

ACCELERATED LEARNING

ENHANCING DEEP LEARNING & FAR TRANSFER
IN SCIENCE EDUCATION:
PRACTICAL LESSONS FROM COGNITIVE SCIENCE

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COURSE GOALS & OUTLINE

- **CENTRAL GOAL: FOSTER DEVELOPMENT OF
ADAPTIVE EXPERTISE**
- **APPLY FINDINGS FROM COGNITIVE SCIENCE TO
IMPROVE DEVELOPMENT OF COGNITIVE SKILLS**
 - **NOVICE -> EXPERT -> ELITE EXPERT**
- **TCD LAW, MBA, ENGINEERING PROGRAMMES**

PEDAGOGICAL HIERARCHY

By three methods we may learn wisdom: first, by reflection, which is noblest; second, by imitation, which is easiest; and third by experience, which is the bitterest

Confucius (circa 551-478 BC) Chinese philosopher

PEDAGOGICAL HIERARCHY

- **EXPERIENCE = DISCOVERY LEARNING**
 - LEARNING TRANSFER?
- **IMITATION = WORKED EXAMPLES**
 - NEAR TRANSFER
- **REFLECTION = KNOWLEDGE ENGINEERING**
 - FAR TRANSFER

**THE FOUNDATIONS OF
SUPERIOR PERFORMANCE**

WHAT IS AN EXPERT?

AN EXPERT IS AN INDIVIDUAL EXHIBITING

- SUPERIOR **KNOWLEDGE**
- SUPERIOR **PROBLEM SOLVING ABILITIES**

TWO TYPES OF EXPERT

ROUTINE EXPERT

- **Excel in solving familiar problems efficiently**

ADAPTIVE EXPERT

- **Exhibit “the ability to apply, adapt and otherwise stretch knowledge so that it addresses new situations - often situations in which key knowledge is lacking” - Weinburg**

EXPERTISE IS KNOWLEDGE-BASED I

- Highest levels of ability shown by individuals with the highest levels of training
- Expert's superior performance is domain specific
- Few child prodigies become exceptional adults; most exceptional adults were not child prodigies
- Exceptional achievements by unexceptional individuals
- Performance is related to quality of knowledge organisation

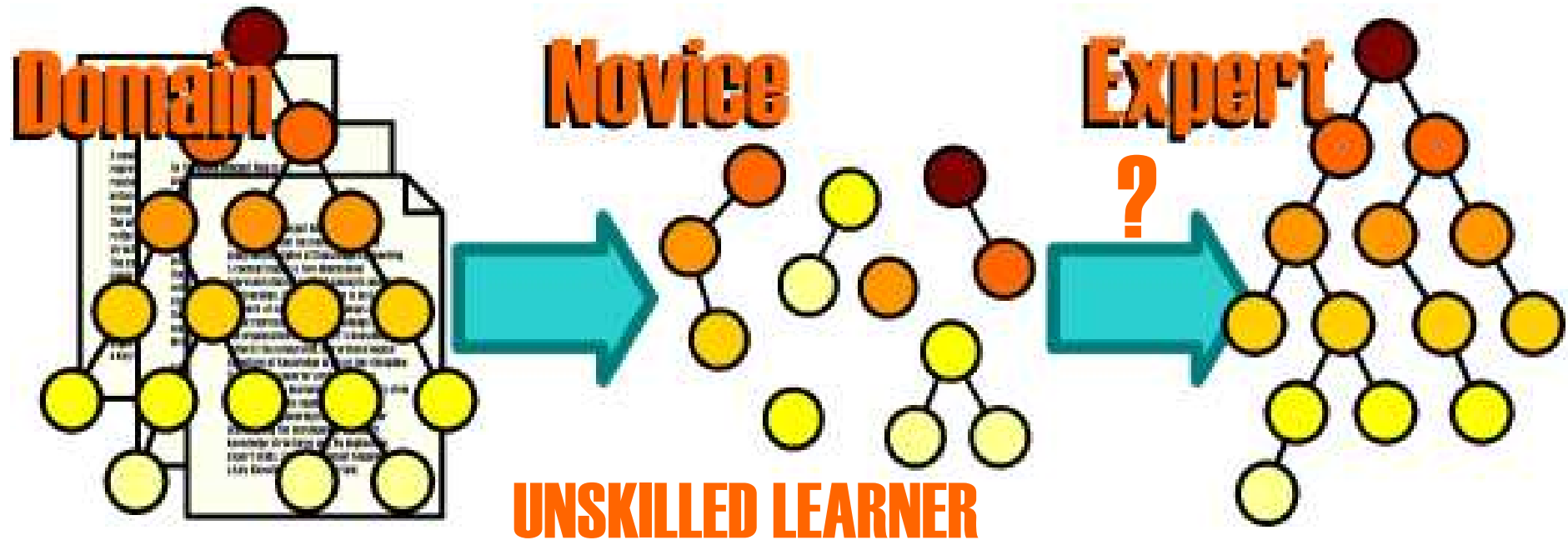
EXPERTISE IS KNOWLEDGE-BASED II

- HISTORICAL IMPROVEMENTS IN TRAINING DRIVES IMPROVEMENTS IN PERFORMANCE
- SCIENCE
 - Differential calculus taught to secondary school students
- MUSIC
 - Tchaikovsky's violin concerto 'unplayable'
 - Paganini "a sorry figure"
- SPORTS
 - Boston marathon qualifying time
 - Rise in chess ELO ratings

EXPERTISE IS KNOWLEDGE-BASED III

- **TRAINING INNOVATIONS DRIVE PERFORMANCE INCREASES**
- **IMPLICATION?**
- **WE'RE ALL UNDERACHIEVERS!**
- **OPPORTUNITY TO RATIONALLY DESIGN METHODS FOR ACCELERATING EXPERTISE**

