Why don’ t we teach what we want students to learn?

Or

What is the secret of disciplinary and interdisciplinary expertise?

Fred Janssen

Universiteit Leiden
ICLON

Teaching and learning after Covid-19

Teachers have to make two kinds of choices

What to teach?

- Content selection an organisation
- Content sequencing

How to teach?

- Method (*didactiek*)
- Media (*techniek*)

Focus during Covid-19

Reigeluth, 2007

What is our most important choice?

Although most of the action rotates around methods and media

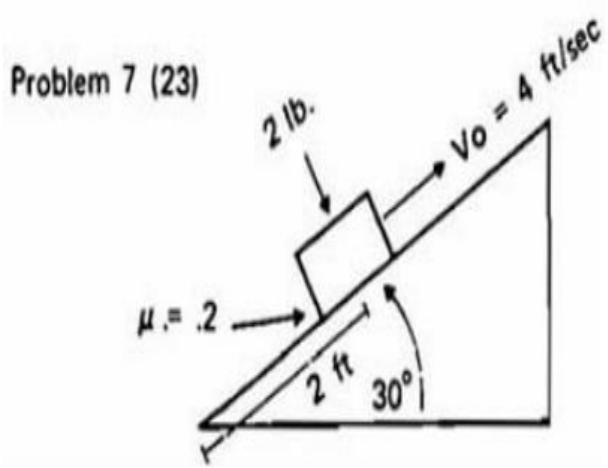
Our most important
choice is what we try to teach

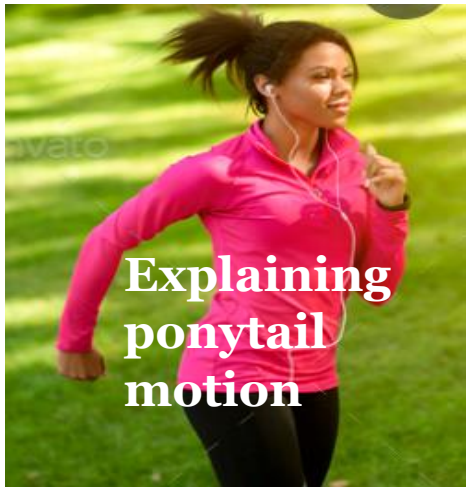
Because many shortfalls we want to address
by newer media en methods
are often more a matter of what we try to teach

Schwab, 1969; Perkins, 1992; Shulman & Quinlan, 1996; Pellegrino, 2012; Janssen et al, 2019

What do we want students to learn?

Beyond remembering





Continuum

Well-structured ⟷ **Ill-structured**

Problem Solving

Simon, 1973; Jonassen, 2000; Ohlsson, 2012; Merrienboer, 2013; Reed, 2016; Law et al, 2020

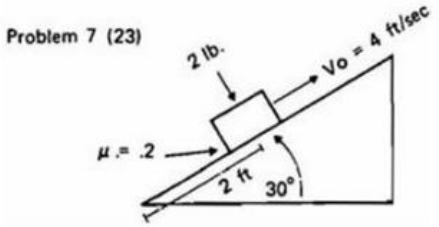
What do we want students to learn?

Beyond remembering:

- ❑ **Well-structured problem solving**
- ❑ **Ill-structured problem solving**

- ✓ Asking important questions
- ✓ Developing (multiple) answers
- ✓ Testing answers in a critical way
- ✓ Making connections (within and between domains)
- ✓ Making responsible choices
- ✓ Learning how to learn

Well-structured



Continuum

Ill-structured

What is critical for problem solving?

