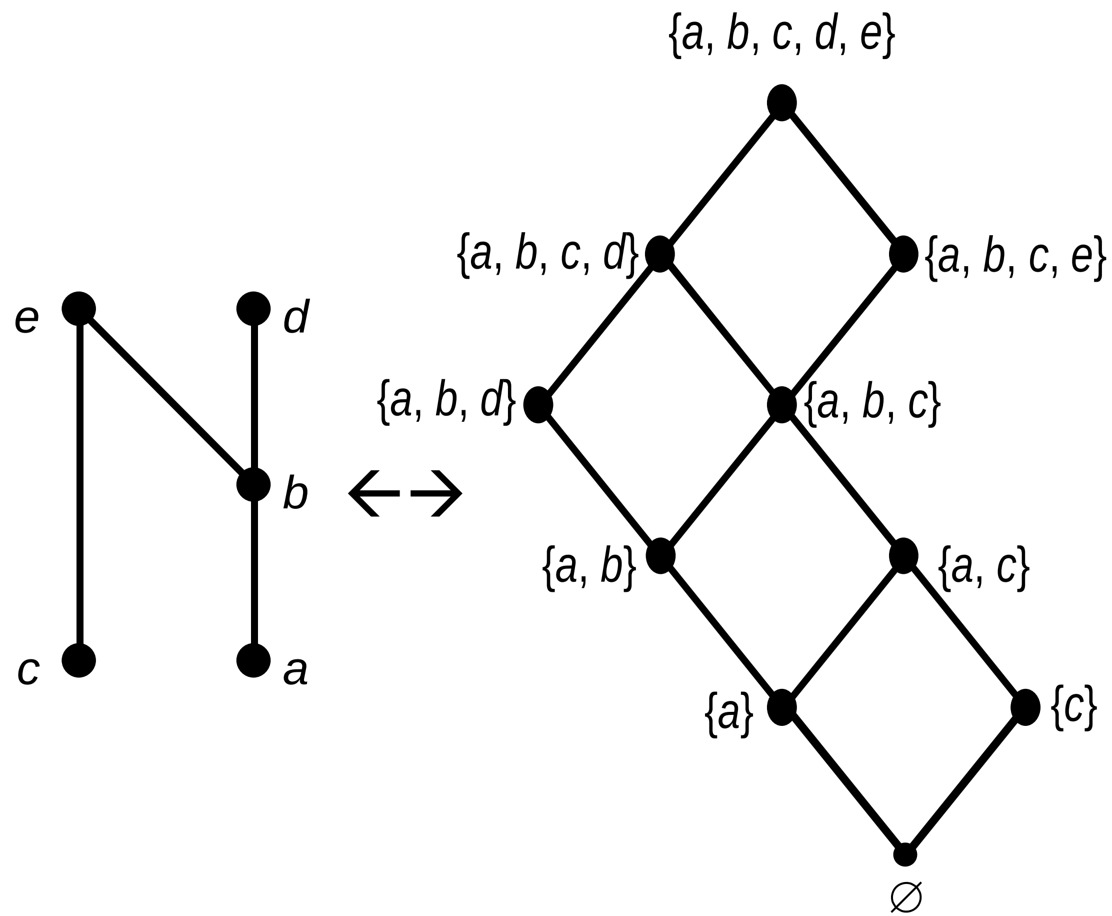
The Power of the Theory

- These two diagrams make understandable the power of the theory and
- enable to remember its main features



The Power of the Theory

- The content and its structure induces the curriculum and vice versa
- The content induces the knowledge states and their structure

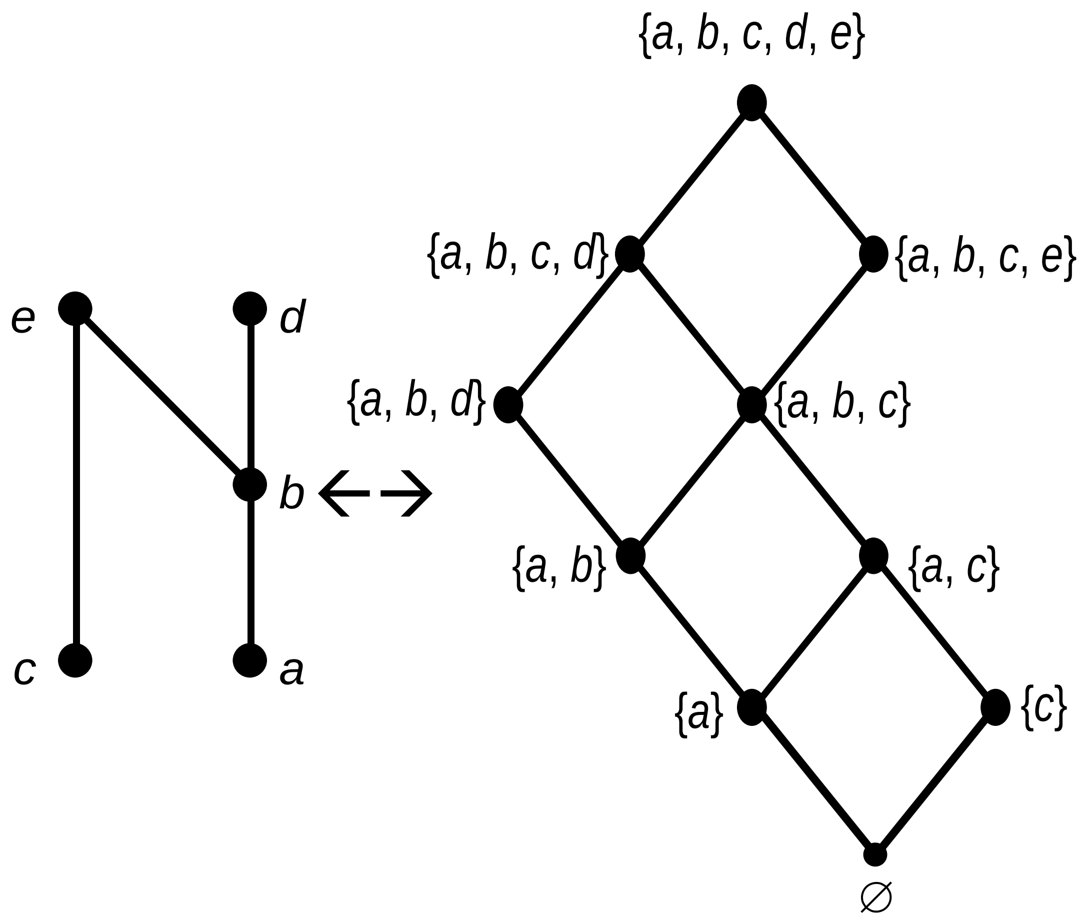


The Power of the Theory

- Personalised assessment for efficiently identifying a persons state of knowledge - like in an oral examination

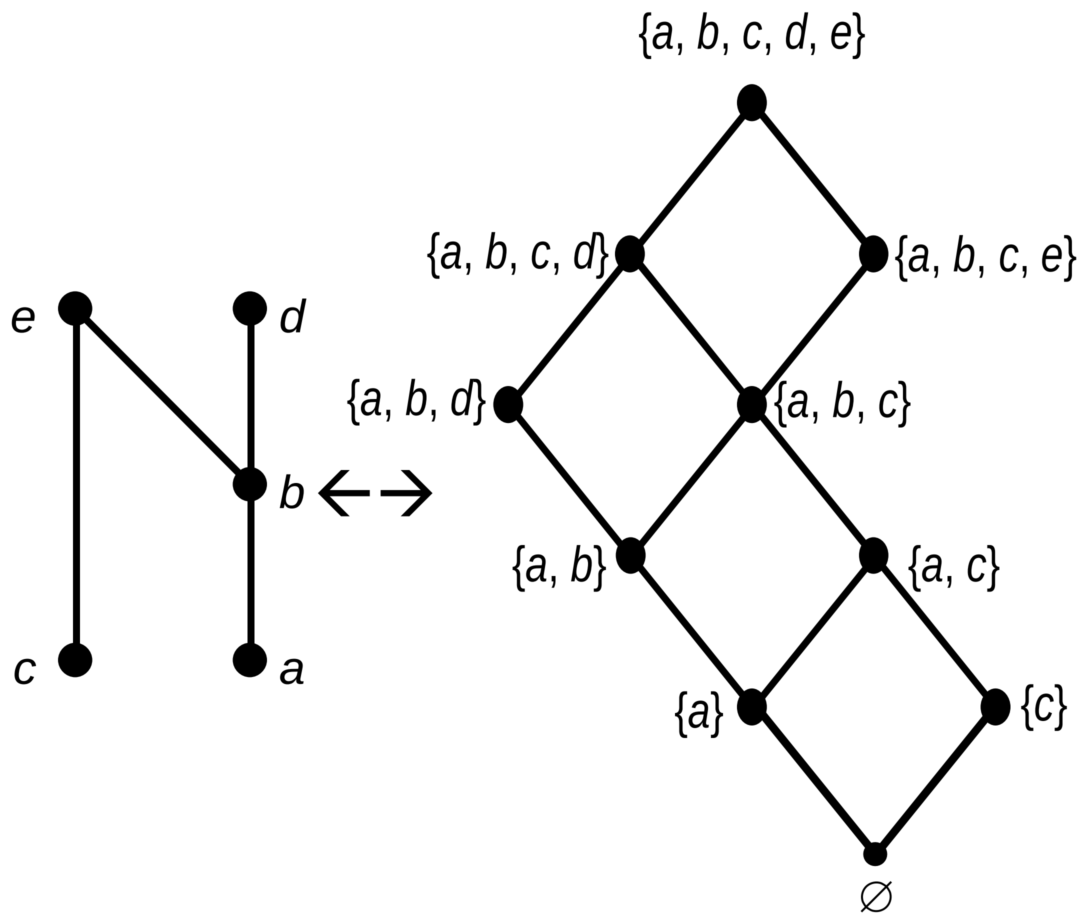
  - by presenting only a subset of problems

(Adaptive Testing!)



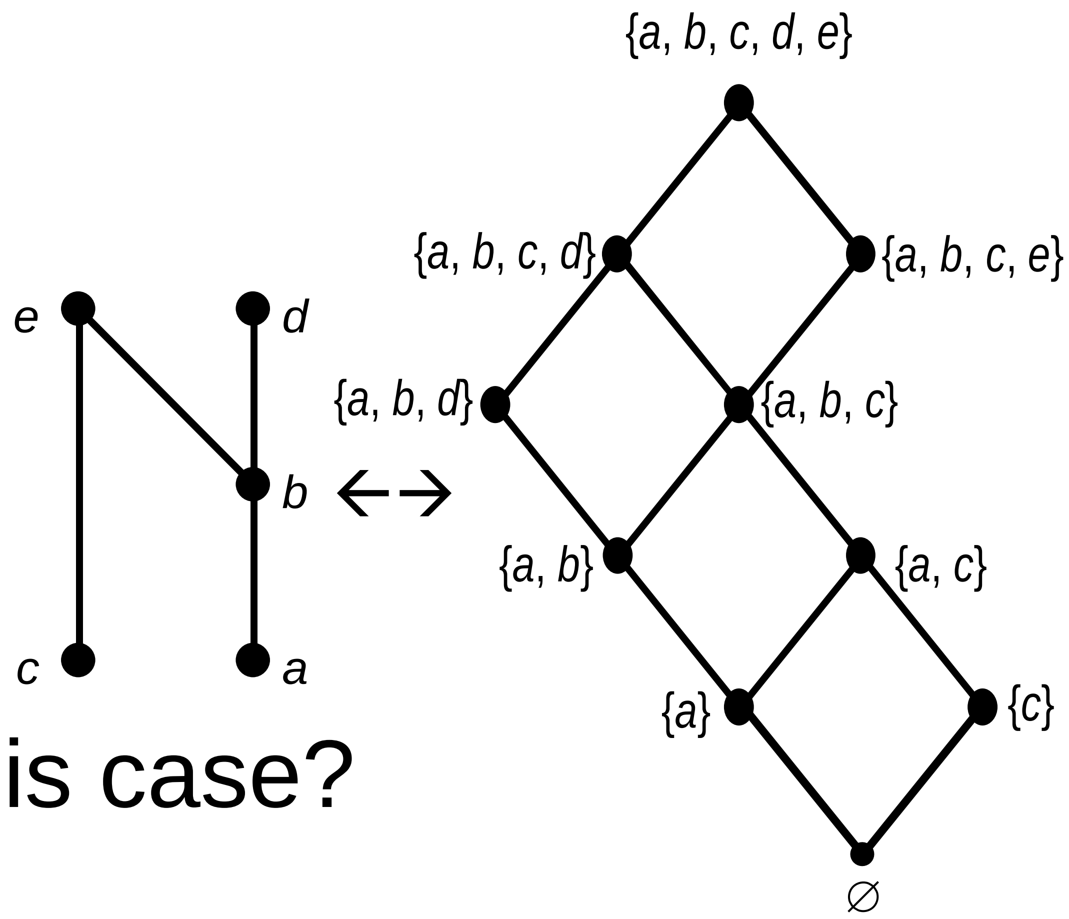
The Power of the Theory

- Individual starting state for learning depending on pre-knowledge
- Individual goal state for learning



The Power of the Theory

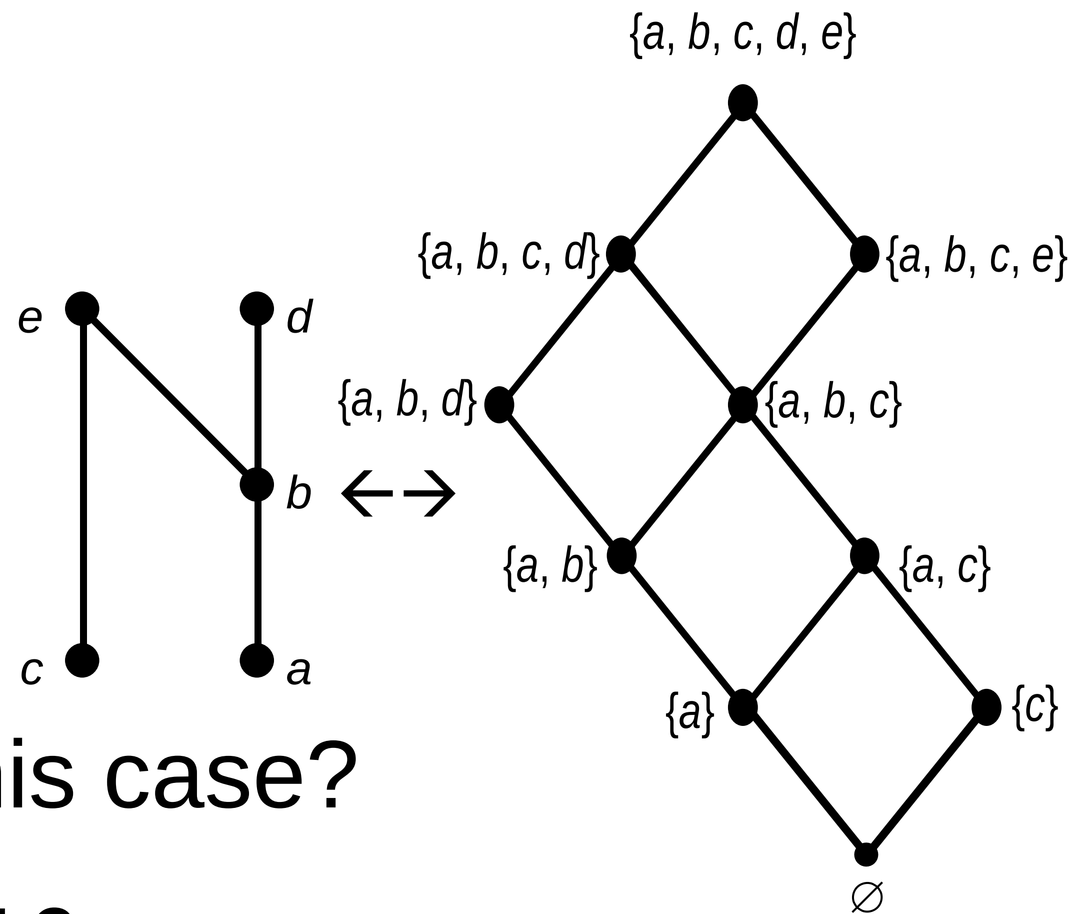
- Individual learning paths



- How many in this case?