CONVENTIONAL DEVELOPMENT of EXPERTISE



- **Fragmented**
- **Non-Hierarchical**
- **Narrow**
- **Integrated**
- **Hierarchical**
- **Extensive**

KNOWLEDGE STRUCTURES: EXPERTS & NOVICES

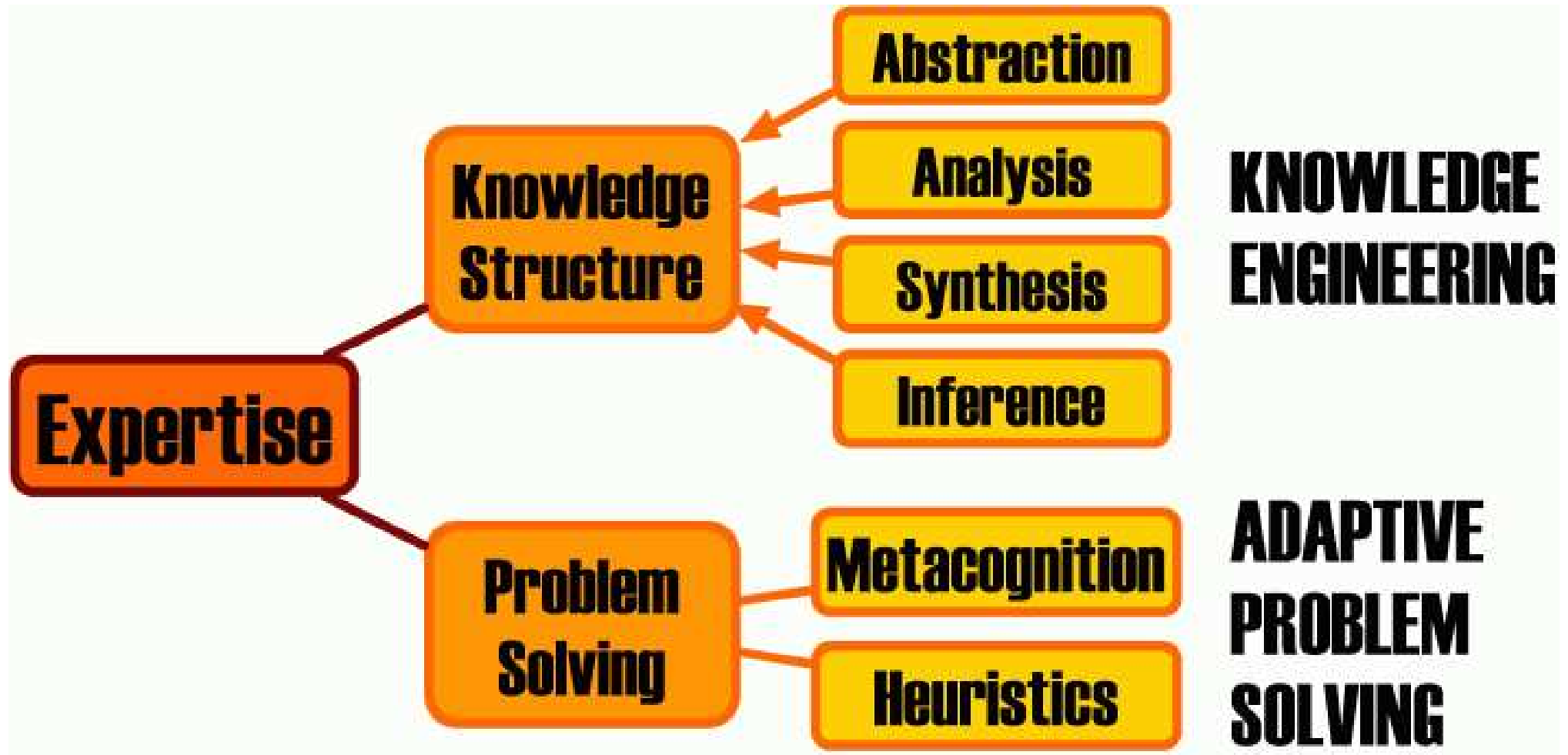
EXPERTS

- **Integrated**
 - Good Learning Transfer
- **Hierarchical**
 - Efficient Problem Solving Strategies

NOVICES

- **Fragmented**
 - Poor Learning Transfer
- **Non-hierarchical**
 - Inefficient Problem Solving Strategies