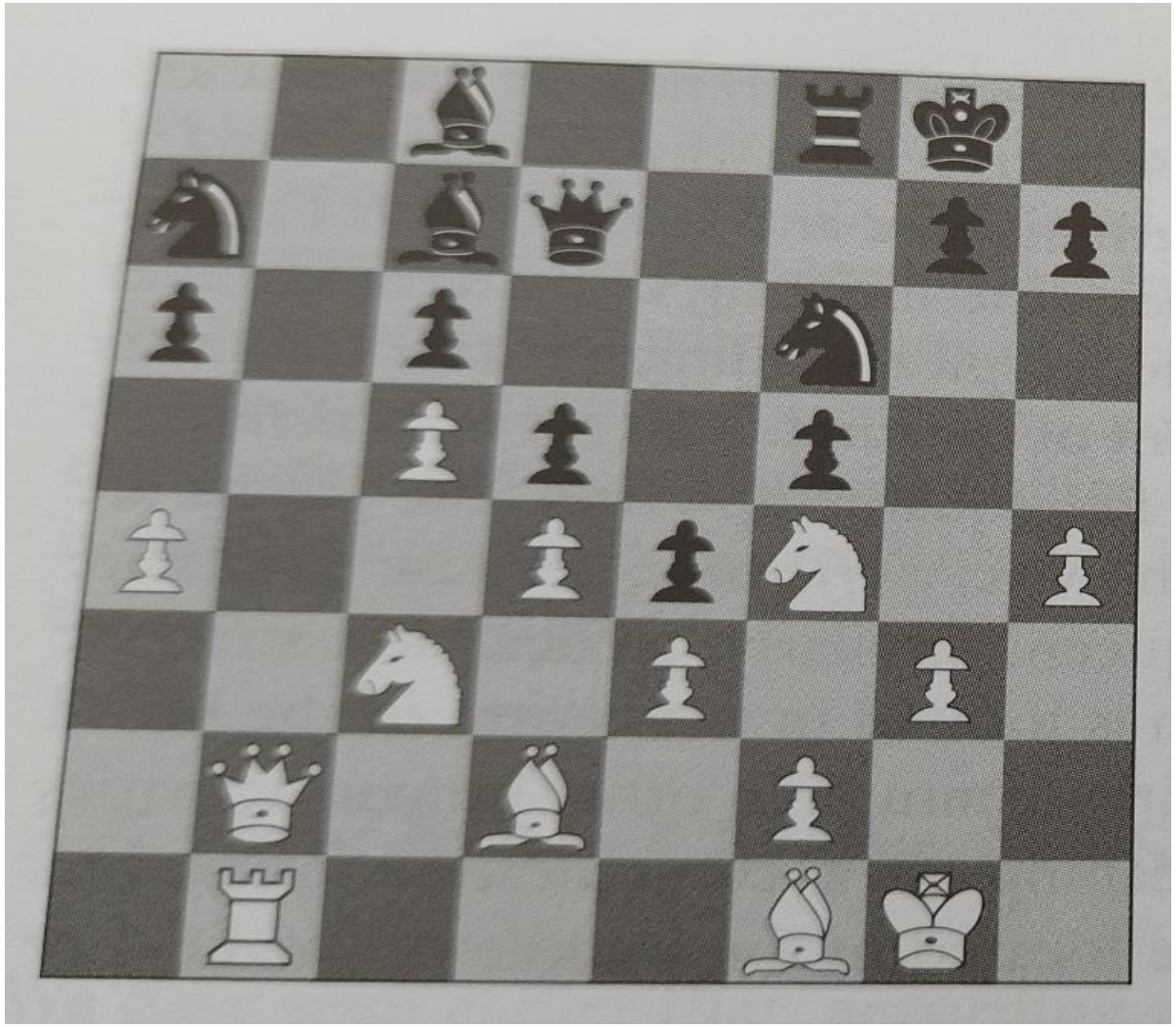
Research on expertise shows:

Not critical
General Skills

Most critical
Knowledge Organisation

De Groot, 1946; Chi et al, 1981; Nokes et al, 2010; Tricot & Sweller, 2014; Gobet, 2016; Chi, 2016; Ericsson et al, 2018

Try to recall this position (5 sec)



De Groot's seminal research on expertise (1946)