The Power of the Theory

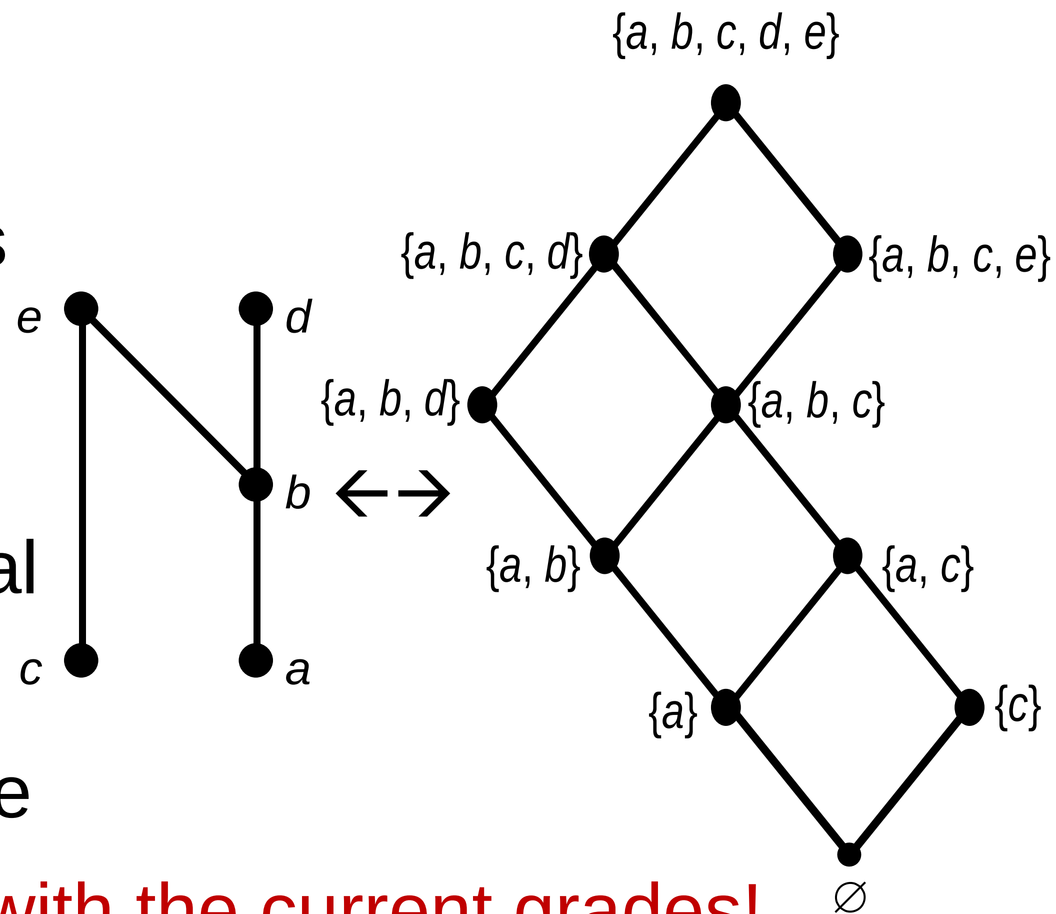
- Individual learning paths



- How many in this case?
- 2 x 2 x 2 x 2 = 16

The Power of the Theory

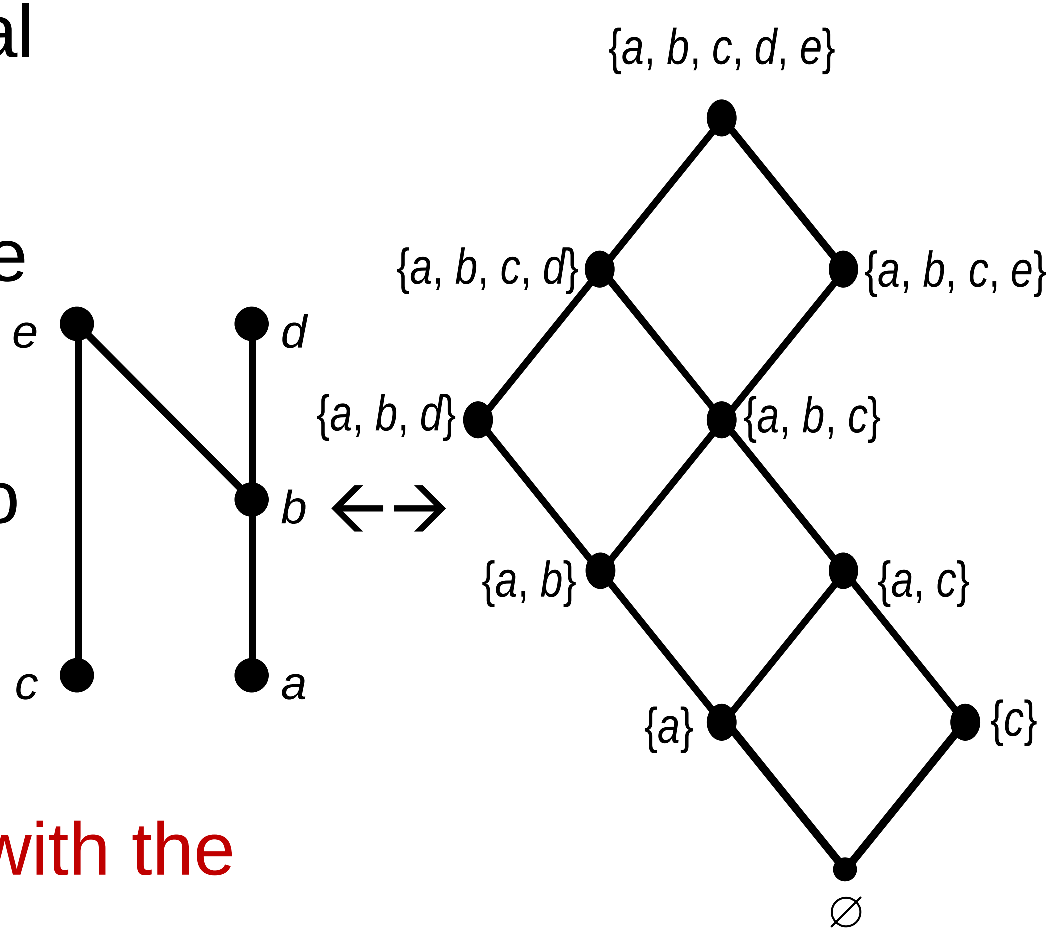
- Detailed characterisation of the learners strengths and weaknesses in a given domain by
- Precise, non-numerical characterisation of the state of knowledge



- Please compare this with the current grades!

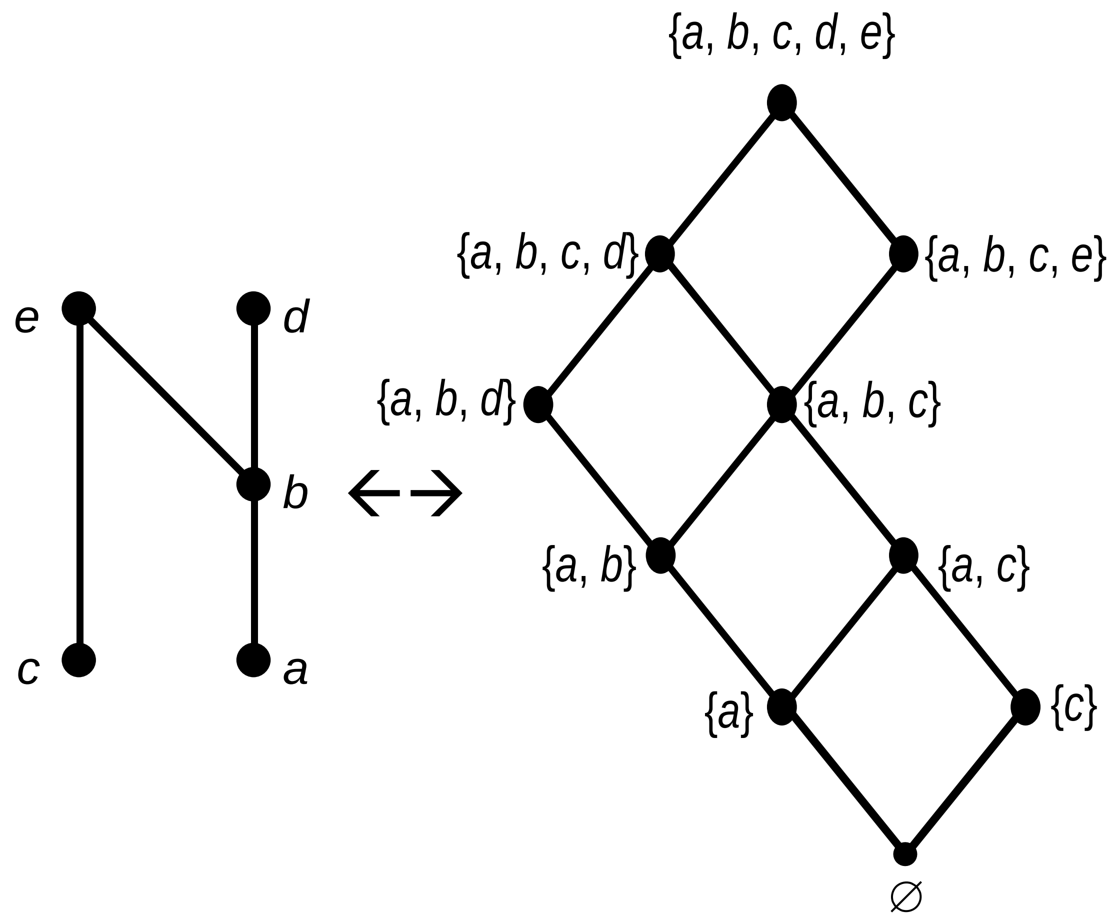
The Power of the Theory

- Precise, non-numerical characterisation of the state of knowledge allows for exactly identifying what has to be teached next and to learned next
- Please compare this with the consequences of current grades like A,B…F !



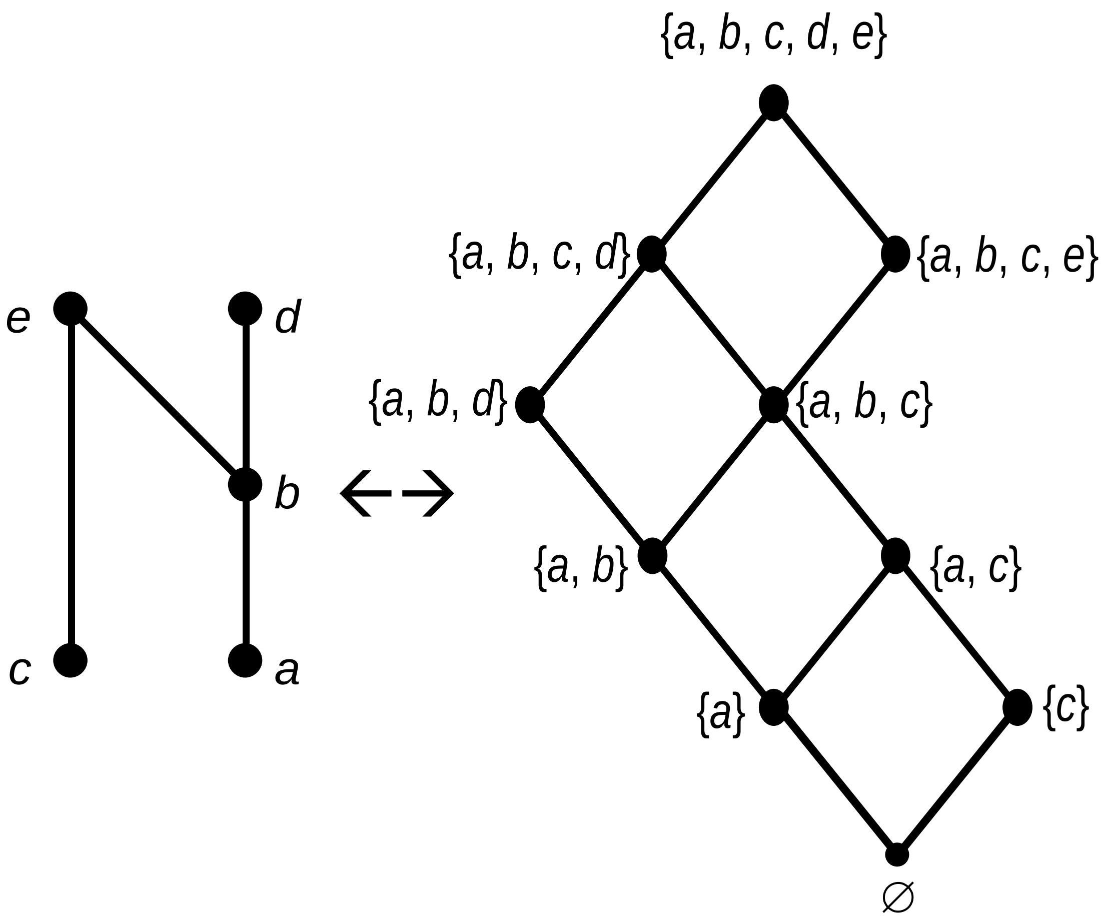
The Power of the Theory

- Access only to those learning objects which the student is ready to learn
- Student is neither overburdened nor underburdened - Challenge just OK (Flow - Motivation!!)



The Power of the Theory

- Reasonable choices for navigation
- No strict order (boring)
- No total freedom (lost in hyperspace)



- Remark:

However, what about SRL, GBL and Open Learner Models???

Validating Knowledge Structures

- Knowledge structures, once they have been established, need to be validated before usage in adaptive assessment and personalised teaching and learning
  - for proving that the structure is empirically adequate
- Comparison between empirical data on the respective problems and the theoretically hypothesed structures via
  - solution frequencies – correspondence with/contraditions to the prerequisites captured by the prerequisite relation
  - investigating confirmations/violations in the empirical data w.r.t. problem pairs among which a prerequisite relationship is assumed
  - calculation of the minimal distances between the answer patterns and the respective knowledge structure

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    - Application: iClass

Application: ALEKS http.//www.aleks.com

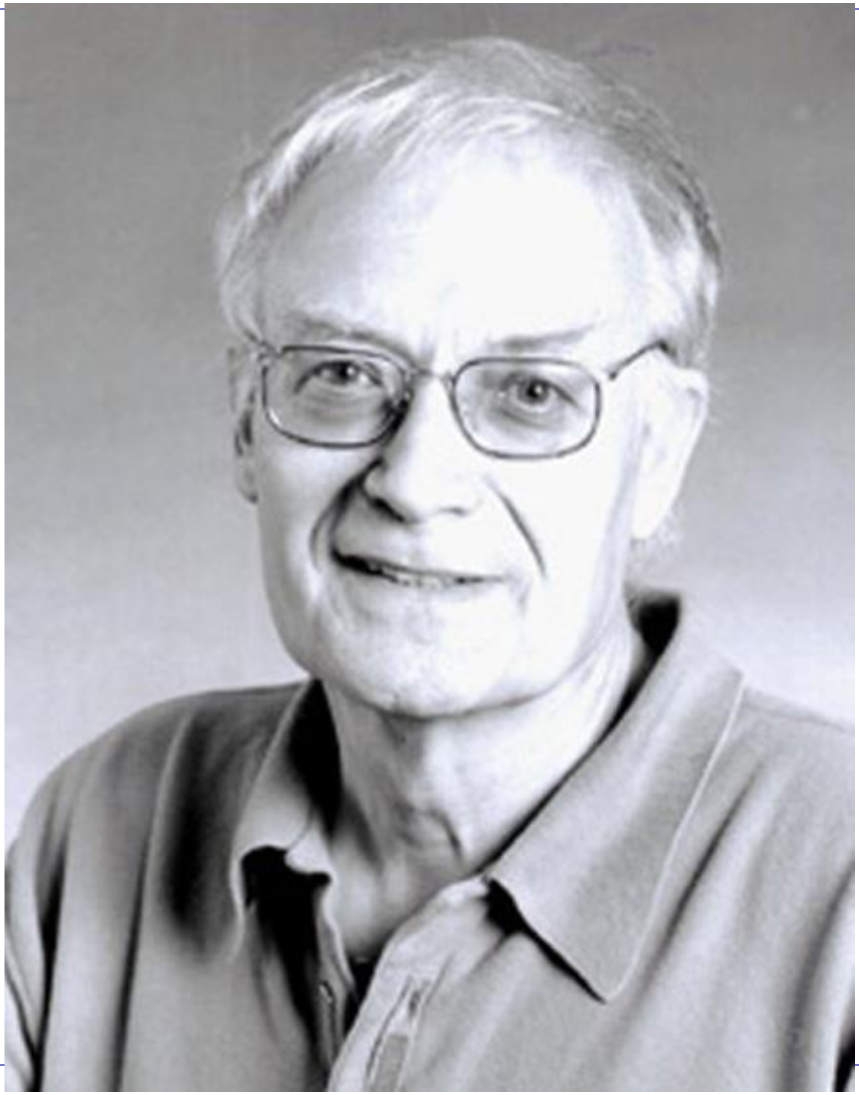
- **ALEKS**

  Adaptive **LE**arning with **K**nowledge **S**paces

  - Fully automated, multi-lingual, adaptive math tutor including explanations, practice, and feedback
  - Assesses personalized which math concepts the student has mastered, which are shaky, and which are new but within reach
  - Enables the student to work on those concepts the student is most ready to learn
  - Closely interacts with the student, continuously updating its precise map of the student's knowledge state.

KST and ALEKS

ALEKS Corporation is a Delaware corporation formed in November 1996 by the Corporation's Chairman, Professor Jean-Claude Falmagne, an internationally recognized researcher in mathematical cognitive science, and his fellow researchers.



http://www.ota.uci.edu/startups/profile6_11.html

Ansicht Chronik Lesezeichen Extras Hilfe

http://www.aleks.com/

ssment and Learning, ...

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Initial Adaptive Assessment Basic Idea

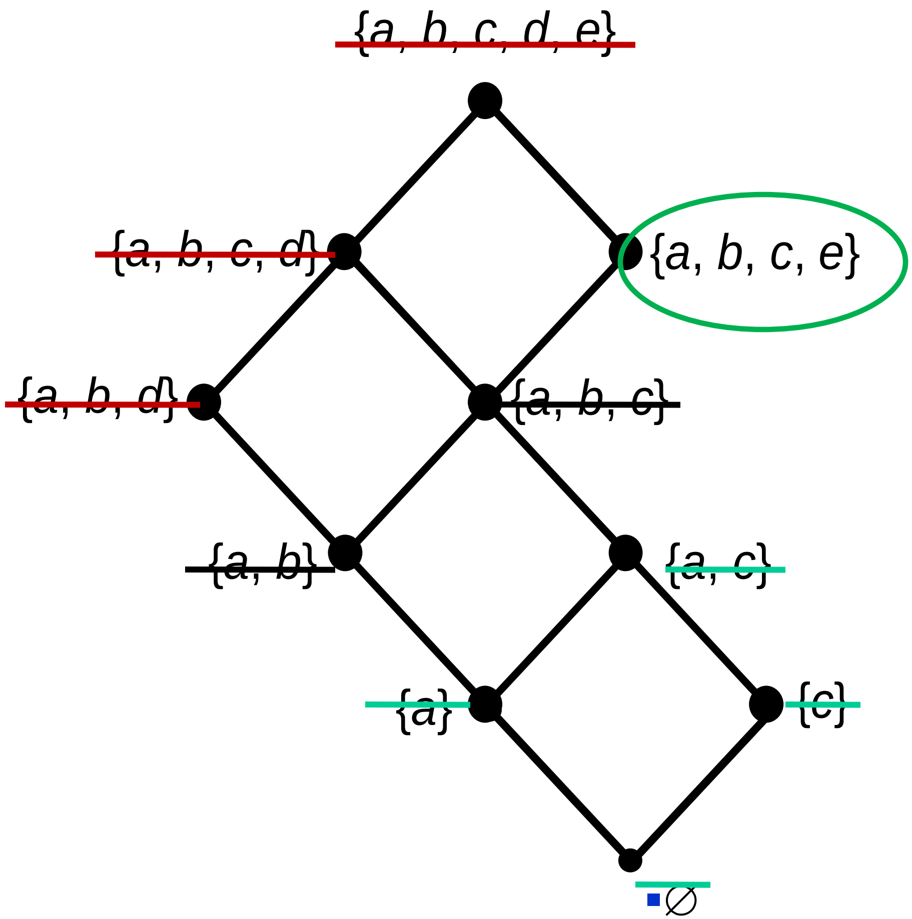
Simplifying assumption: Neither lucky guesses nor careless errors.

- Pose a problem that is contained in about half of the knowledge states.
- Eliminate/Leave all states that are in/consistent with the answer received.
- Continue until there is only one knowledge state left.