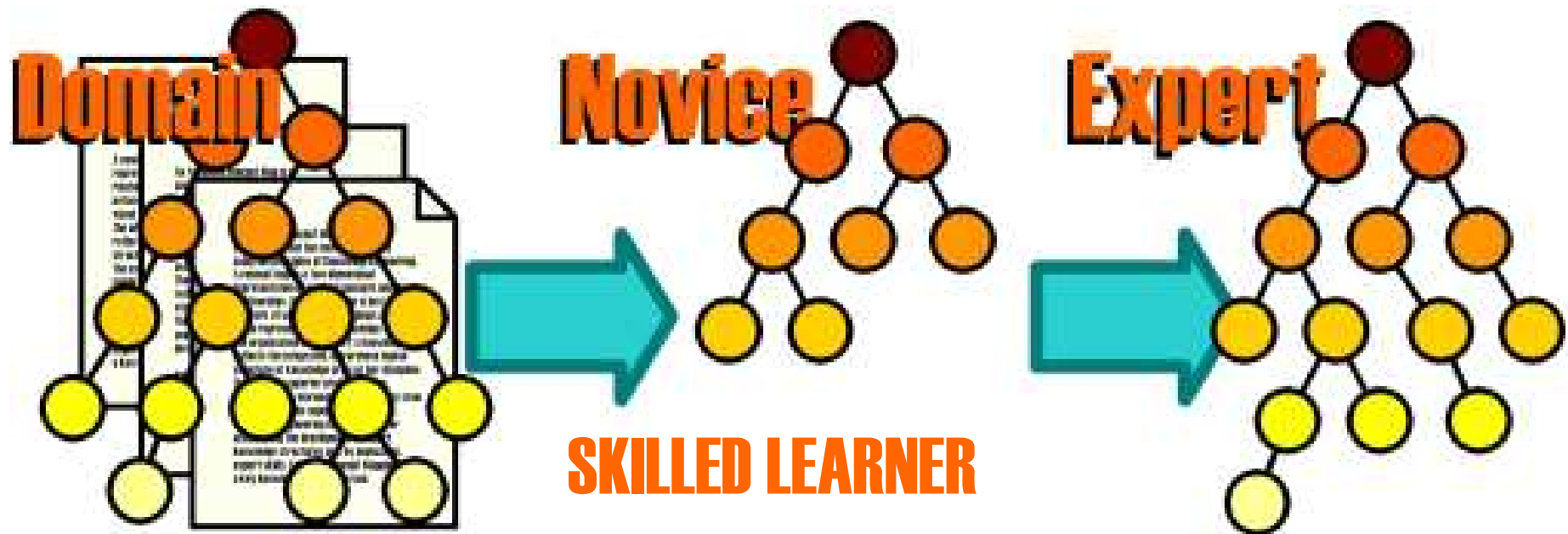
ACT FRAMEWORK: A MODEL OF EXPERTISE



KNOWLEDGE ENGINEERING

- 
- The diagram illustrates the progression of knowledge engineering through three stages: Domain, Novice, and Expert. Each stage is represented by a hierarchical tree structure of nodes. The 'Domain' stage shows a complex, interconnected network of nodes. The 'Novice' stage shows a simpler, more structured tree. The 'Expert' stage shows a highly refined and optimized tree structure. Two large blue arrows point from the Domain stage to the Novice stage, and from the Novice stage to the Expert stage, indicating the direction of knowledge engineering.
- **EXPLICIT CONSTRUCTION OF EXPERT SCHEMATA**
 - **ACCELERATE ATTAINMENT OF EXPERT**
 - **COMPREHENSION**
 - **PROBLEM SOLVING**
 - **LEARNING**
 - **MEMORY**

ACT DEVELOPMENT OF EXPERTISE

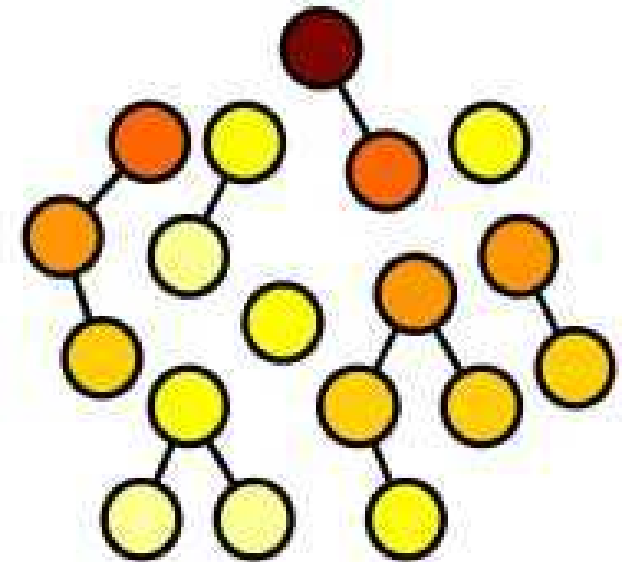
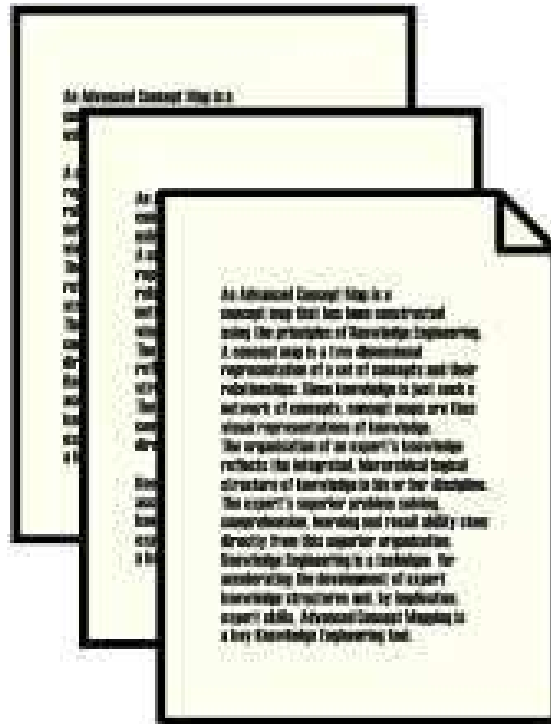