Deterministic Assessment

1. Problem *b* solved
2. Problem *d* failed
3. Problem *e* solved

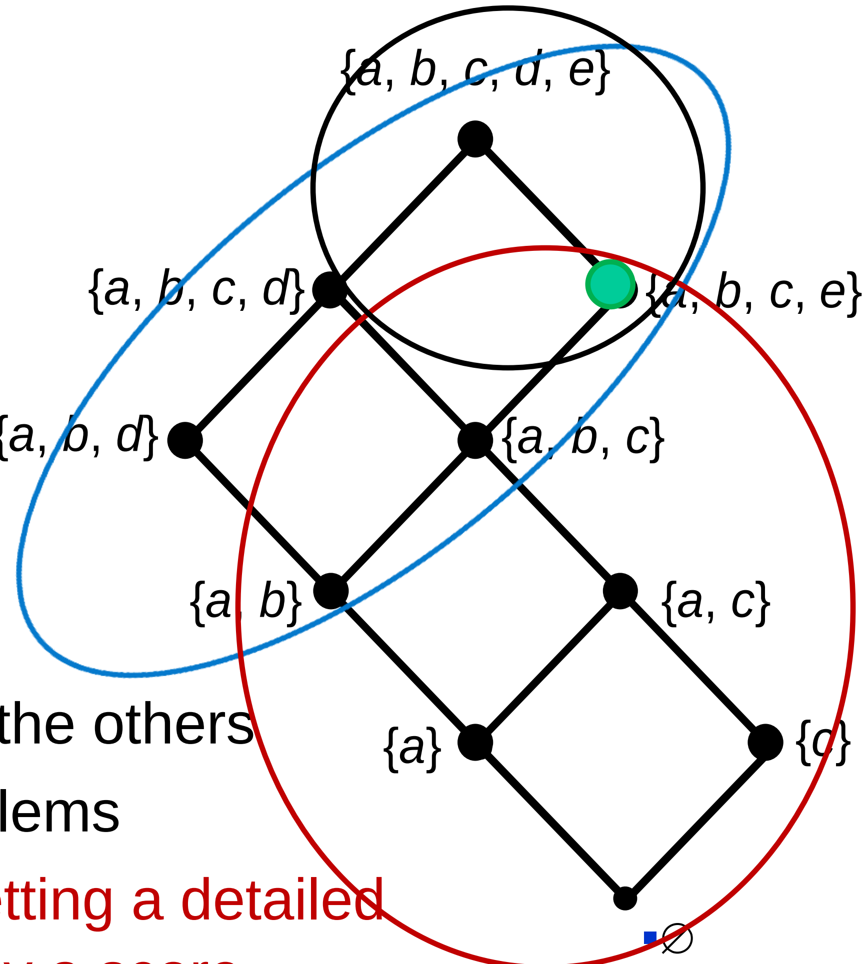
Result: *{a, b, c, e}*



Probabilistic Assessment

1. Problem *b* solved
2. Problem *d* failed
3. Problem *e* solved

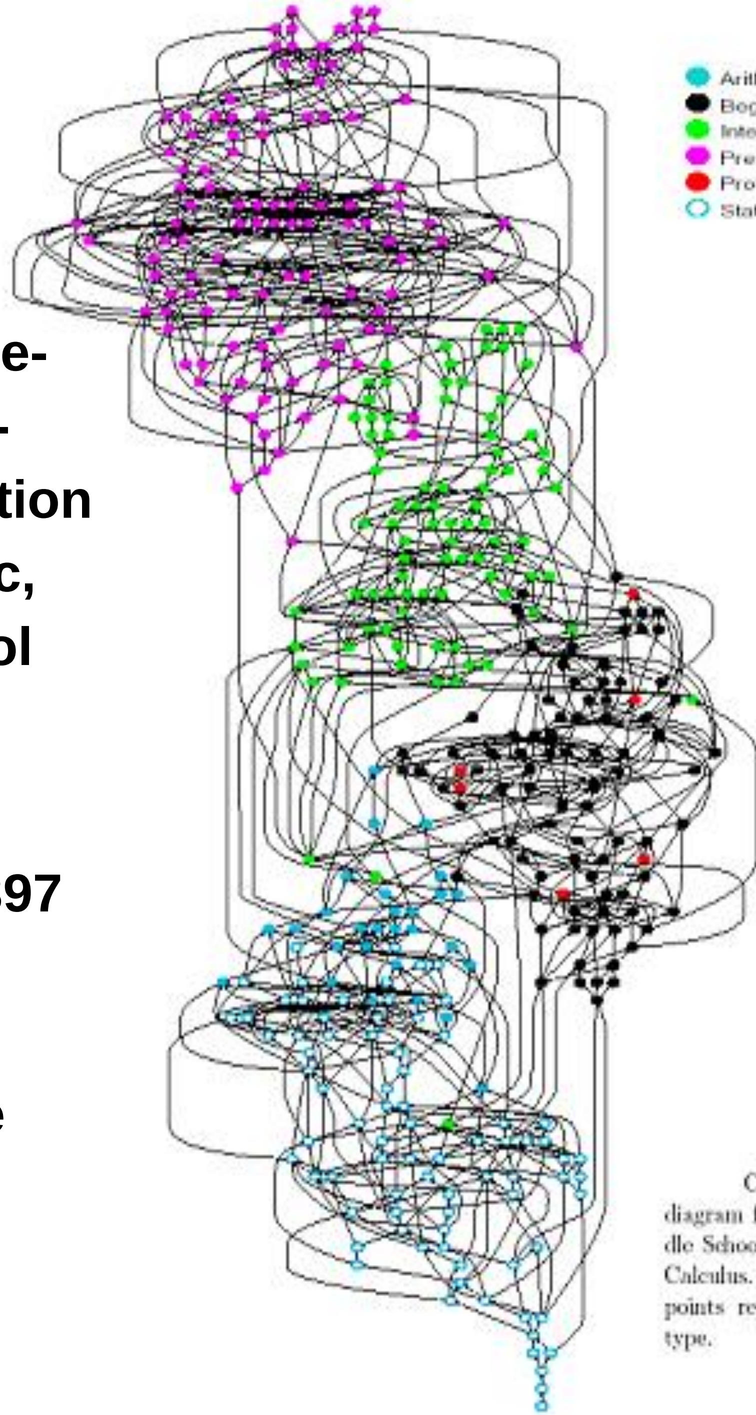
Result: *{a, b, c, e}*



Principle: Increase likelihoods of all the states which are in accordance with the correct/ incorrect answer & decrease the others

Advantage: Only a subset of problems has to be presented for getting a detailed knowledge profile - not only a score

- **Combined pre-requisite/pre-cedence relation for Arithmetic, Middle School Algebra, and Pre-Calculus**
- **Each of the 397 points represents a problem type**

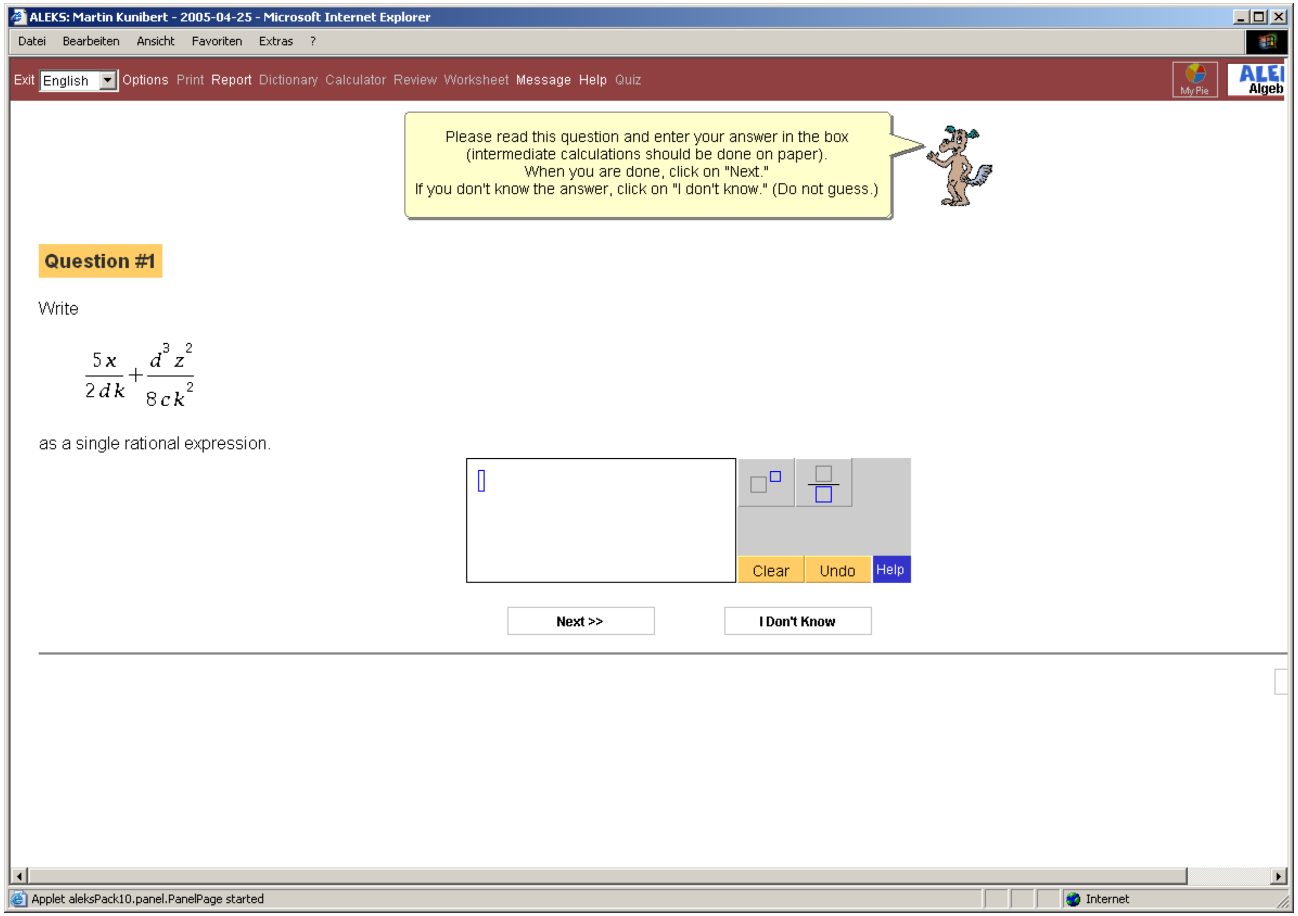


Combined precedence diagram for Arithmetic, Middle School Algebra, and Pre-Calculus. Each of the 397 points represents a problem type.

ALEKS
Initial Adaptive Assessment

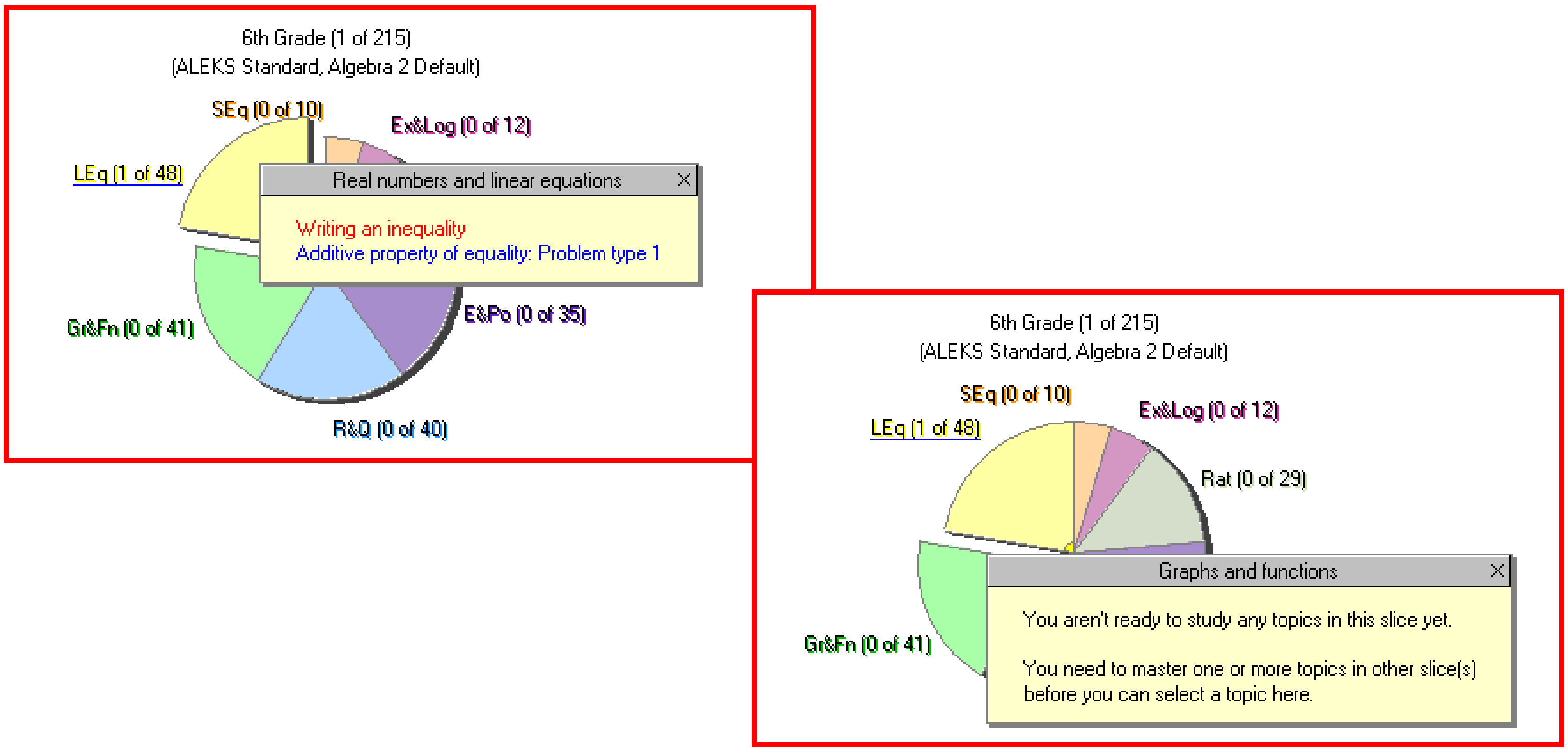
- The slide above is about the prerequisite relation used in ALEKS for a given domain
- The corresponding knowledge structure is extremely huge, however less than 2 to the power of 397 because of the constrains given by the prerequisite structure
- The books of Falmagne and Doignon describe the intelligent algorithms for computing