SKILLED LEARNER

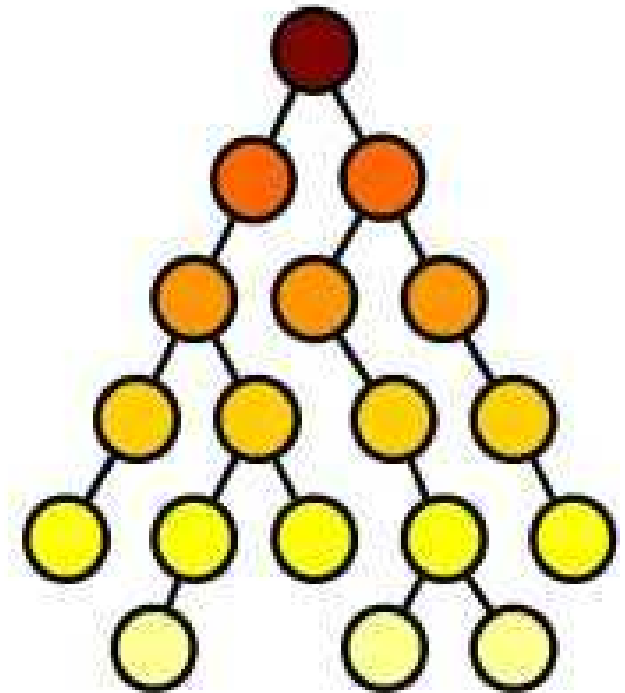
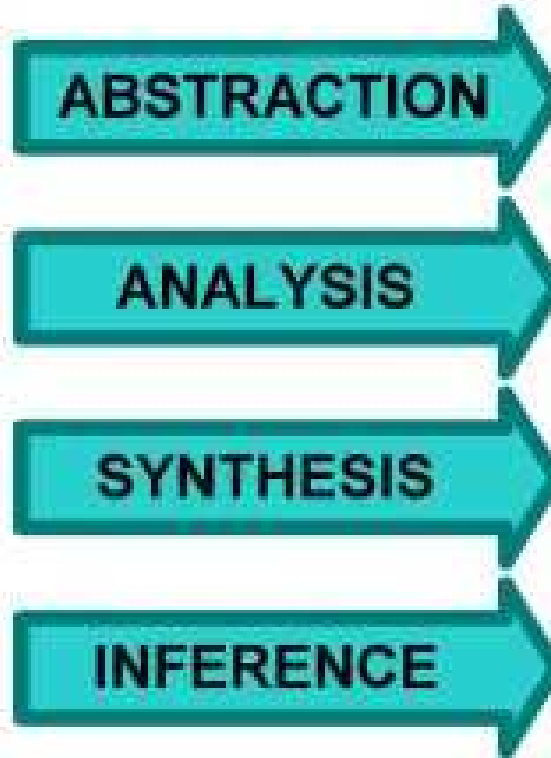
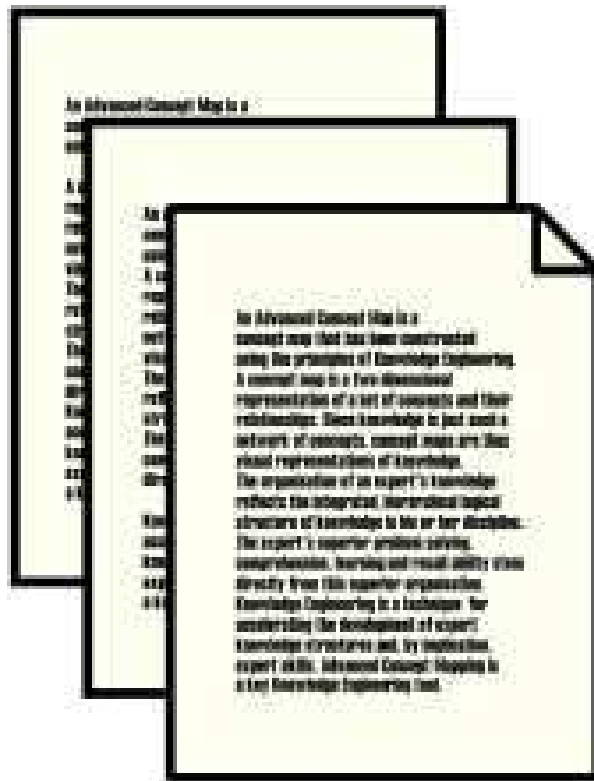
- **Integrated**
- **Hierarchical**
- **Narrow**