ALEKS
Initial Adaptive Assessment



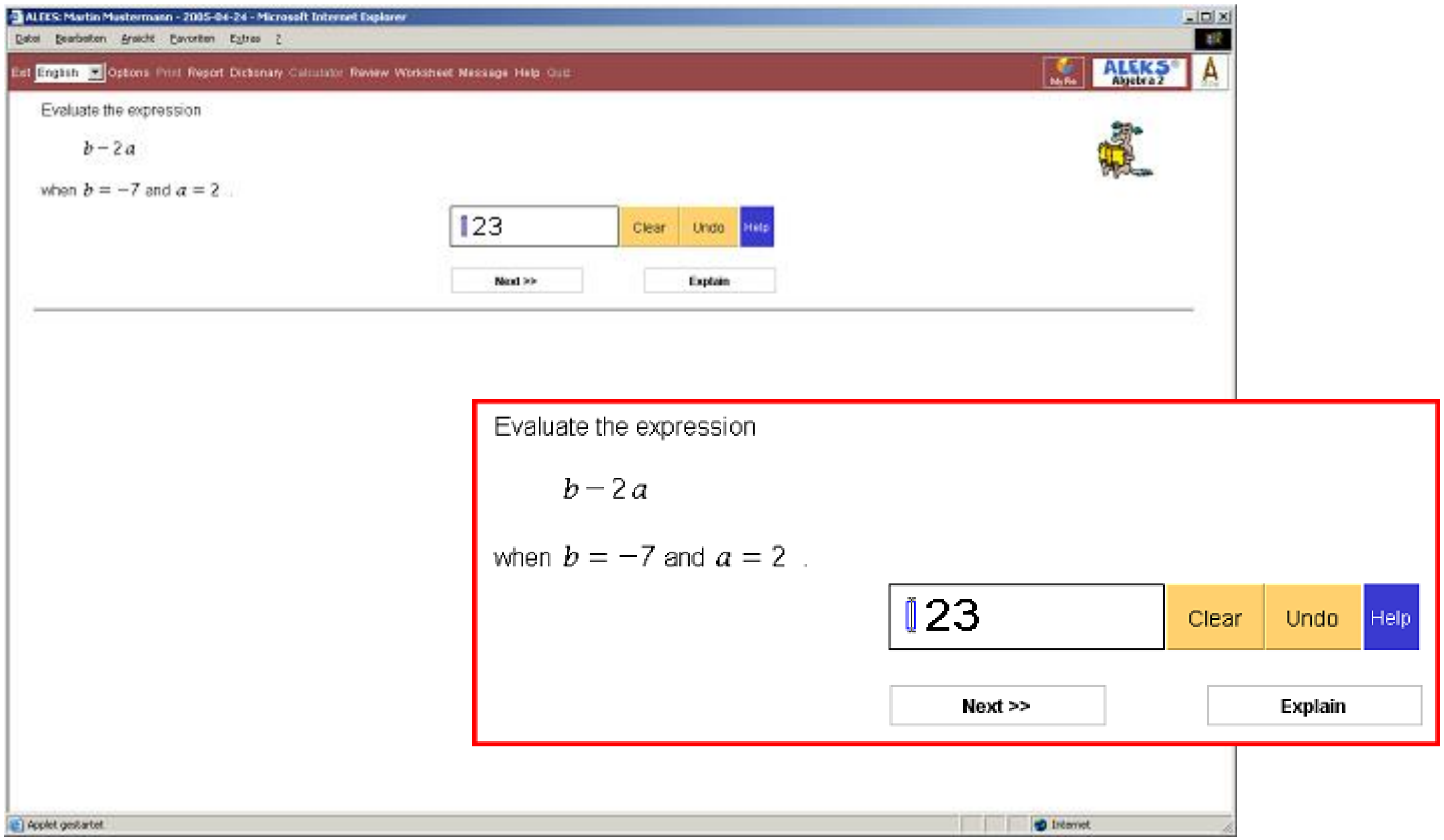
ALEKS
End of Initial Assessment

- ... details



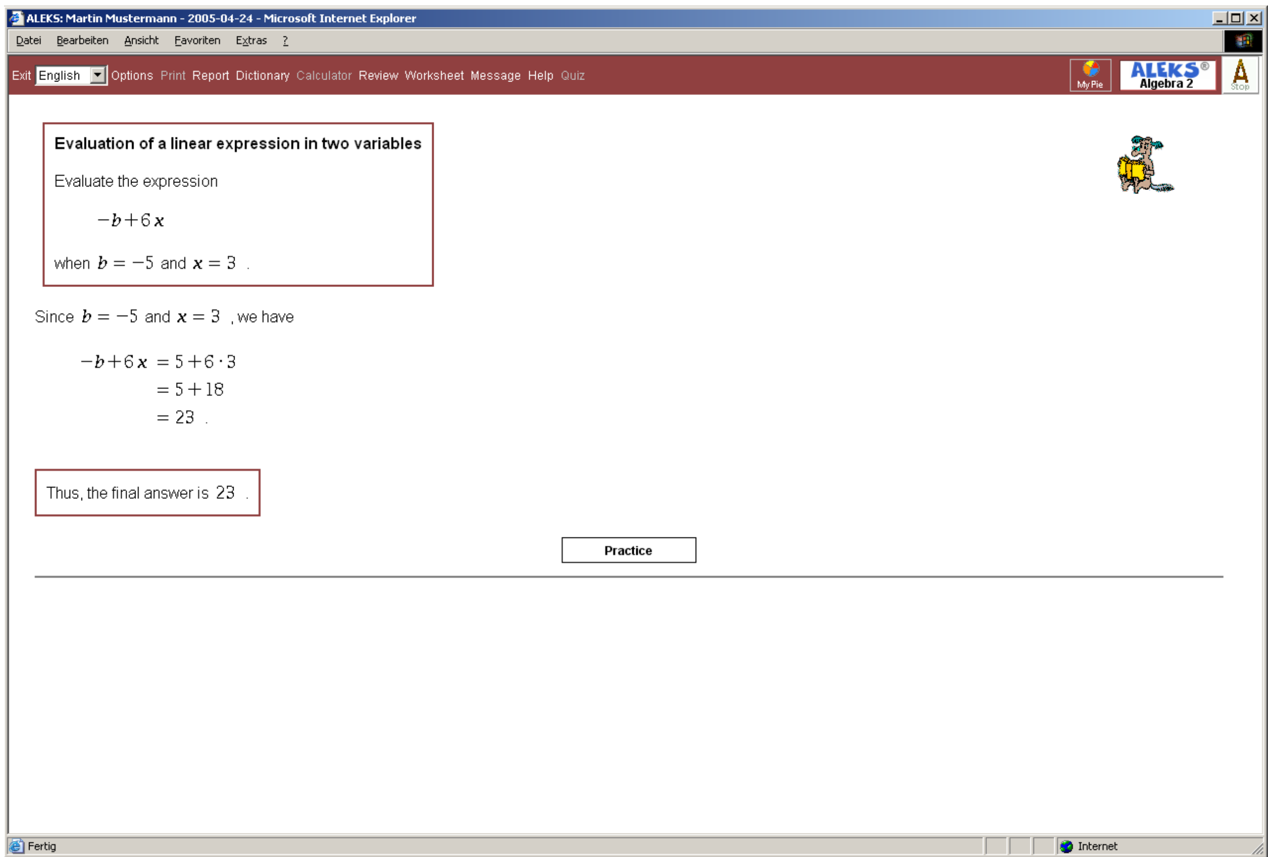
ALEKS
Learning Phase

- **Prototypical task or problem**



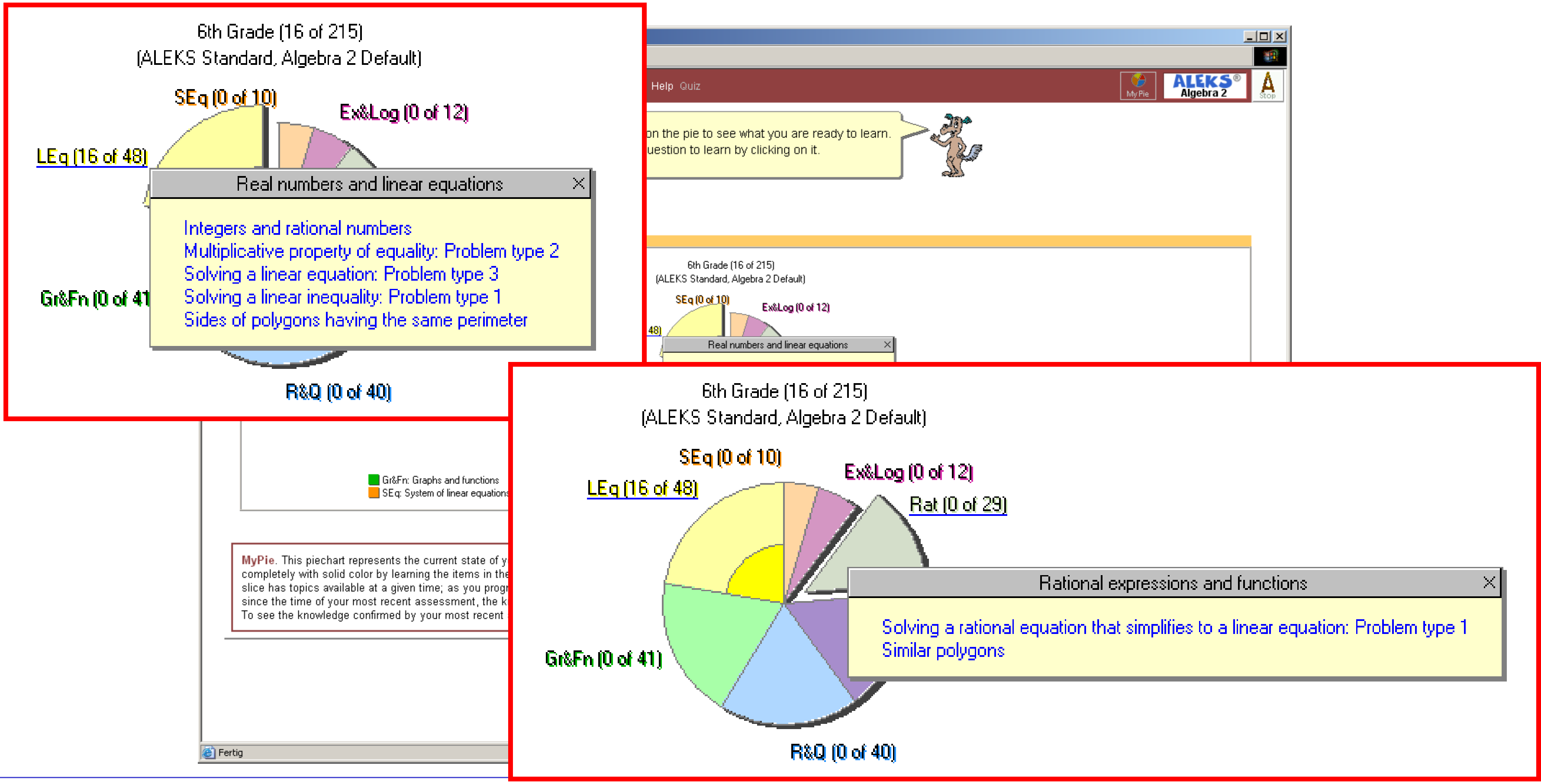
ALEKS
Learning Phase

- **Lesson → Explanation for a task**

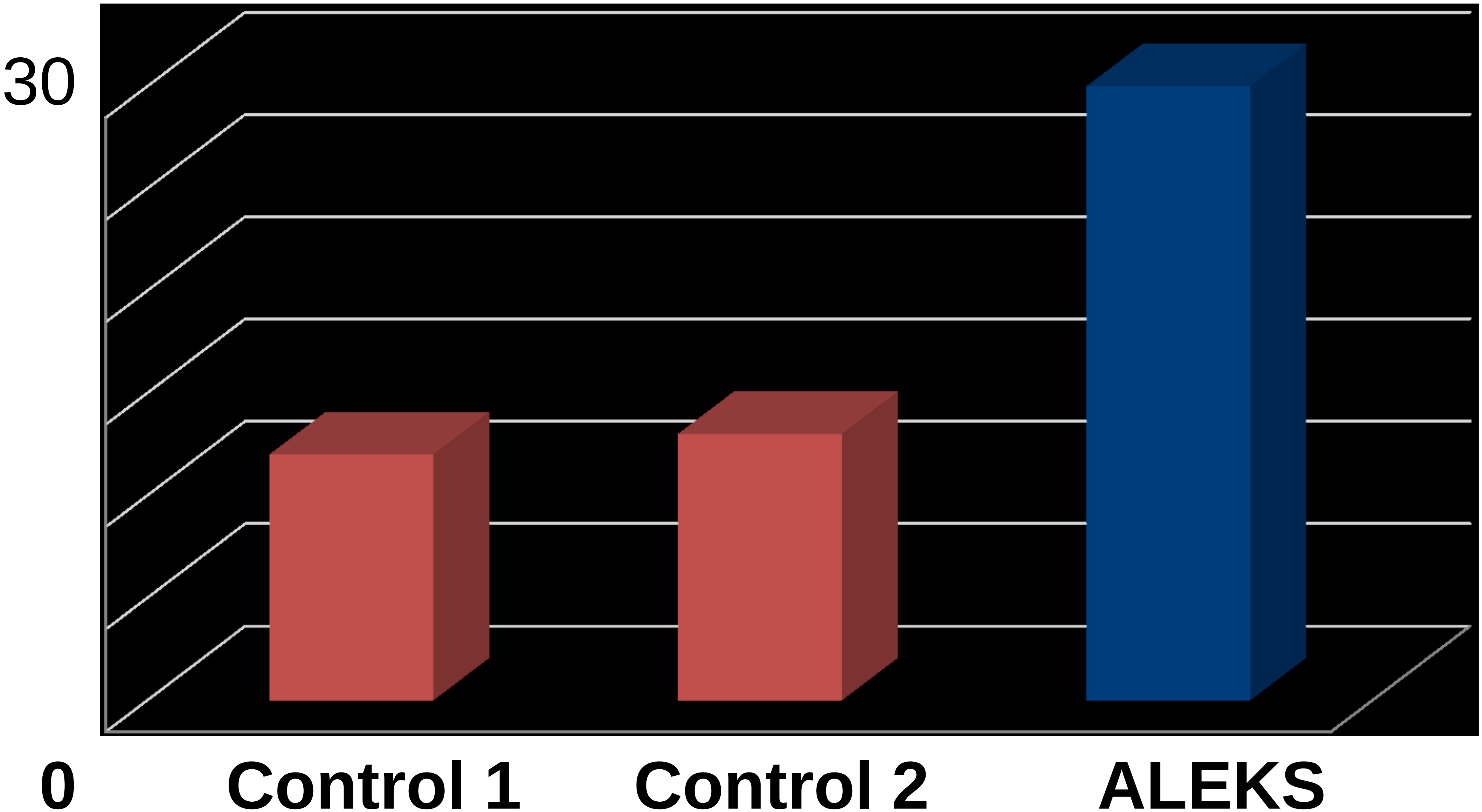


ALEKS
Learning Phase

- **Overview of learning progress**



Increase in Math CST score
CST: California Standard Test



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Elementary Probability Example Problem

Example of one PROBLEM

An urn contains three red and three blue balls

Two balls are drawn successively

Drawing is performed with replacement

The drawn balls are red

Compute the probability of this event

Six problems, labeled A, B, C, ...F of this kind are used

Components and their Attributes

Example of one PROBLEM-COMPONENT with three ATTRIBUTES:

method of drawing

with three attributes:

(1) drawing one ball

(2) drawing multiple balls with replacement, and

(3) drawing multiple balls without replacement

Demands and Types of Lessons

The DEMANDS

0. Definition of random experiments and elementary events

1. Knowledge that, in general, Laplace probabilities are computed as the ratio between the number of favourable events and the number of possible events

2. Ability to determine the number of possible events

3. Ability to determine the number of favourable events if one ball is drawn

4. Ability to determine a favourable event if one ball is drawn, or if the sample for which the probability has to be computed consists of equally coloured balls

5. Knowledge that if an outcome like “exact/at least n balls are of colour x” is asked for, all possible sequences of drawing are favourable events

Demands and Types of Lessons

6. Knowledge that probabilities are added for two disjoint events A and B
7. Knowledge that probabilities are muliplied for two events A and B that are (stochastically) independent
8. Knowledge that the probability of drawing a ball of a specific colour is not equal to 0.5 if there are different numbers of balls of different colours in the urn
9. Knowledge that drawing without replacement reduces both, the total number of balls in the urn as well as the number of balls that have the same colour as the drawn ball
10. Knowledge that drawing at least a number of certain balls includes the - not explicitly stated - results of drawing more balls of the certain kind

Demand-based Component Approach

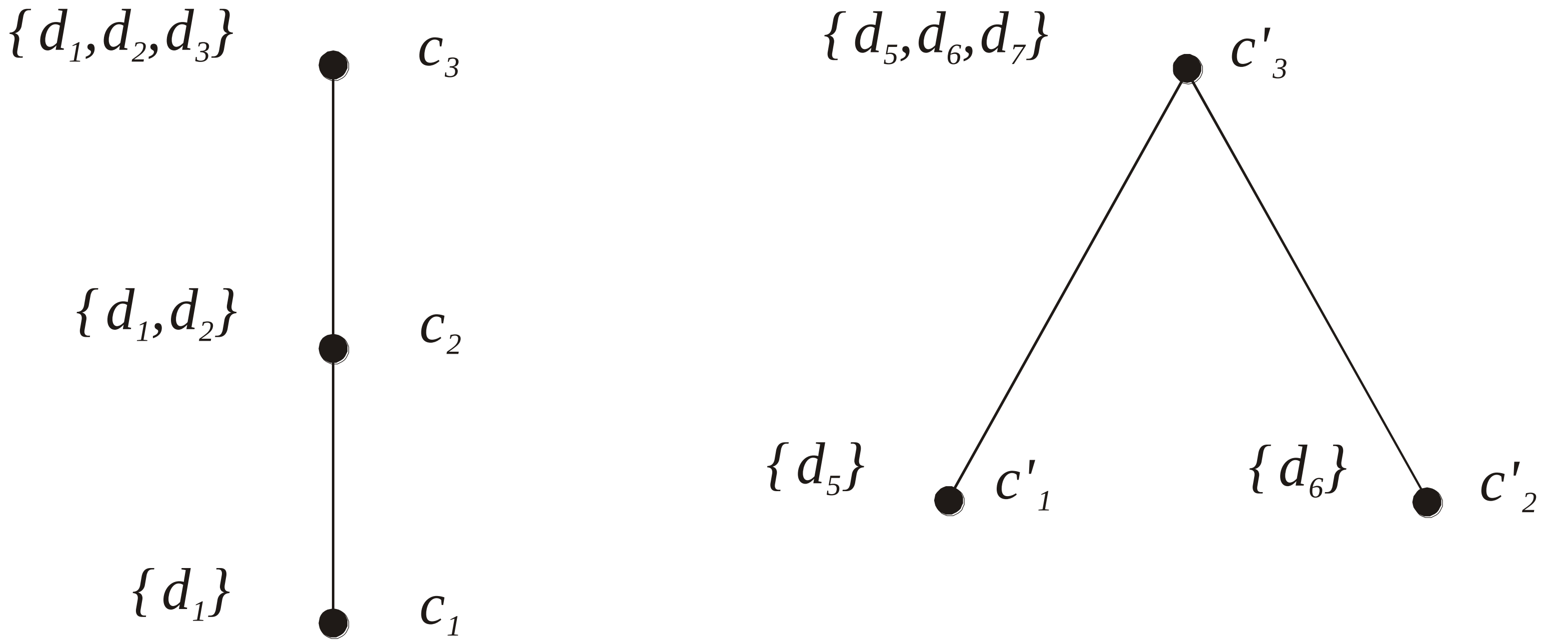
Where these demands come from?

- Problems of a knowledge domain are analysed/constructed with respect to the cognitive demands they pose to the learner
- The cognitive demands are considered
  - to constitute elementary attributes assigned to components for characterising and ordering problems
  - to establish the lessons presented to the learner

Ordering Attributes by Set Inclusion

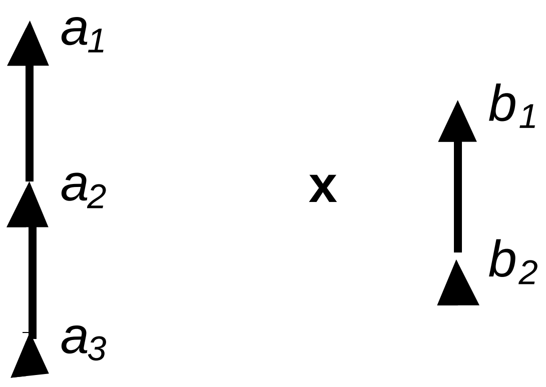
How to use the demands for ordering attributes?

- Demand-induced difficulty structures for attributes:

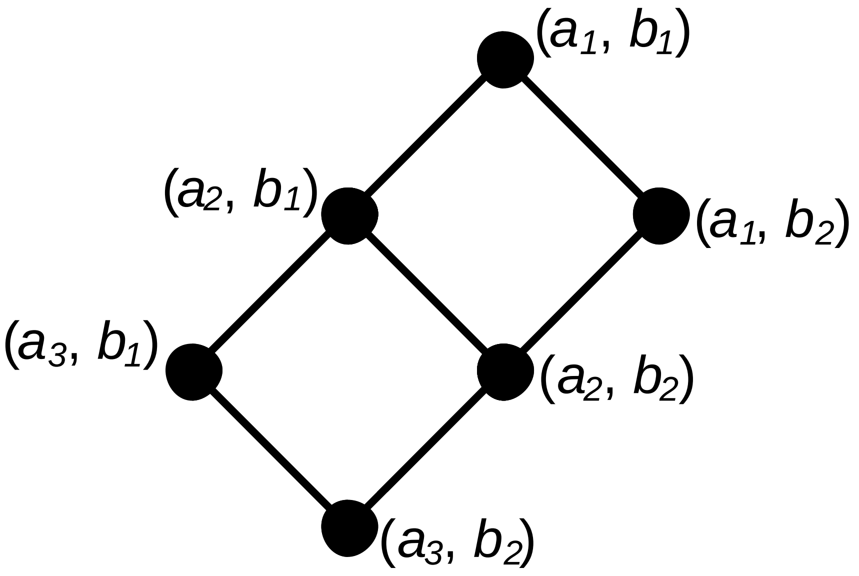


Surmise Relation via Component-wise ordering

- Principle of component-wise ordering
  - Cartesian product of problem components → problem types
  - Dominance rule applied on attribute tuples (problem types) → surmise relation