- **Integrated**
- **Hierarchical**
- **Extensive**

UNSKILLED LEARNING

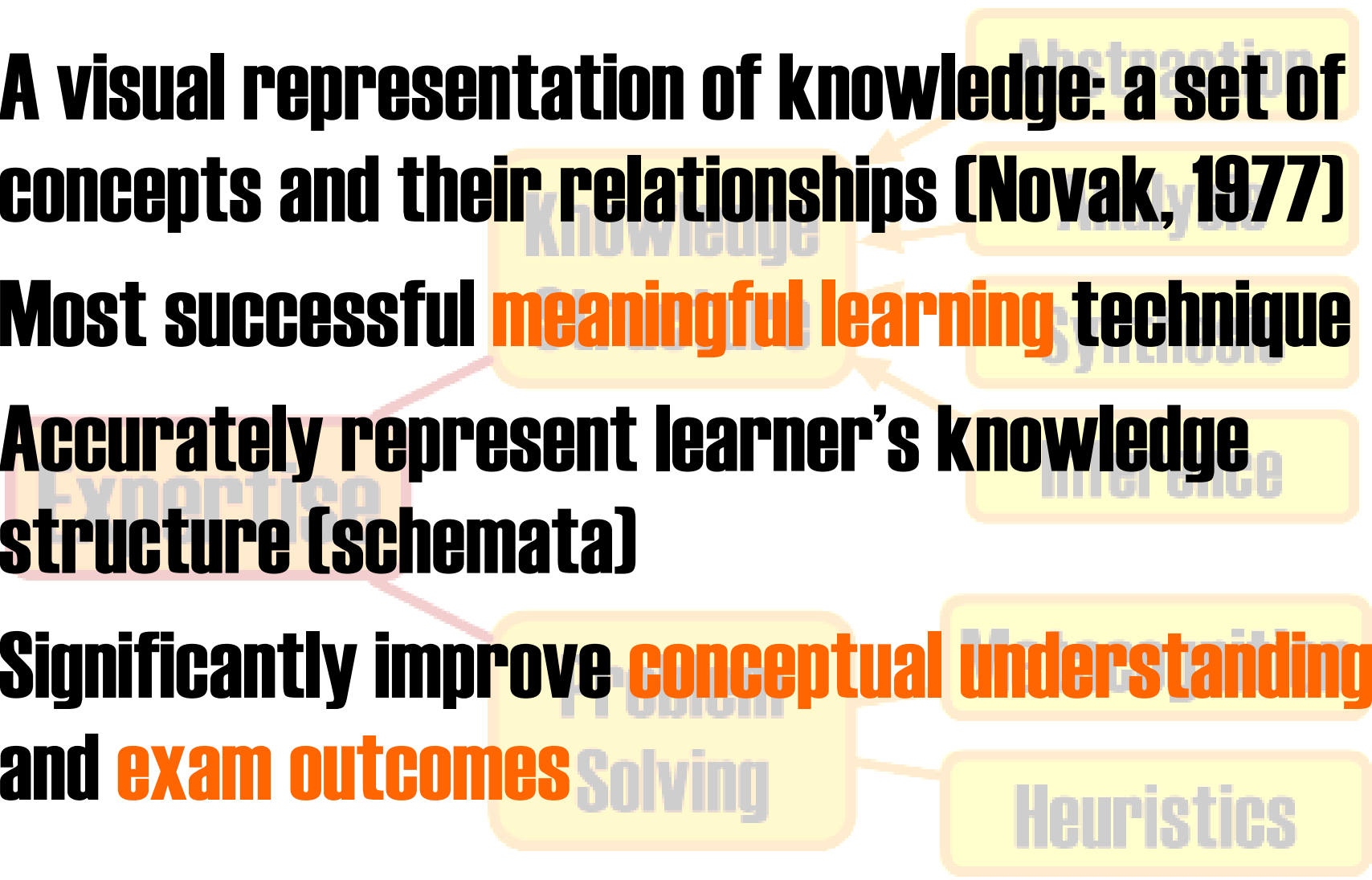


SKILLED LEARNING: KNOWLEDGE ENGINEERING

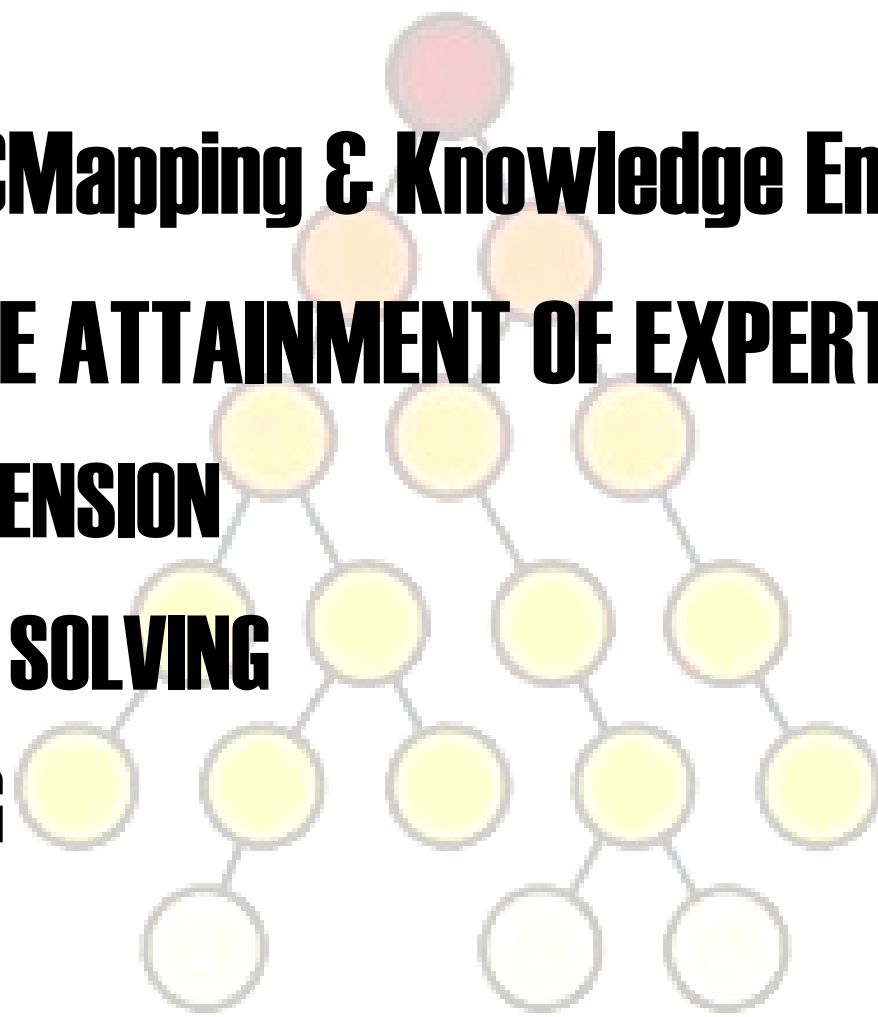


MEANINGFUL LEARNING TOOL: CONCEPT MAPS

- **A visual representation of knowledge: a set of concepts and their relationships (Novak, 1977)**
- **Most successful meaningful learning technique**
- **Accurately represent learner's knowledge structure (schemata)**
- **Significantly improve conceptual understanding and exam outcomes**