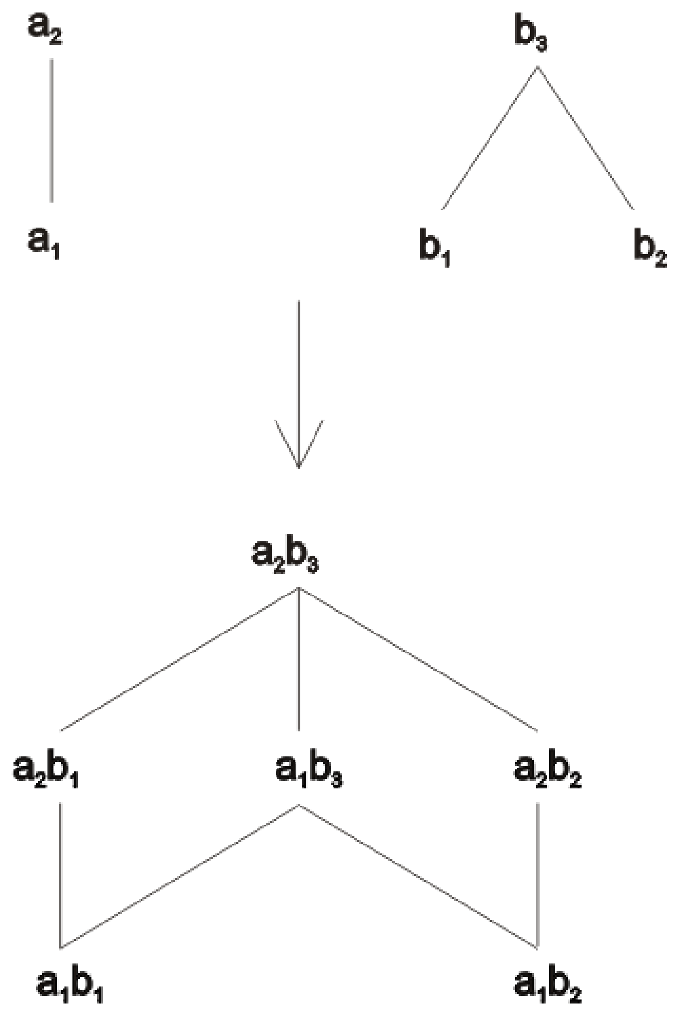
Attribute orders



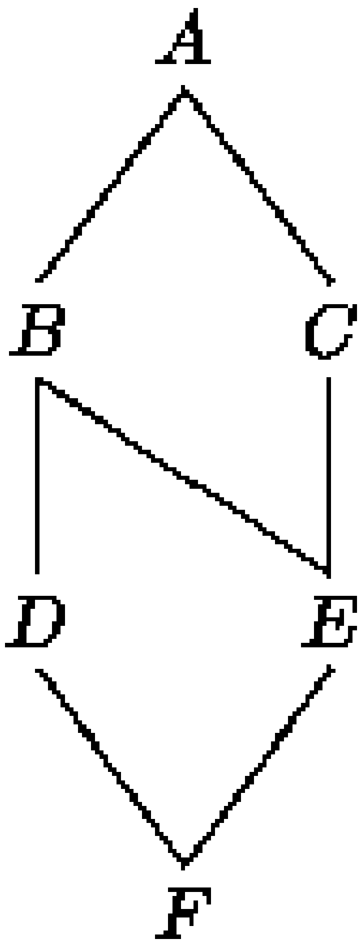
Surmise relation

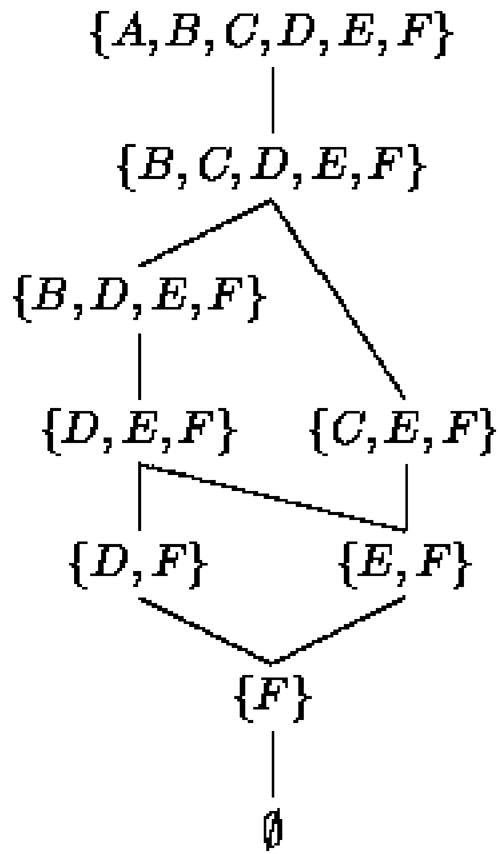
In other words

- Difficulty structures for attributes
- Surmise structure for problems



Problem Structure and Knowledge Space





Demand, Lesson and Skill Structure

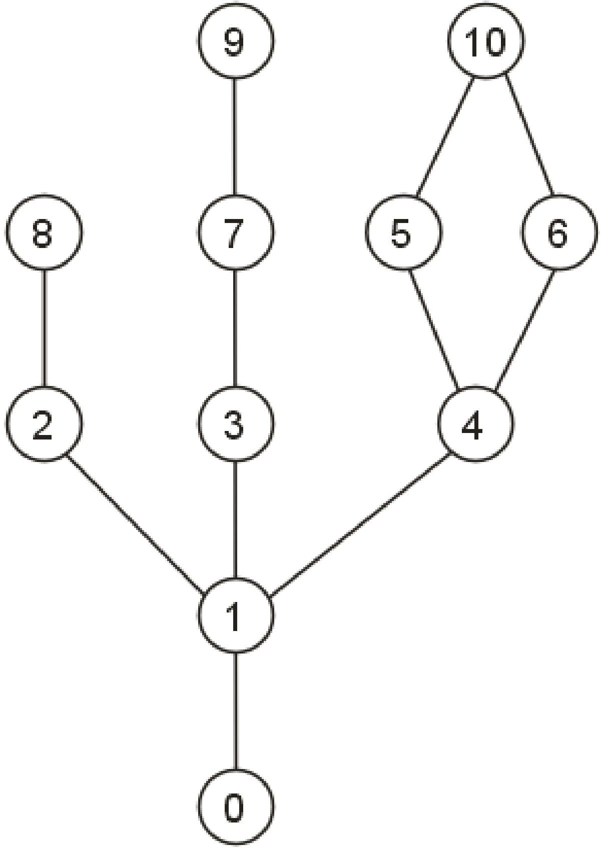
Demand assignments for attributes of *way of drawing*

Attribute	Demands
a1	1, 2
a2	1, 2, 3
a3	1, 2, 3, 4

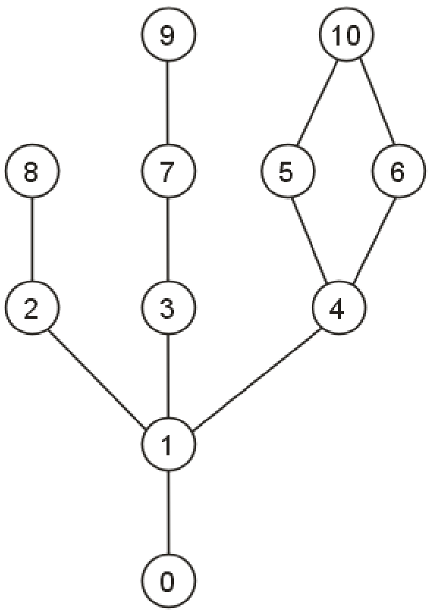
Attribute assignments for Skills/Lessons/Dem.

Skills (Lessons/ Demands)	Attributes
1	a1, a2, a3
2	a1, a2, a3
3	a2, a3
4	a3

Demand and Lesson Structure



Combined Surmise Structure of Lessons and Problems



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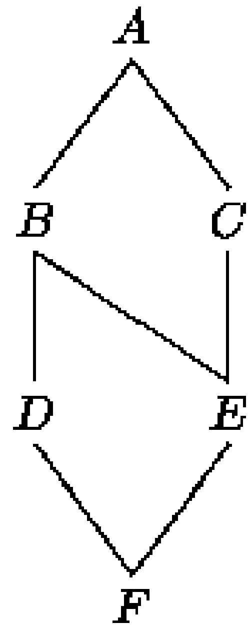

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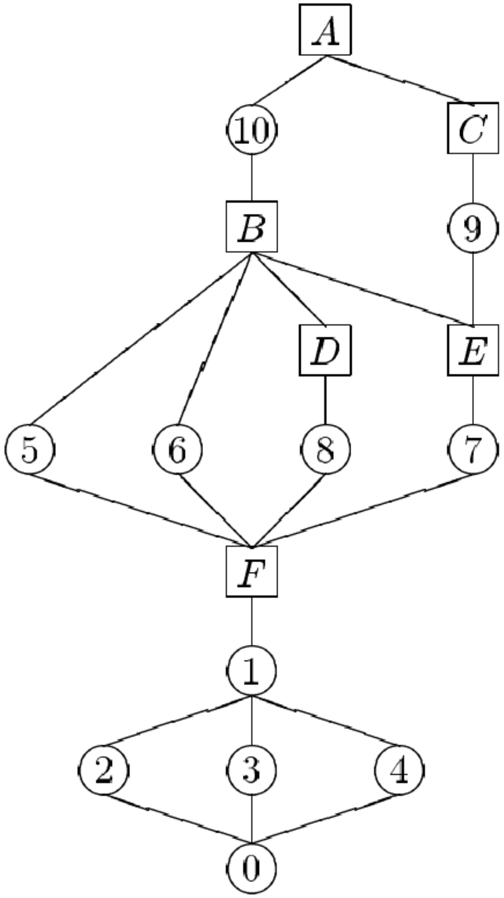
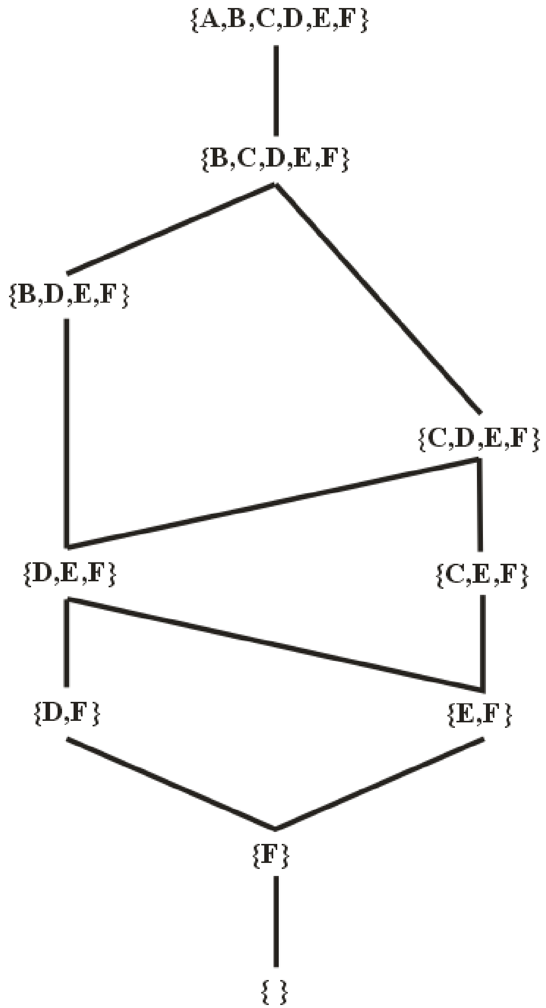


Induced Knowledge Space with Lessons: Didactic



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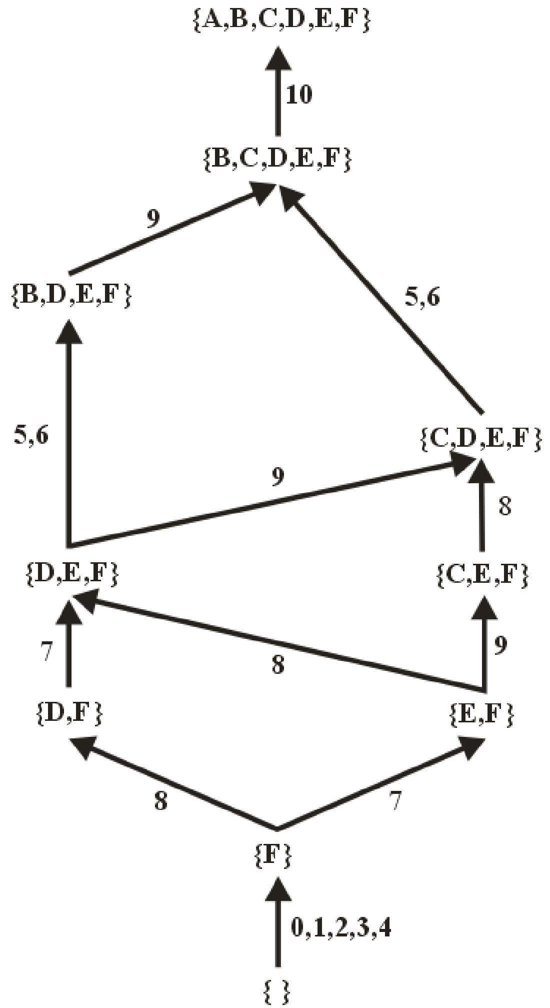

- Introduction
- Knowledge Space Theory
  - Application: ALEKS
- **Demand Component Approach**
  - **Application: RATH**
- Competence-Performance Approach
  - Application: APeLS
- Ontology-based Skill Approach
  - Application: iClass

Application: RATH http://css.uni-graz.at/rath

- **RATH**
  Relational **A**daptive **T**utoring **H**ypertext
  - Adaptive course on elementary probabilistic theory
    - Lessons, exercises, tests
    - Personalized learning paths: efficient selection of appropriate learning objects
  - Based on three sources
    - A mathematical model of Hypertext
    - The Relational Database Theory
    - A correspondence between a mathematical hypertext model and Knowledge Space Theory

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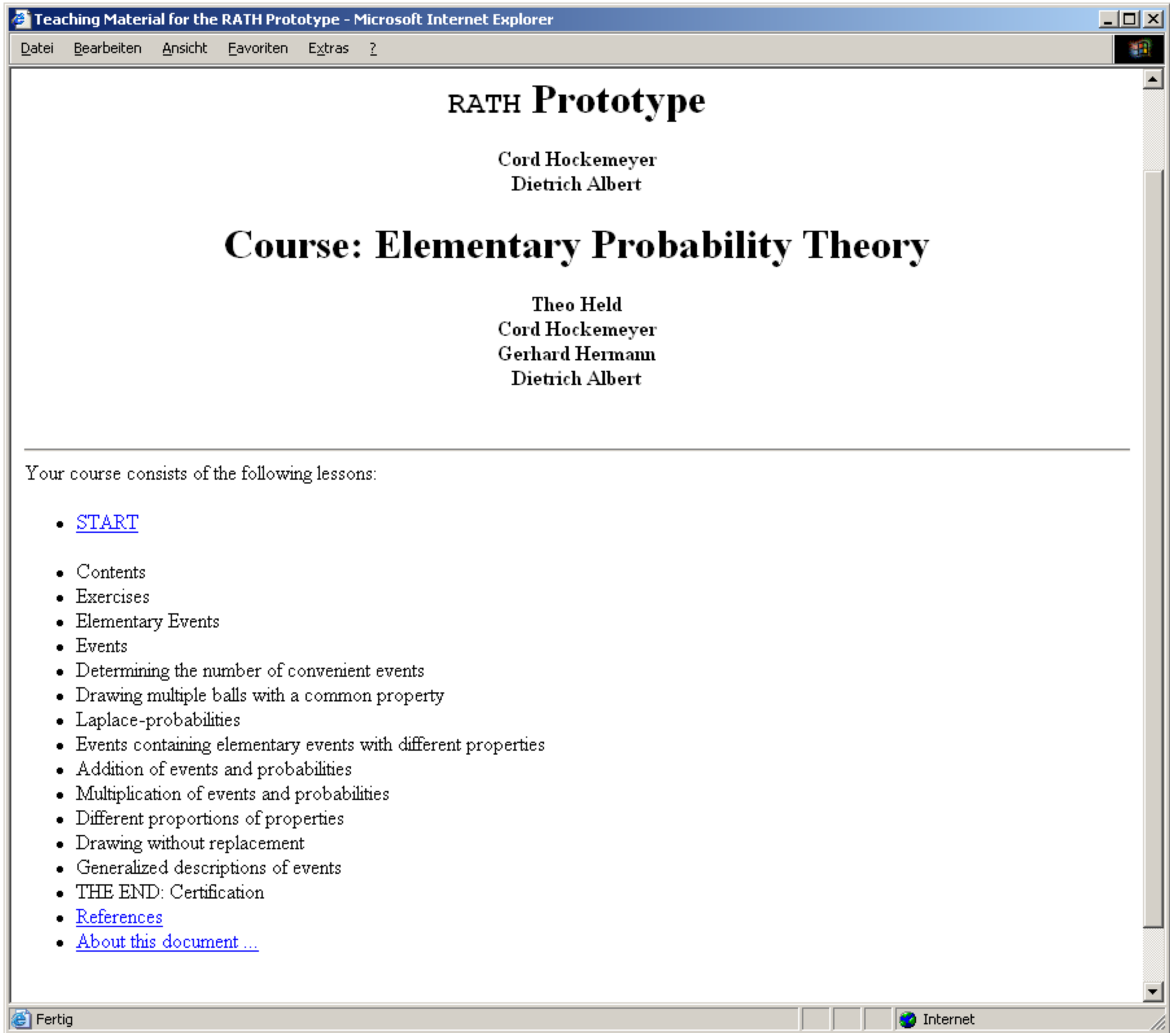
RATH Starting Page


Teaching Material for the RATH Prototype - Microsoft Internet Explorer

Datei Bearbeiten Ansicht Favoriten Extras ?

RATH Prototype

Cord Hockemeyer
Dietrich Albert

Course: Elementary Probability Theory

Theo Held
Cord Hockemeyer
Gerhard Hermann
Dietrich Albert

Your course consists of the following lessons:

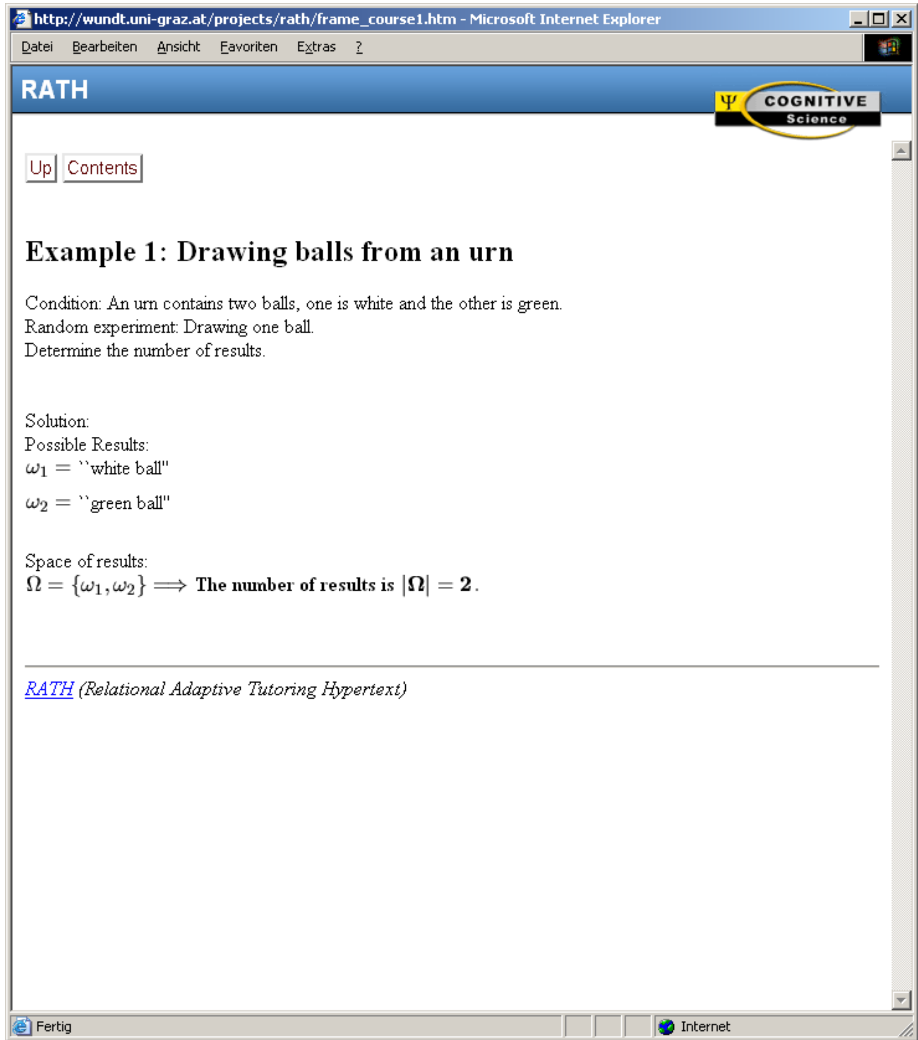
- START

- Contents
- Exercises
- Elementary Events
- Events
- Determining the number of convenient events
- Drawing multiple balls with a common property
- Laplace-probabilities
- Events containing elementary events with different properties
- Addition of events and probabilities
- Multiplication of events and probabilities
- Different proportions of properties
- Drawing without replacement
- Generalized descriptions of events
- THE END: Certification
- References
- About this document ...