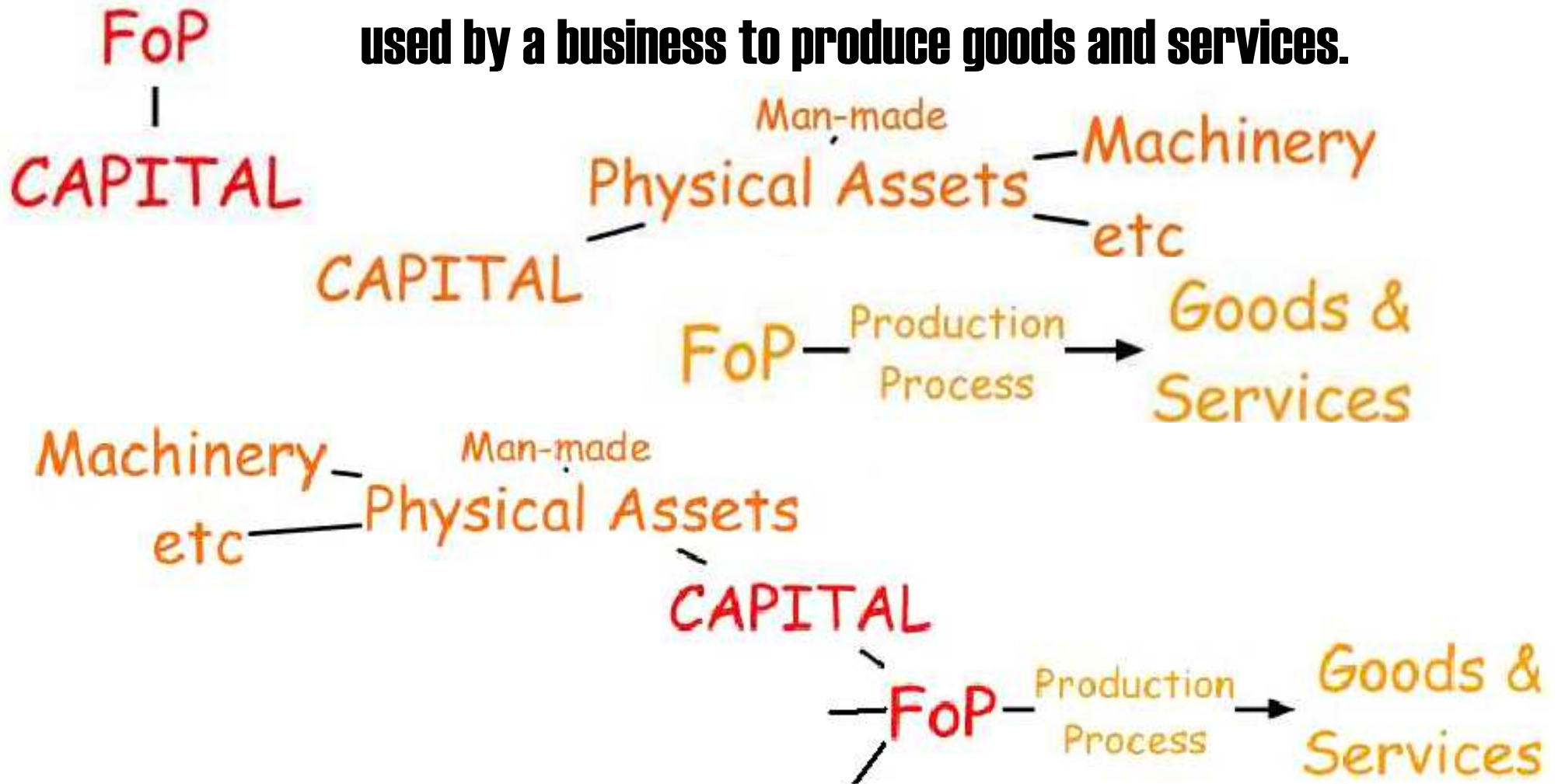


ADVANCED CONCEPT MAPPING

- **Combines CMapping & Knowledge Engineering**
 - **ACCELERATE ATTAINMENT OF EXPERT**
 - **COMPREHENSION**
 - **PROBLEM SOLVING**
 - **LEARNING**
 - **MEMORY**
- 

MAPPING 'CAPITAL'

CAPITAL: The man-made FACTOR OF PRODUCTION encompassing all the physical assets, such as machinery, used by a business to produce goods and services.



CORE LOGICAL THINKING SKILLS

- **ABSTRACTION**



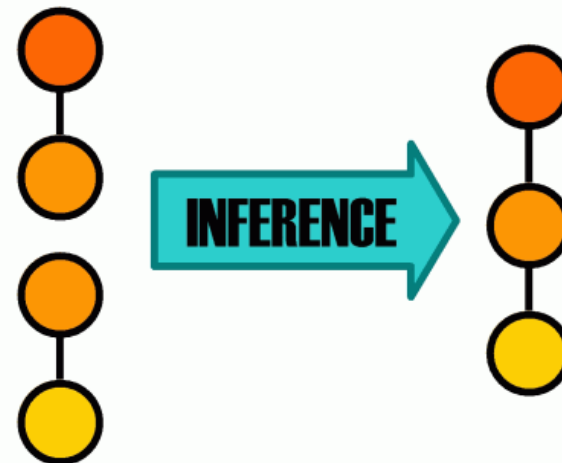
- **ANALYSIS**



- **SYNTHESIS**



- **INFERENCE**



ABSTRACTION

Evidence that abstraction enhances learning transfer

- **ALGEBRA** (Singley and Anderson, 1989)
- **COMPUTER LANGUAGES** (Klahr and Carver, 1988)
- **MOTOR SKILLS** (e.g., dart throwing, Judd, 1908)
- **ANALOGICAL REASONING** (Gick and Holyoak, 1983)
- **VISUAL LEARNING** (e.g., sexing chicks, Biederman and Shiffrar, 1987)

THEMATIC ABSTRACTION

ANALOGICAL PROBLEM SOLVING

da Vinci: Sound of a bell + stone hitting water =
sound travels in waves

LOGICAL PROBLEM SOLVING

Wiles: T-S CONJECTURE [Fermat's last theorem]

REVERSE ENGINEERING OF EXPERTISE

LEARNING FROM GENIUSES

ADVANCED KNOWLEDGE ENGINEERING

EXPERT [Superior Knowledge, Superior Problem Solving Abilities]

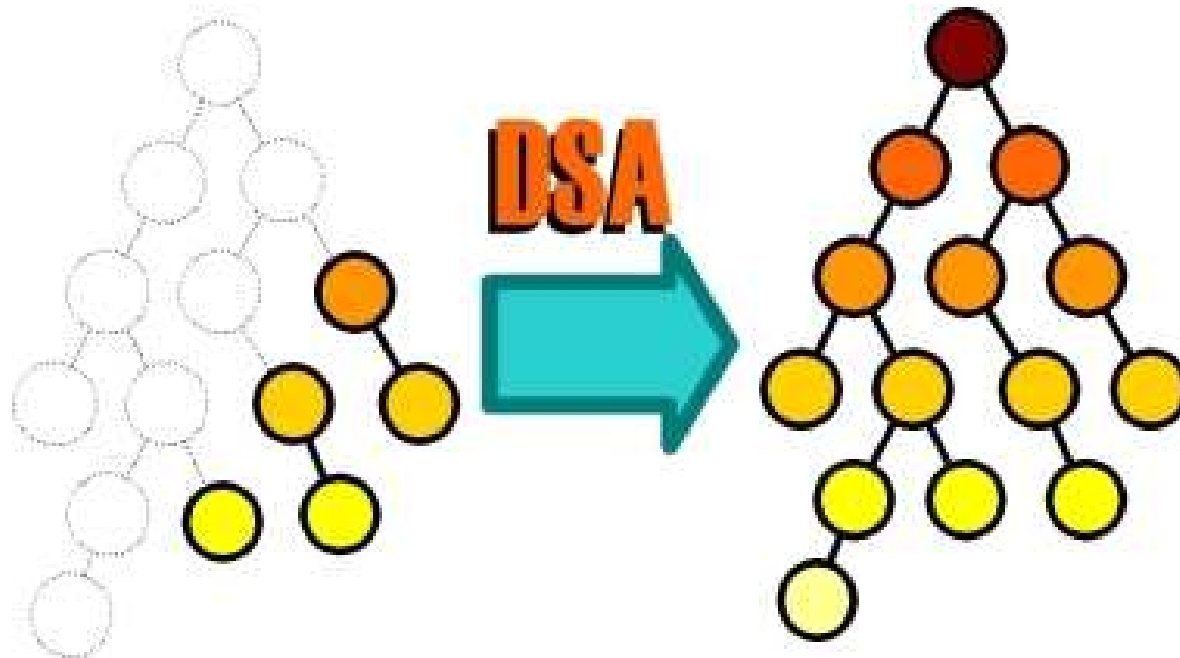
REVERSE ENGINEERING OF EXPERTISE exposes expert knowledge structures & problem solving strategies