Fertig Internet

COGNITIVE Science

RATH Part of a Lesson



http://wundt.uni-graz.at/projects/rath/frame_course1.htm - Microsoft Internet Explorer

Datei Bearbeiten Ansicht Favoriten Extras ?

RATH

Up Contents

Example 1: Drawing balls from an urn

Condition: An urn contains two balls, one is white and the other is green.
Random experiment: Drawing one ball.
Determine the number of results.

Solution:
Possible Results:
$\omega_1 =$ ``white ball''

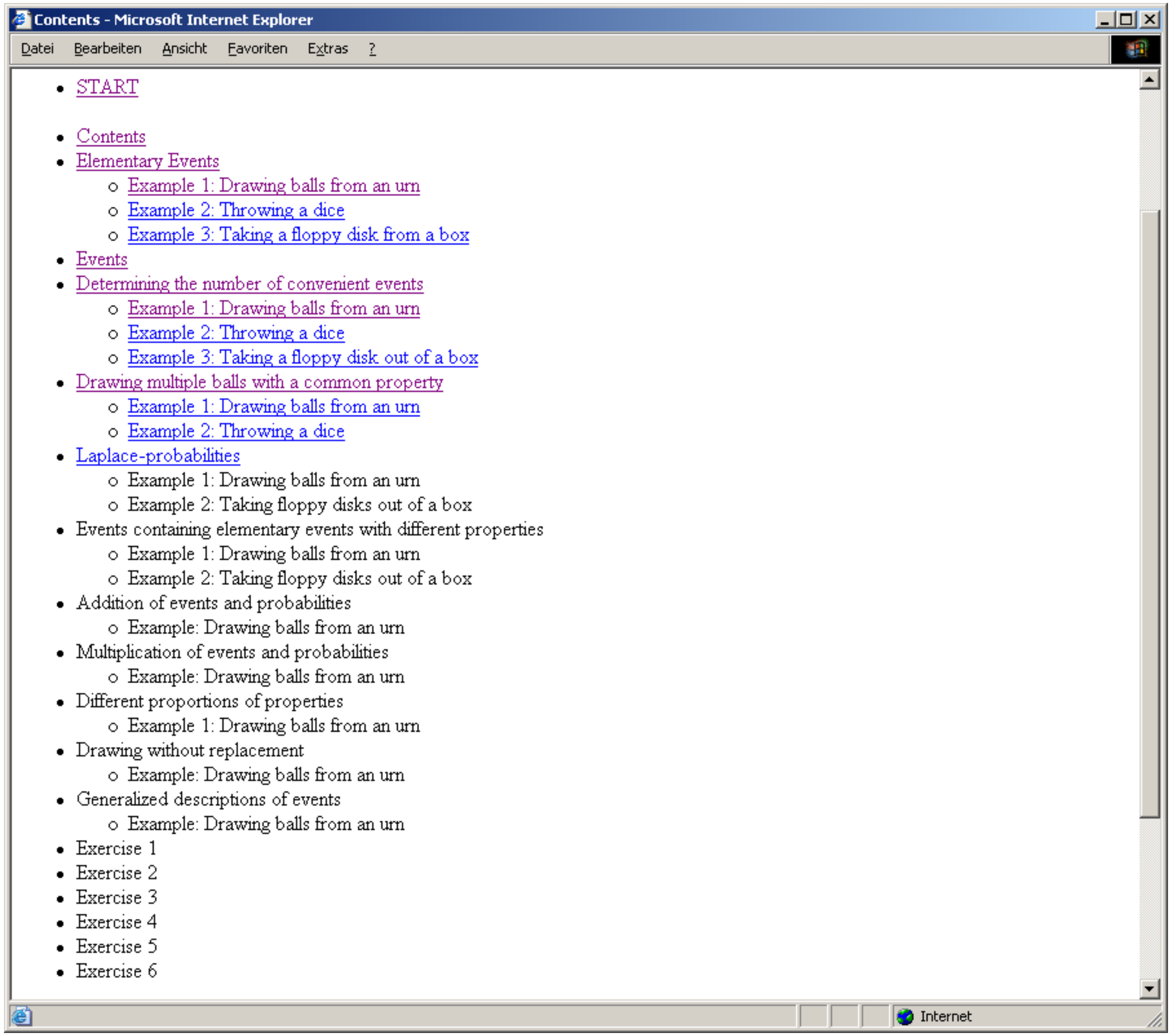
$\omega_2 =$ ``green ball''

Space of results:
$\Omega = \{\omega_1, \omega_2\} \Longrightarrow$ **The number of results is** $|\boldsymbol{\Omega}| = \mathbf{2}$.

RATH *(Relational Adaptive Tutoring Hypertext)*

Fertig Internet

RATH: Access to other Lessons



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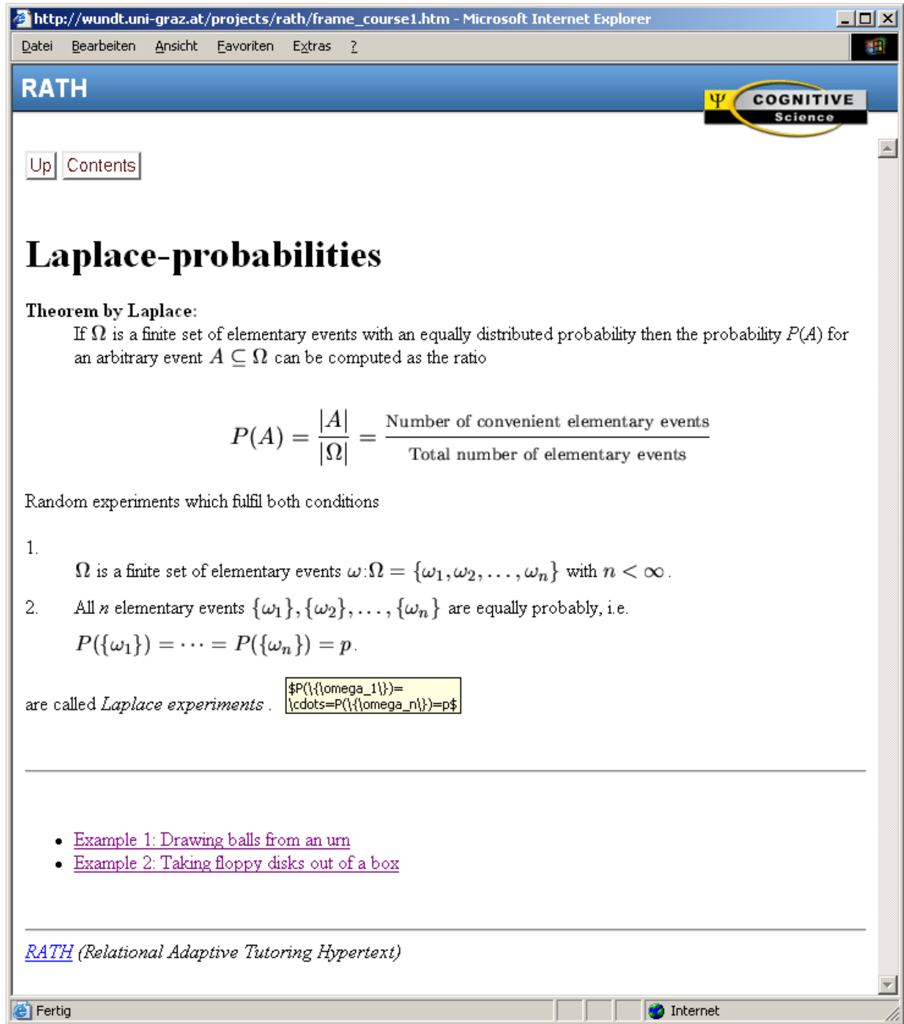
RATH: Part of a Lesson



http://wundt.uni-graz.at/projects/rath/frame_course1.htm - Microsoft Internet Explorer

Datei Bearbeiten Ansicht Favoriten Extras ?

RATH

Up | Contents

Laplace-probabilities

Theorem by Laplace:

If Ω is a finite set of elementary events with an equally distributed probability then the probability $P(A)$ for an arbitrary event $A \subseteq \Omega$ can be computed as the ratio

$$P(A) = \frac{|A|}{|\Omega|} = \frac{\text{Number of convenient elementary events}}{\text{Total number of elementary events}}$$

Random experiments which fulfil both conditions

1. Ω is a finite set of elementary events ω: $\Omega = \{\omega_1, \omega_2, \ldots, \omega_n\}$ with $n < \infty$.
2. All n elementary events $\{\omega_1\}, \{\omega_2\}, \ldots, \{\omega_n\}$ are equally probably, i.e. $P(\{\omega_1\}) = \cdots = P(\{\omega_n\}) = p$.

are called *Laplace experiments*.

```
$P(\{\omega_1\})=
\cdots=P(\{\omega_n\})=p$
```

- Example 1: Drawing balls from an urn
- Example 2: Taking floppy disks out of a box

RATH *(Relational Adaptive Tutoring Hypertext)*

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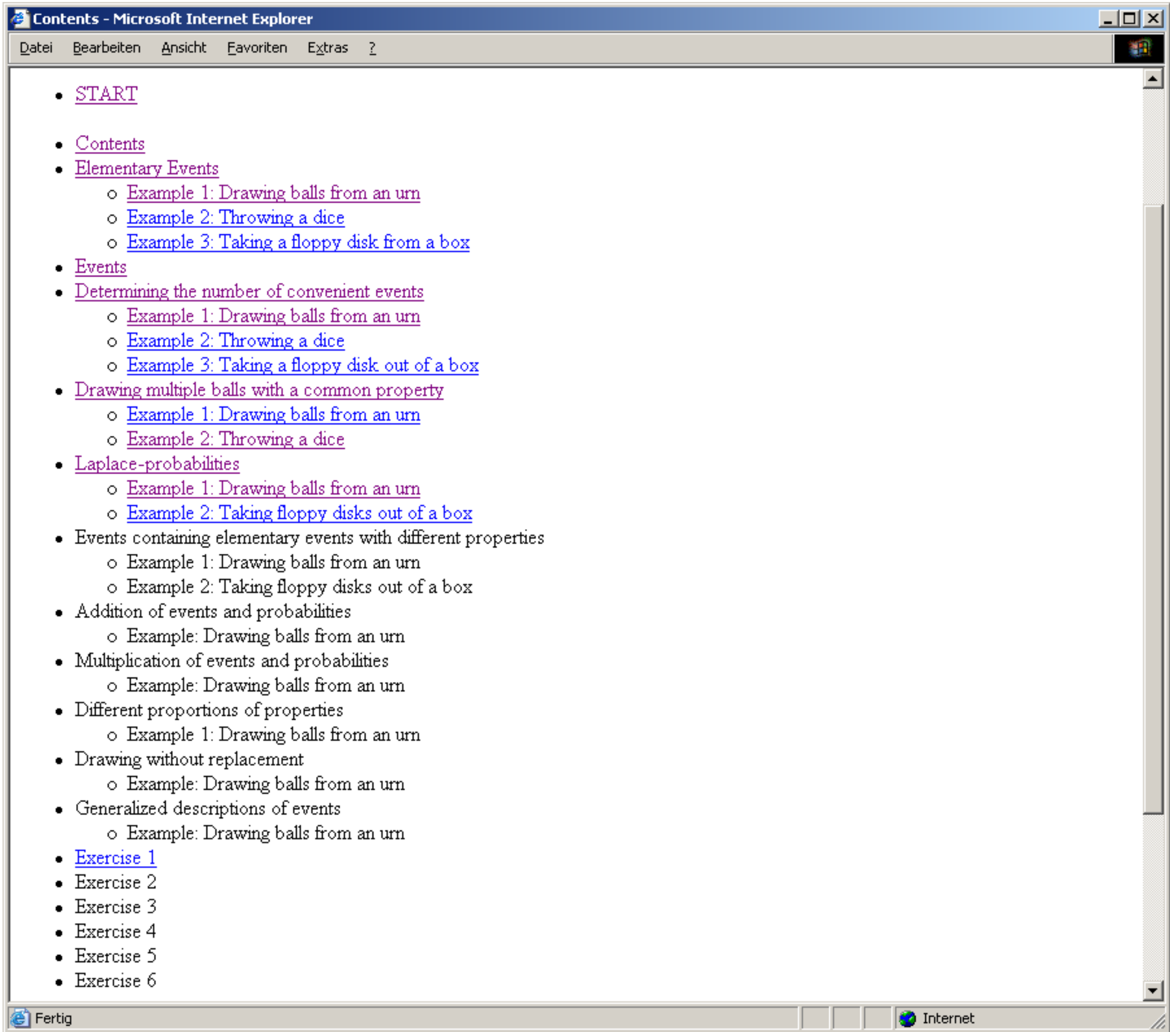
RATH: Access to Exercise



RATH Access to other Lessons

Contents - Microsoft Internet Explorer

Datei Bearbeiten Ansicht Favoriten Extras ?

- START
- Contents
- Elementary Events
  - Example 1: Drawing balls from an urn
  - Example 2: Throwing a dice
  - Example 3: Taking a floppy disk from a box
- Events
- Determining the number of convenient events
  - Example 1: Drawing balls from an urn
  - Example 2: Throwing a dice
  - Example 3: Taking a floppy disk out of a box
- Drawing multiple balls with a common property
  - Example 1: Drawing balls from an urn
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  - Example 1: Drawing balls from an urn
  - Example 2: Taking floppy disks out of a box
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  - Example: Drawing balls from an urn
- Different proportions of properties
  - Example 1: Drawing balls from an urn
- Drawing without replacement
  - Example: Drawing balls from an urn
- Generalized descriptions of events
  - Example: Drawing balls from an urn
- Exercise 1
- Exercise 2
- Exercise 3
- Exercise 4
- Exercise 5
- Exercise 6

Fertig | Internet

RATH Access to other Exercises

- Introduction
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Extending KST: Competence-based Approach

- Knowledge Space Theory in its original formalisation is purely behaviouristic
  - focus on observable behaviour
- The underlying competences and skills have to be taken into account

→ Competence/skill-based extensions of Knowledge Space Theory: CbKST

- (e.g. Doignon, 1994; Düntsch & Gediga, 1995; Korossy, 1997; Hockemeyer, 2003)

Competence-based KST (CbKST)

- Competence-based Knowledge Space Theory (CbKST)
  - Incoporates underlying skills and competencies
  - provides information for teaching
  - Includes explicit learning objects
  - explains transfer of knowledge
  - explains creating new knowledge
  - etc.

CbKST - Competence Performance Approach

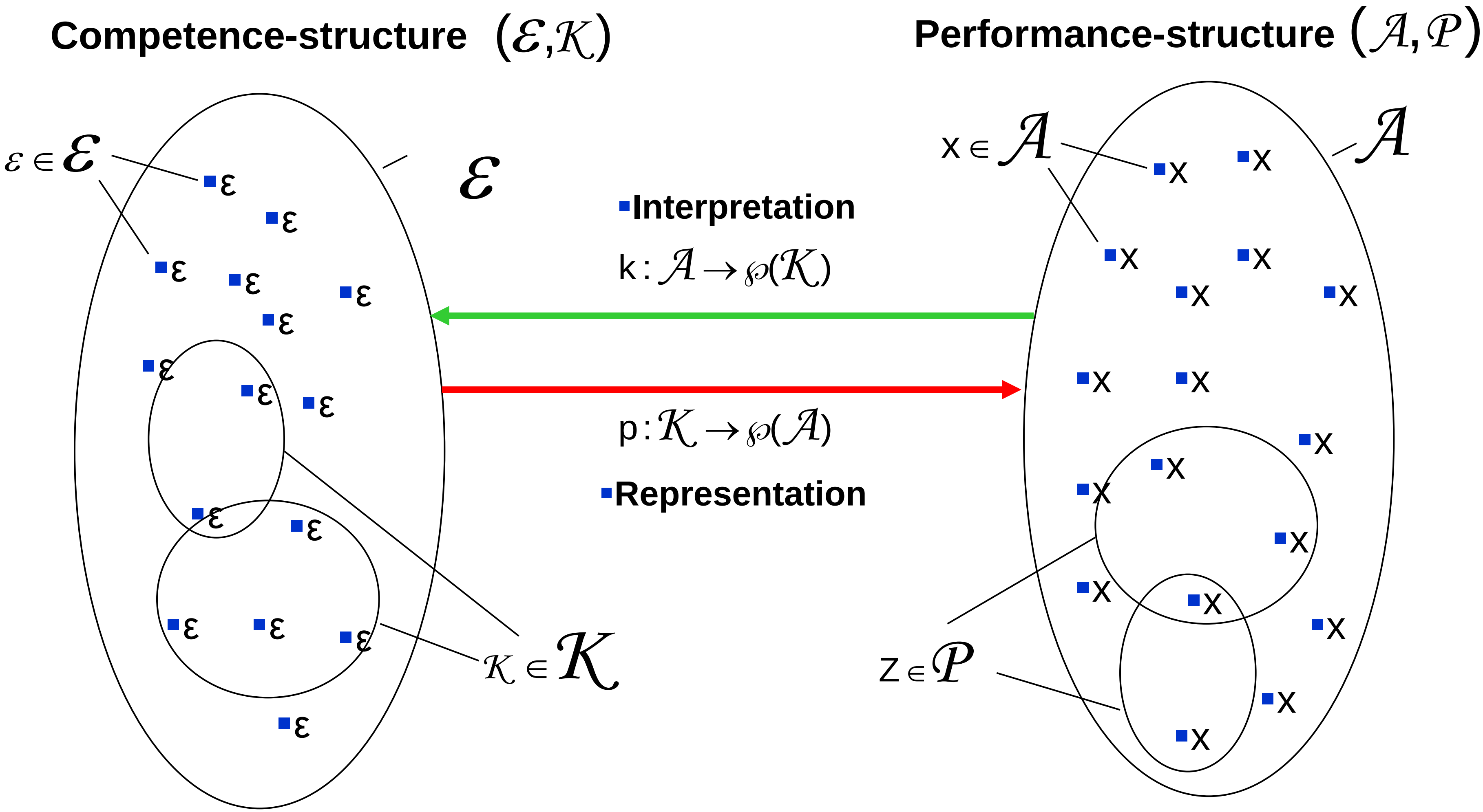
- Modelling knowledge through

  (latent) competencies and

  (observable) behaviour and performances

- Interpretation function (skill function)
  - Assigning to each item/problem the subset of competencies necessary to solve the item
- Representation function (problem function)
  - Assigning to each competence state the subset of items/problems solvable in this state

Competence Performance Approach



Competence Performance Approach

- Interpretation Function k: to each item **x** (of ***A***) a subset k_x of Competence States is assigned in which the item is solvable
- Representation Function p: to each Competence State **e** (out of **K**) a set p(**e**) of items solvable in this state is assigned

Competence Performance Approach

- Interpretation/skill and representation/problem function induce competence and performance spaces/structures
- Both concepts are equivalent, i.e. given one function the other is uniquely determined
- The assignment of competences/skills puts constraints on the possible knowledge states and thus defines a knowledge structure
- Additionally, by a theoretically derived competence structure the number of competence and knowledge/performance states can be reduced

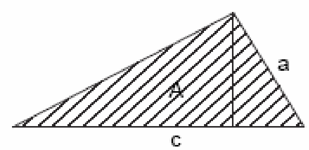
Competence Performance Approach

- Assessing a learner's competence state by Problem-based skill assessment
  - Step 1: adaptive assessment of the knowledge respectively performance state
  - Step 2: mapping to corresponding competence state

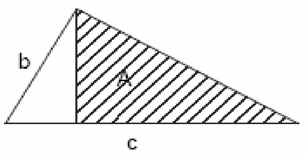
Example: Material and Structure

Geometry problems

- adapted from Korossy (1993, 1996)
- based on a Competence Performance Modeling
- e.g.



given: a = 5 cm, c = 8 cm
area A = ?



given: b = 3 cm, c = 9 cm
area A = ?

Example: Material and Structure

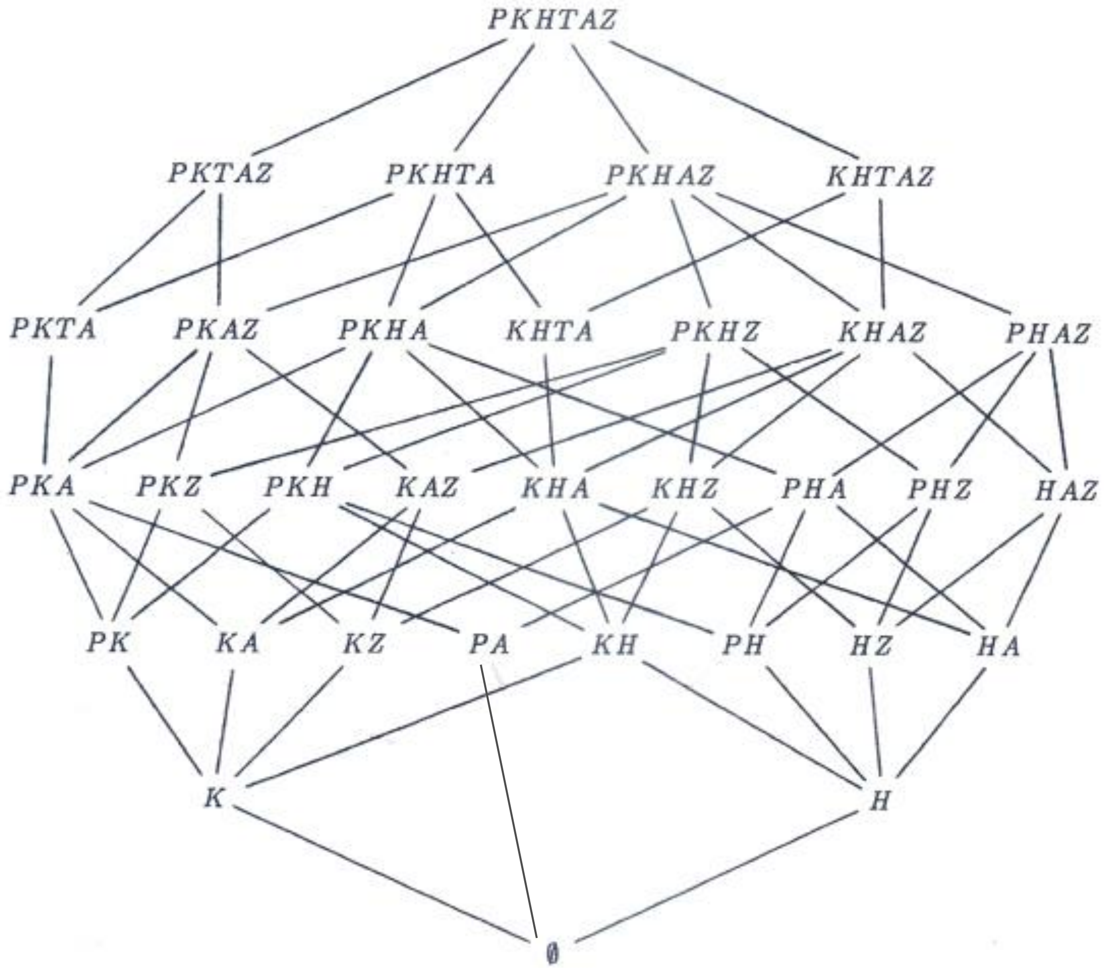
- Elementary Competencies:

abbreviation	*domain-specific meaning*
P	knowledge of the Theorem of Pythagoras
K	knowledge of the Kathetensatzes
H	knowledge of the Euclid's altitude theorem
A	knowledge about calculating the area of a right-angled triangle
Z	knowledge of constructing a square with the same area as a given rectangle
T	knowledge of properties of tangents on circles

Example: Material and Structure

- definition of dependencies between the Elementary Competencies
- resulting Competence Structure:
  32 Competence States

Competence Structure



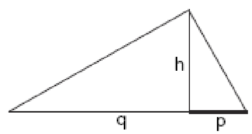
(Korossy, 1996, p. 293)

Material and Structure

- In accordance with Competence Structure: construction of 10 geometry problems
- solution analysis: identification of possible solution ways applying the Elementary Competencies

Material and Structure

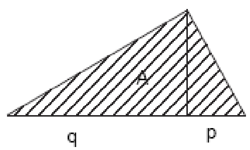
a)



gegeben: q = 7 cm, h = 5 cm

gesucht: p

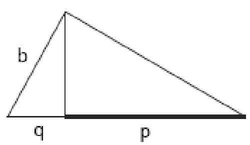
b)



gegeben: q = 7 cm, p = 6 cm

gesucht: Flächeninhalt A

c)



gegeben: b = 5 cm, q = 3 cm

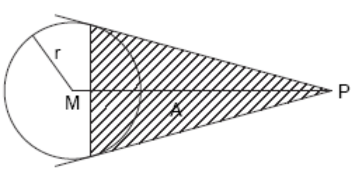
gesucht: p

d)

gegeben: Rechteck

Verwandle zeichnerisch in ein flächeninhaltsgleiches Quadrat, d.h. nur durch Benutzung von Geodreieck, Zirkel, Bleistift und ohne Durchführung von Berechnungen!

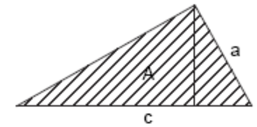
e)



gegeben: r = 3 cm, PM = 7 cm

gesucht: Flächeninhalt A

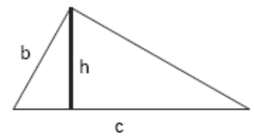
f)



gegeben: a = 5 cm, c = 8 cm

gesucht: Flächeninhalt A

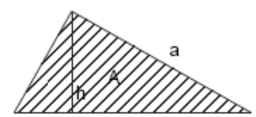
g)



gegeben: b = 4 cm, c = 9 cm

gesucht: h

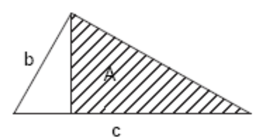
h)



gegeben: a = 9 cm, h = 5 cm

gesucht: Flächeninhalt A

i)



gegeben: b = 3 cm, c = 9 cm

gesucht: Flächeninhalt A

j)

gegeben: Rechteck, Quadrat (unten)

Konstruiere ein Quadrat mit dem gleichen Flächeninhalt wie das gegebene Rechteck und Quadrat zusammen haben. D.h. nur durch Benutzung von Geodreieck, Zirkel, Bleistift und ohne Durchführung jeglicher Berechnungen!

Material and Structure

- Interpretation Function:

a	*{H, PK}*
b	*{HA, KA}*
c	*{K, PH}*
d	*{KZ, HZ)*
e	*{PKTA, KHTA}*
f	*{PA, KHA}*
g	*{PK, KH, PA}*
h	*{PHA, PKA}*
i	*{KHA, PKA}*
j	*{PKZ, PHZ}*

Material and Structure

- Representation Function (extract):

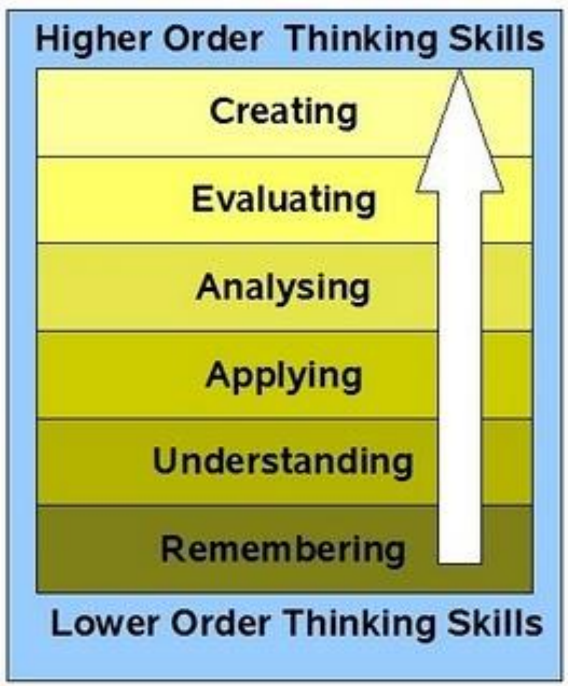
Ø	*Ø*	*KHA*	*abcfgi*
K	*c*	*PHA*	*abcfgh*
H	*a*	*PKZ, PKHZ*	*acdgj*
KA	*bc*	*PHZ*	*acdj*
KZ	*cd*	*KHZ*	*acdg*
PK, KH, PKH	*acg*	*KHAZ*	*abcdfgi*
PKA, PKHA	*abcfghi*	*PKTAZ, PKHTAZ*	*abcdefghij*
KHTAZ	*abcdefgi*	…	…

CbKST: iClass Skill Definition

- skill components
  - declarative component:

    concept(s) (e.g. Pythagorean Theorem)
  - procedural component:

    action verb (e.g. state, apply)
    - may be associated with Bloom's revised taxonomy of edcuational objectives:
      - levels of cognitive processing

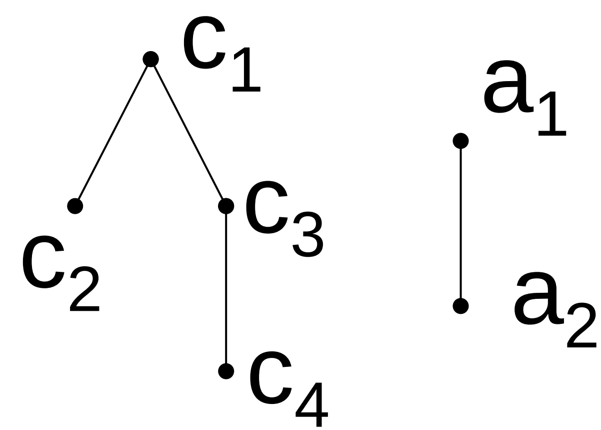


(e.g. Heller, Steiner, Hockemeyer, & Albert, 2006; Anderson et al., 2001)

CbKST: iClass Skill Definition

- concepts with their hierachical structure
  - e.g. `Theorem of Pythagoras´ is prerequisite for `Altitude Theorem´ corresponding to curriculum
  - order on the action verbs

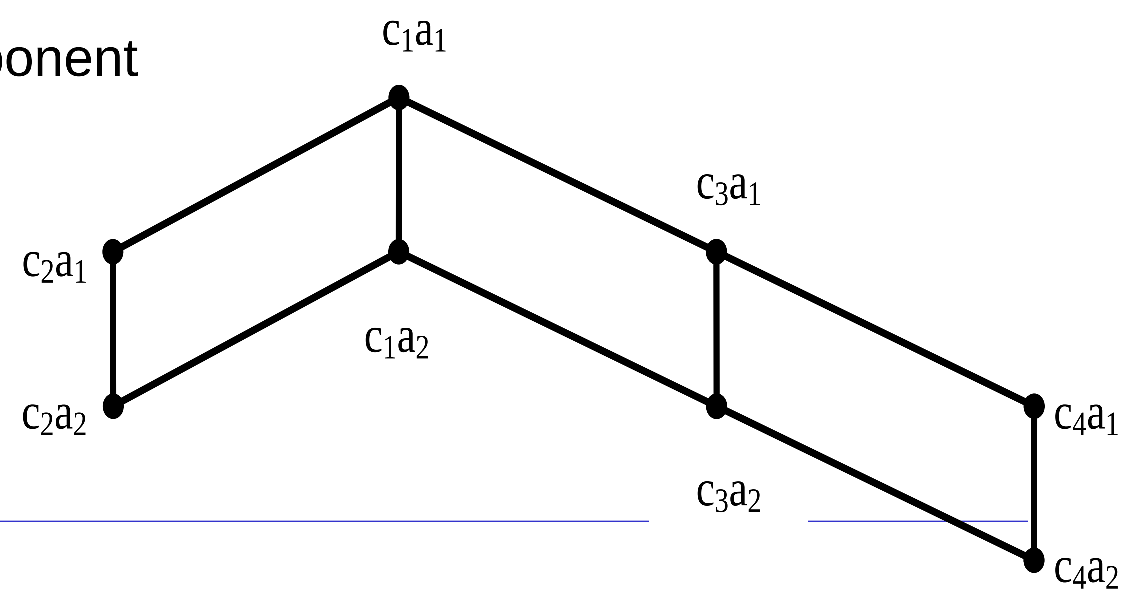
    e.g.: `state´ is prerequisite for `apply



- the product of these two component orderings results in a surmise relation on the skills

e.g. skill c_2a_2 is a prerequisite

to the skills c_2a_1, c_1a_2, an



CbKST: Personalised Learning Paths

- Once the competence state of a learner has been determined a personalised learning path may be selected
  - based on skill assignments to learning objects
- Deciding upon next learning object, given a certain competence state
  - referring to learning path of the competence structure

    a suitable learning object is selected, featuring
    - required skills that the learner has already available
    - taught skills that correspond to next step in learning path

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Application: APeLS http://css.unigraz.at/demos/apels

- **APeLS**

  Advanced **Pe**rsonalised **L**earning **S**ystem (TCD)

  http://css.uni-graz.at/demos/apels

  Unser name: admin pass word: atwundt

- Competence learning structures
  - Set of learning objects and a set of assigned competencies: **Taught vs. required competencies**
  - Competence structures only implicitly defined (by metadata)

Newtonian Mechanics: Examples of Kinematics: Two Exercises

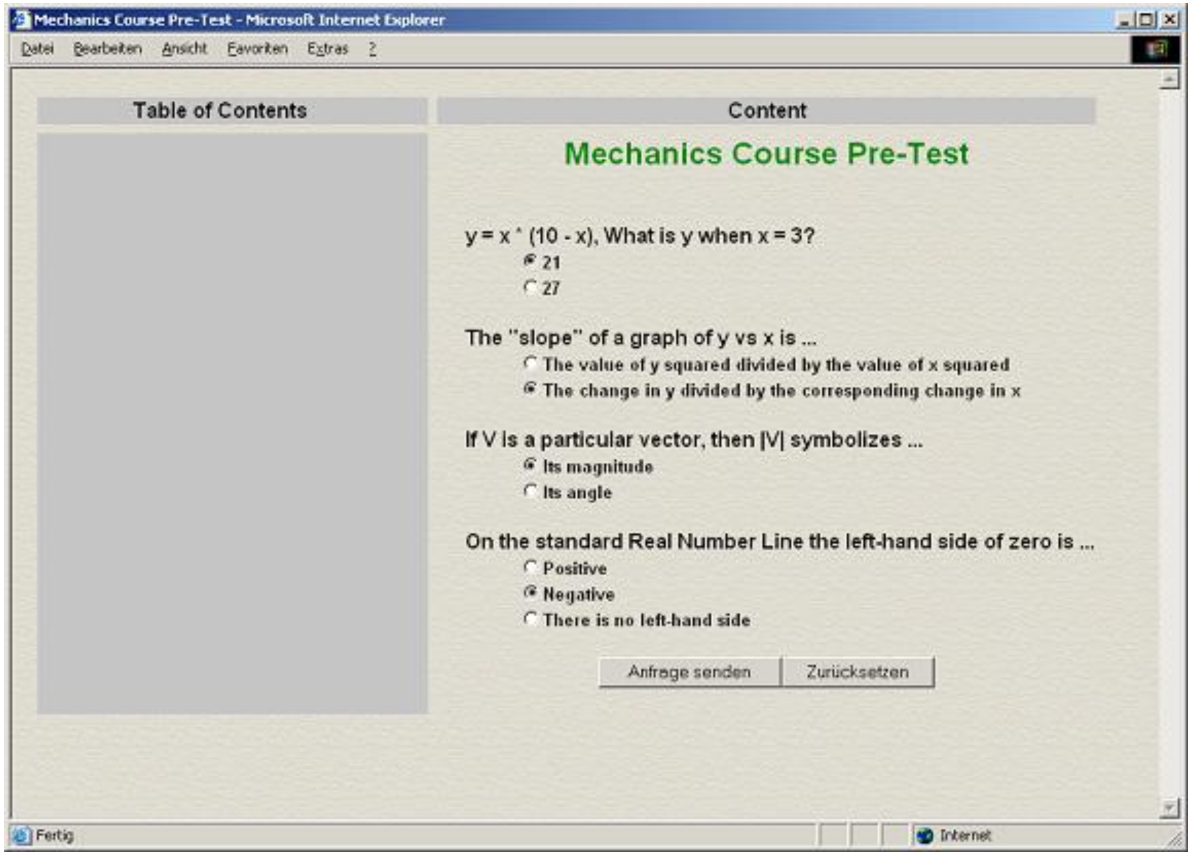
Exerc. 5. A body moves vertically away from earth, according to the law $s = 19{,}6\ t - 4{,}9\ t^2$. Demonstrate that it has only the half velocity after rising 14,7 m.