KNOWLEDGE: DEEP STRUCTURE ANALYSIS

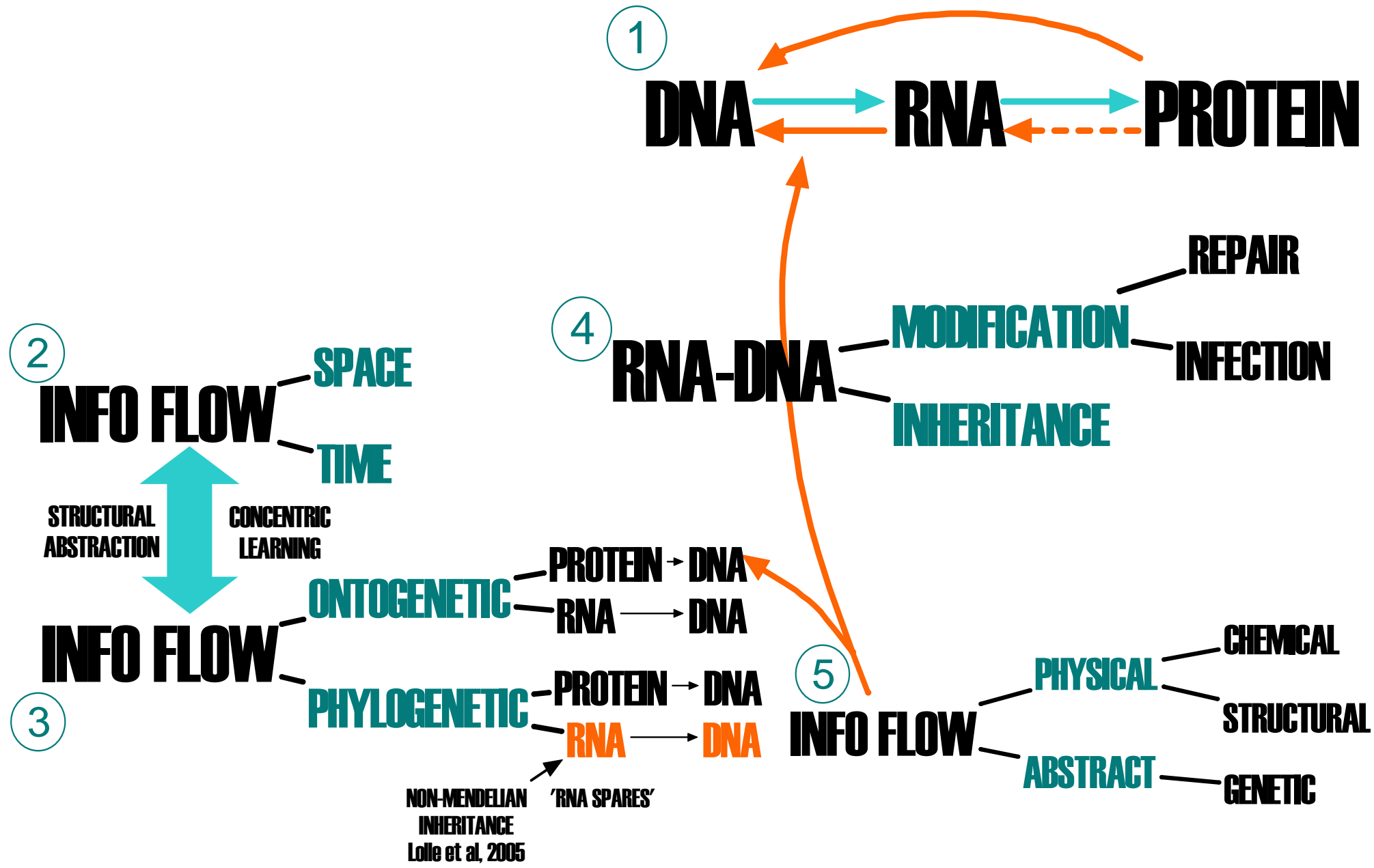
PROBLEM SOLVING: HEURISTICS ANALYSIS

DEEP STRUCTURE ANALYSIS

- **A Knowledge Engineering technique for exposing hidden connections in knowledge**
- **An Insight building Thinking Tool**



DSA CASE STUDY: GENETIC INFORMATION FLOW



DSA CASE STUDY: ELECTROPHYSIOLOGICAL FEATURE (EPF) ANALYSIS

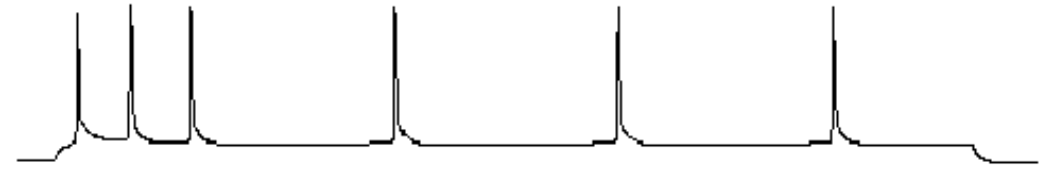
COMMON CELL TYPES

REGULAR FIRER (NON-ADAPTING)



(B) IAHP 2.3 nS, ID 40 nS

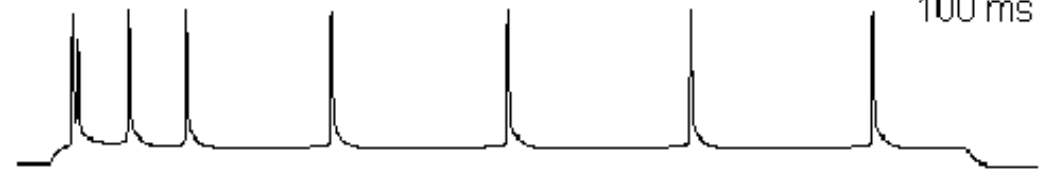
REGULAR FIRER (ADAPTING)



(C) IAHP 2.3 nS, ID 0 nS

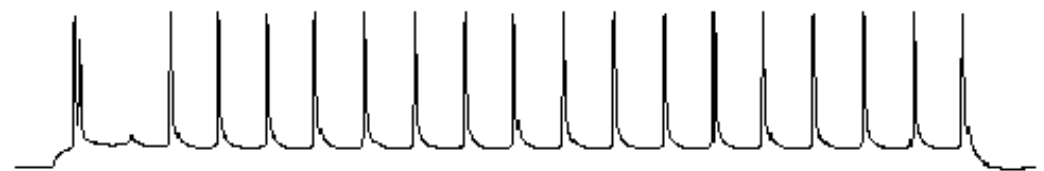
40 mV
100 ms

BURSTER (ADAPTING)



(D) IAHP 0 nS, ID 0 nS

BURSTER (NON-ADAPTING)



0.55 nA

DSA CASE STUDY: EPF ANALYSIS

- CONVENTIONAL ELECTROPHYSIOLOGY: CELL TYPES
- EPFs = CATEGORY (DISCRETE, STATIC)
 - CELL TYPE = CLUSTER OF RELATED EPFs
 - E.G. BURSTER = BURST + ABP – sAHP – SFA
 - LOW INFORMATION CONTENT
 - FUNDAMENTALLY FLAWED APPROACH!
- EPFs = DIMENSION (CONTINUOUS, DYNAMIC)
 - CELL TYPES DISAPPEAR!
 - SET OF EPFs = **HYPERDIMENSIONAL EPF STATE SPACE**
 - NEURON = POINT IN EPF SPACE
 - HIGH INFORMATION CONTENT

SUMMARY

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- **Expertise/Intelligence ~ Training**
 - **Difficulty of Subject ~ Connected Understanding**
 - **Modern education is inefficient**
 - **ACT: Effectively develop adaptive expertise**
 - **Core ACT Skills:**

Knowledge Engineering & Adaptive Problem Solving

The End