Exerc. 6. During the upwards motion of an freight elevator ($v_0 = 0{,}8$ m / s) the cable breaks. Which velocity does the cabin have, when the catching mechanism takes action 25 cm after begin of the free fall? Which lag is acting when the cabin comes to stand after

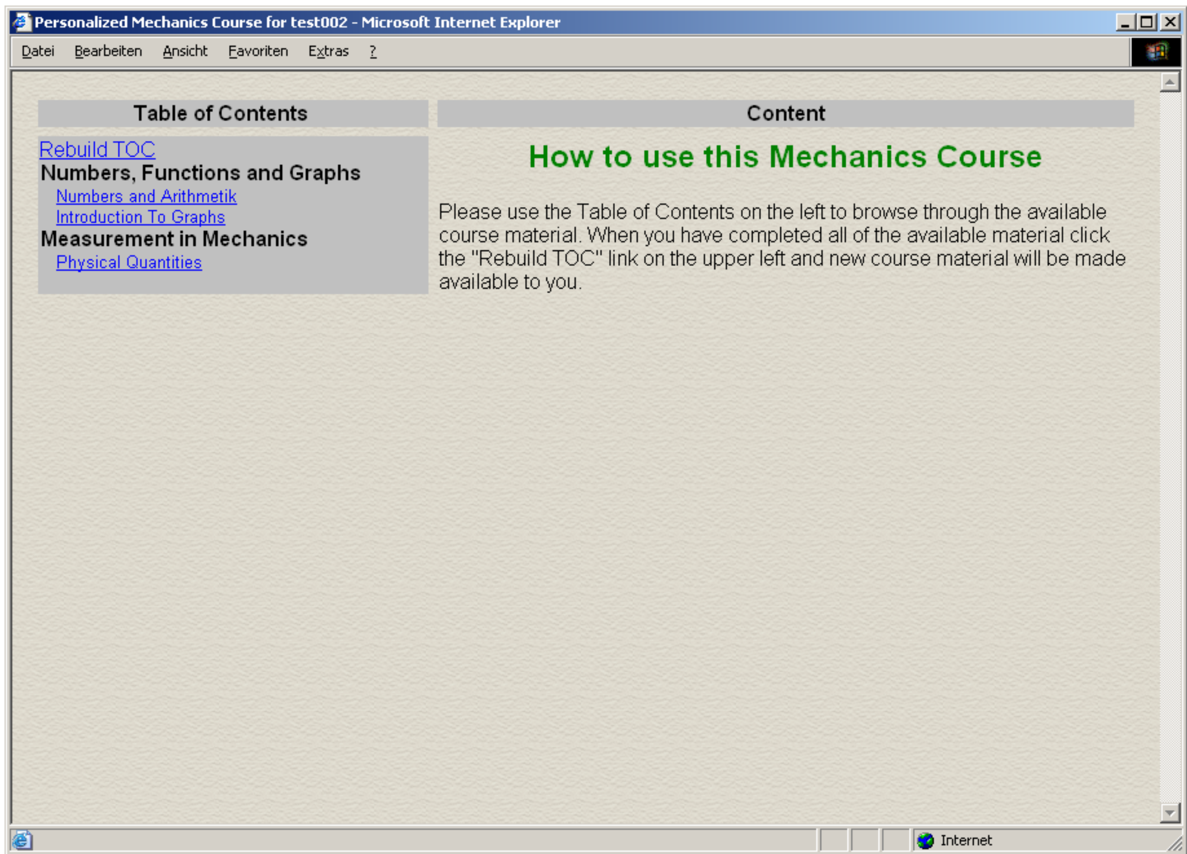
Kinematics Skills

p_1	To be able to transform and apply formula. $\Delta s = v \cdot \Delta t$
p_2	To be able to state and apply the definition of acceleration.
p_3	To be able to perform computations concerning the free fall.
P_4	To be able to transform and apply formulae for steadily accelerated motion with initial velocity zero.
p_5	To be able to transform and apply formulae for steadily accelerated motion with initial velocity unequal zero.
p_6	To be able to state and apply the connection between braking distance, initial velocity and braking lag. $\Delta s = \frac{v_0^2}{2a}$
p_7	To be able to compose motions by vector addition, with at least one of the motions being unequal.

APeLS Initial Assessment



APeLS Start of the Course



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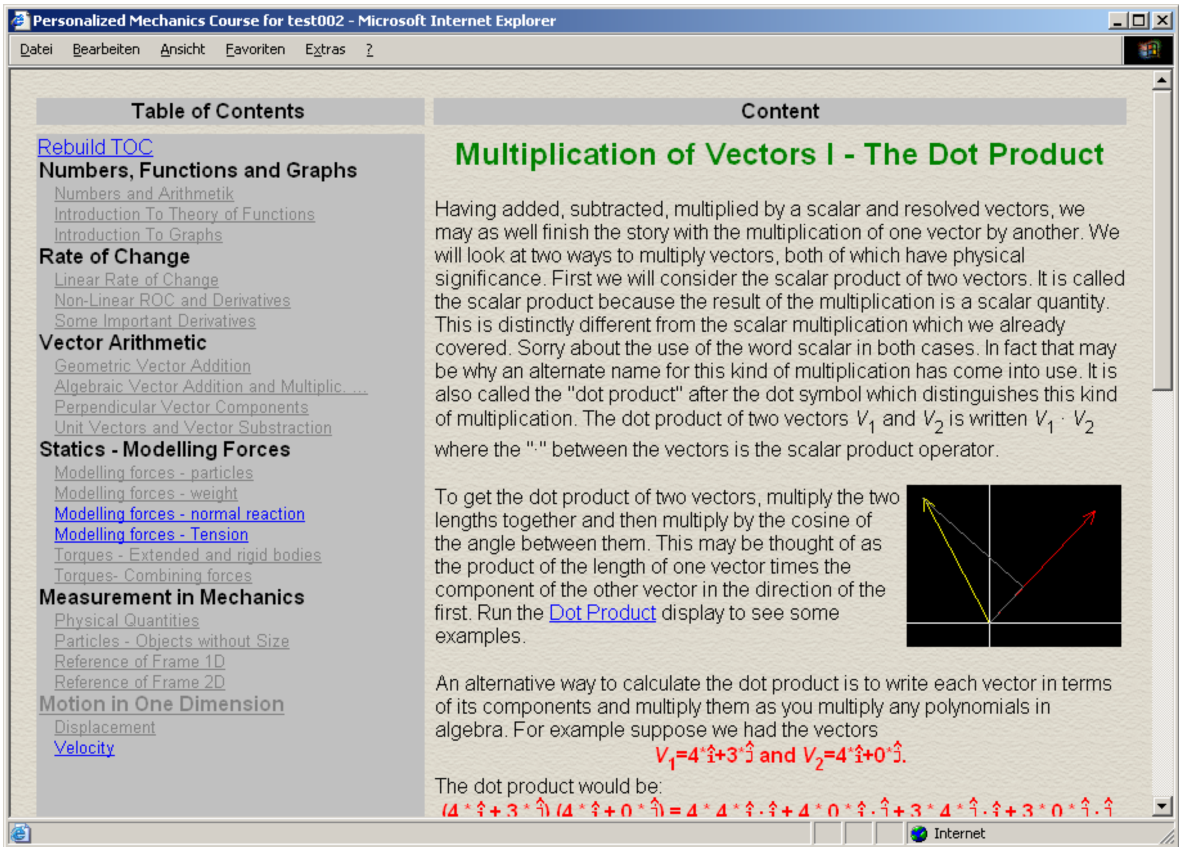
APeLS Learning Progress

- **Learning progress (learning object va4)**



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APeLS

UNI GRAZ

TOC of learning objects

COGNITIVE Science

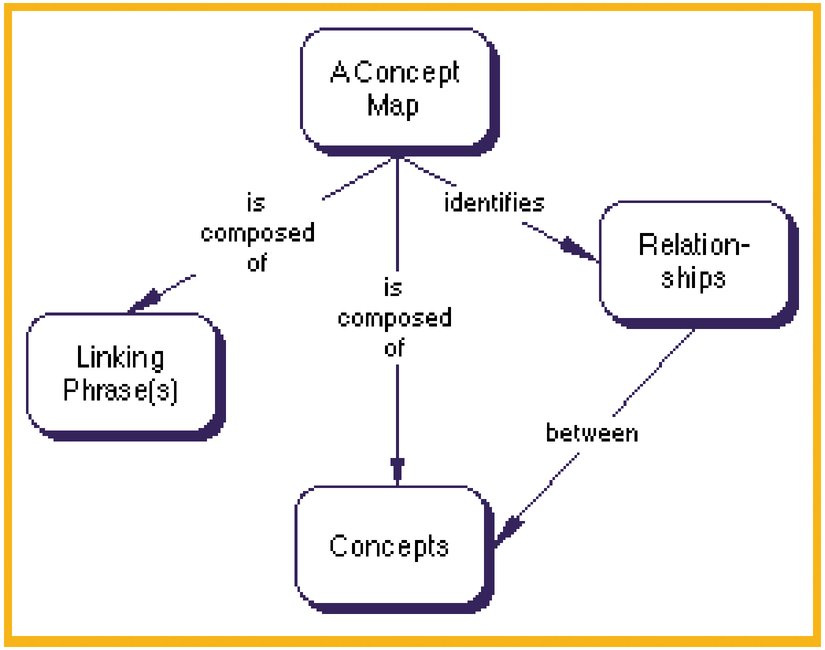
- Introduction
- Knowledge Space Theory
  - Application: ALEKS
- Demand Component Approach
  - Application: RATH
- Competence-Performance Approach
  - Application: APeLS
- **Ontology-based Skill Approach and**
  - **Application: iClass**

Ontology-based Skill Approach and iClass-Application

- **iClass**: **i**ntelligent distributed **C**ognitive-based open **l**earning **s**ystem for **s**chool
- http://css.uni-graz.at/projects/iclass/iclass.php
- The iClass System incorporates main features of the above mentioned knowledge space based systems. However, iClass goes beyond these systems with regard to the needs of the stakeholders (students, teachers, parents, educational authorities).

Concept Maps

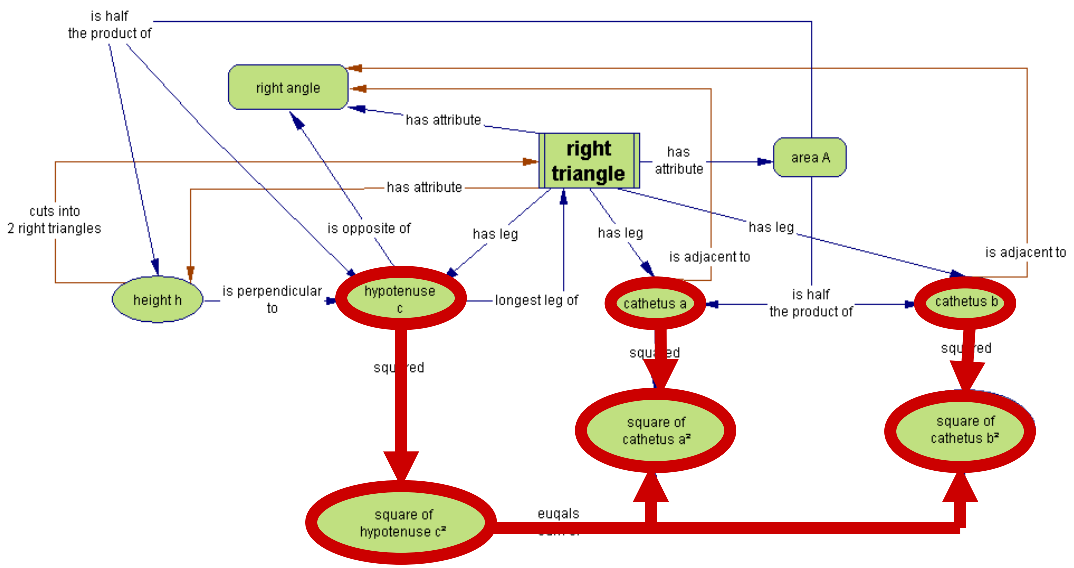
- Concept map = a directed graph := a set of propositions
- Proposition connects two related concepts



- *A Concept Map is composed of Linking Phrases.*
- *A Concept Map is composed of Concepts.*
- *A Concept Map identifies Relationships.*
- *Relationships are between Concepts.*

Deriving Skills from Domain Ontologies

- Competence = subset of propositions of expert concept map
- Example: Geometry of right triangles



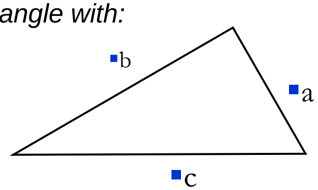
- Competence ‚Knowing the Theorem of Pythagoras'

An Application Example

- deriving dependencies between problems from concept maps
  - typical problems of a knowledge domain

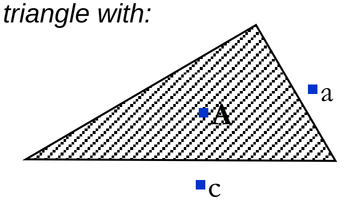
a

- *Given a right triangle with:*
  - *a = 4 cm*
  - *c = 7 cm*
- *b = ?*



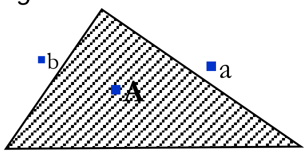
b

- *Given a right triangle with:*
  - *a = 5 cm*
  - *c = 8 cm*
- *area A = ?*

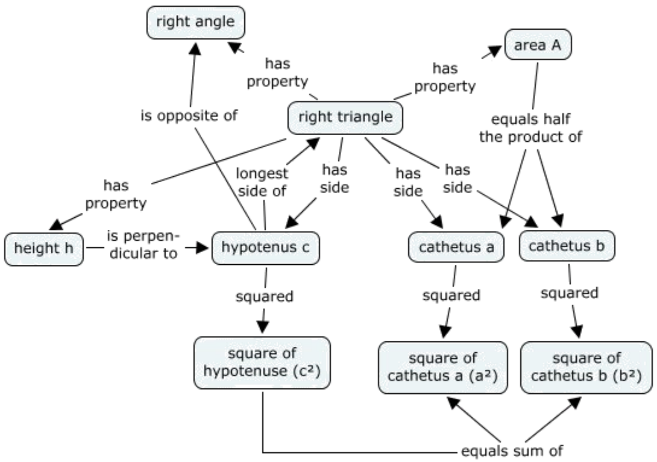


c

- *Given a right triangle with:*
  - *a = 6 cm*
  - *b = 3 cm*
- *area A = ?*

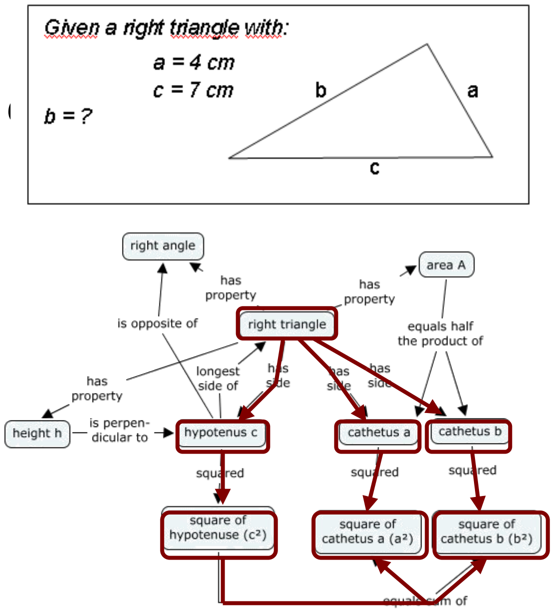


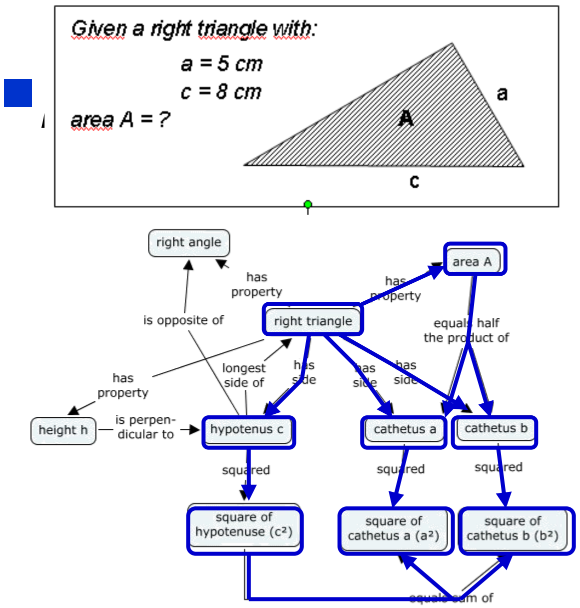
- concept map representing the semantic structure of the domain

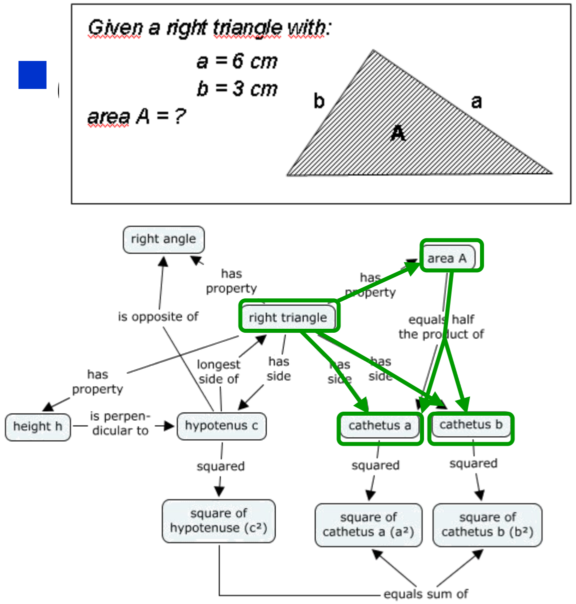


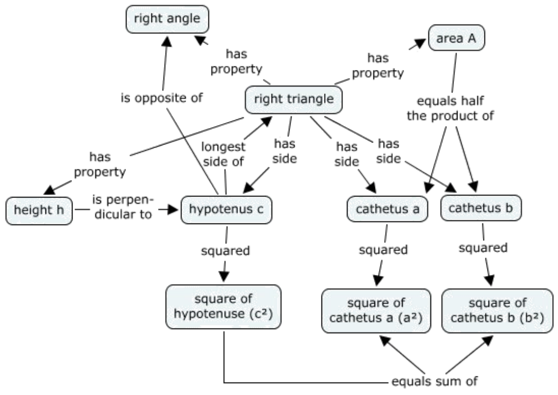
(e.g. Steiner & Albert, 2008; Steiner et al., 2007)

An Application Example

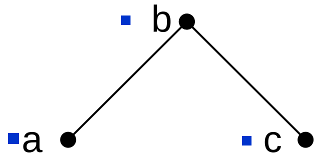








- the representations of both, a and c, are subsets of the concept map of problem b



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Advantages

- By using ontologies (concept maps, proposition sets) the content, the curriculum, the learner and the needs of the other stakeholder can be described and structured by a common, interrelated framework
- The relationship with e.g. conceptual graphs will in the future allow to generate semi- automatically the involved structures on the basis of digital information in test books, official documents etc.

Handing over

- In this first motivating part some basics of KST and CbKST have been illustrated
- In the third part we will come back to more recent applications like SRL, GBL, to resources etc.
- In the following, the mathematical part, some of the already mentioned and extended concepts will be defined and explained in more detail by **Reinhard SUCK**

END OF THE FIRST PART