Illustrates the power of organising knowledge in meaningful patterns

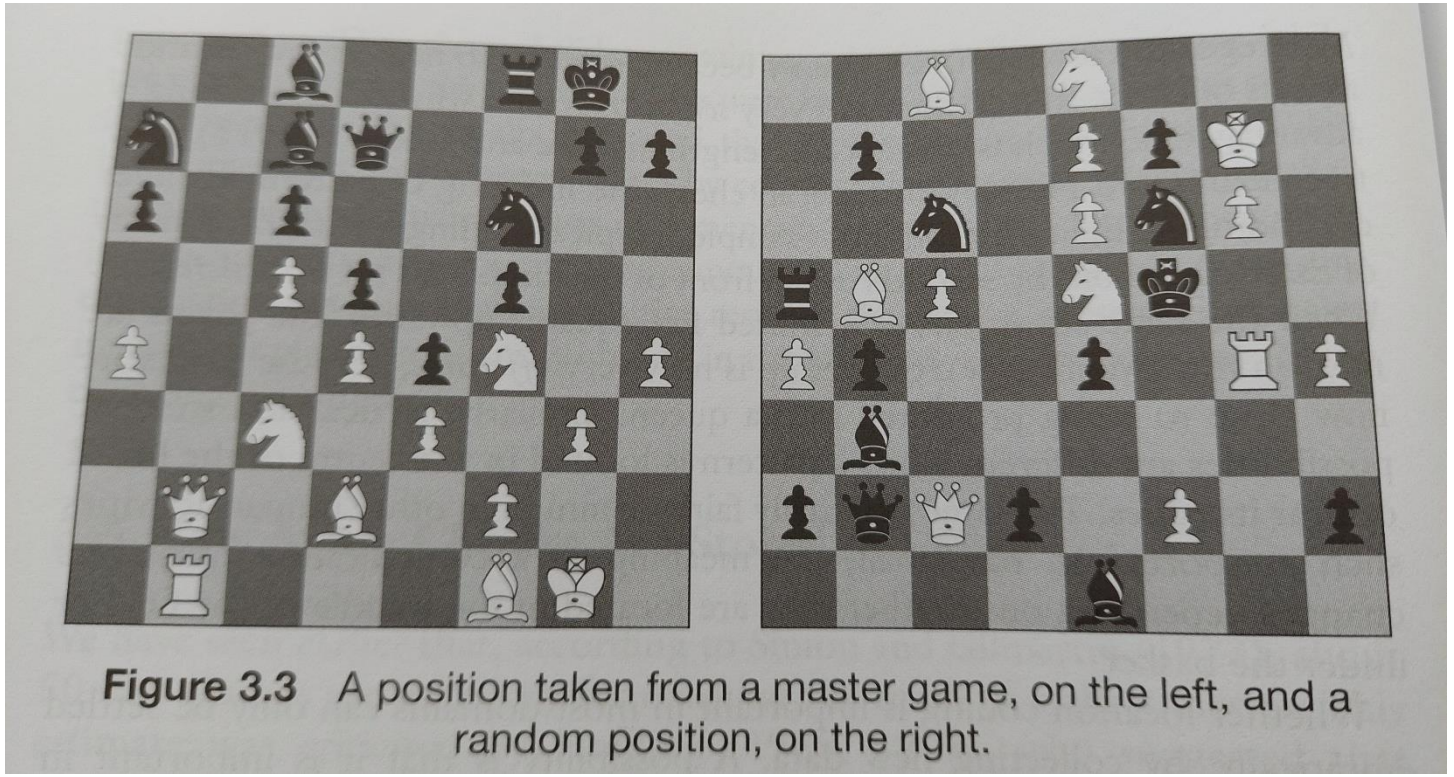
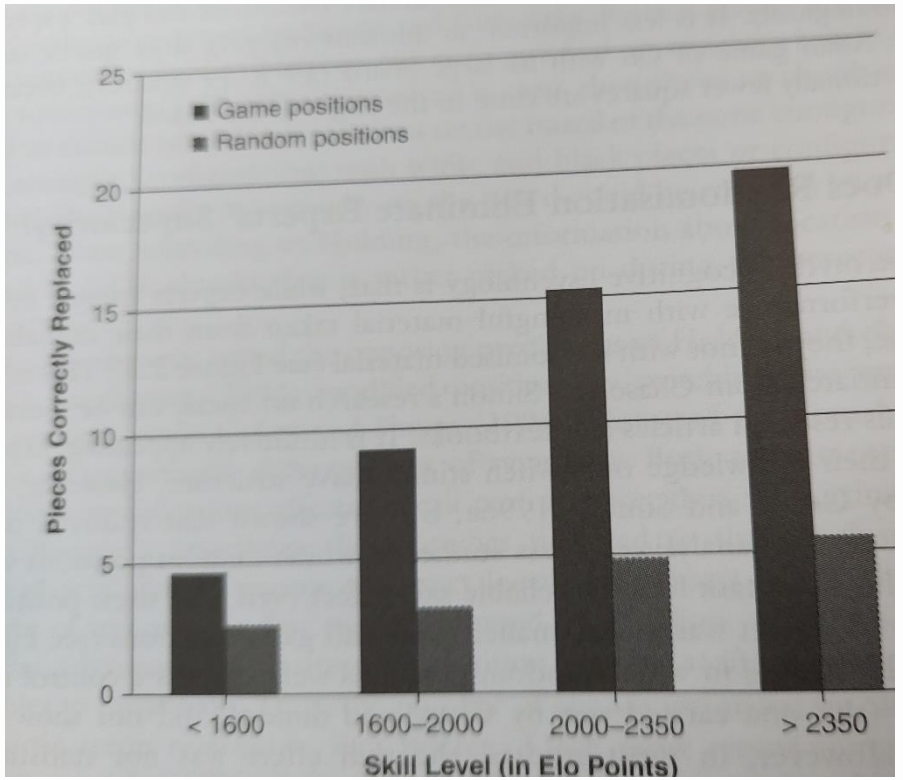
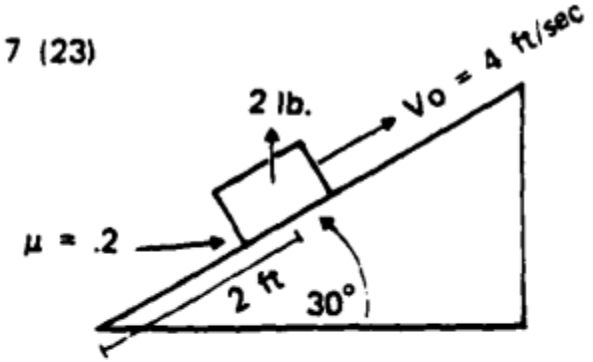


Figure 3.3 A position taken from a master game, on the left, and a random position, on the right.

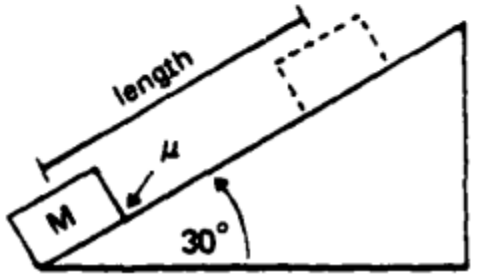


De Groot, 1946; Gobet & Simon, 1996

Problem 7 (23)



Problem 7 (35)



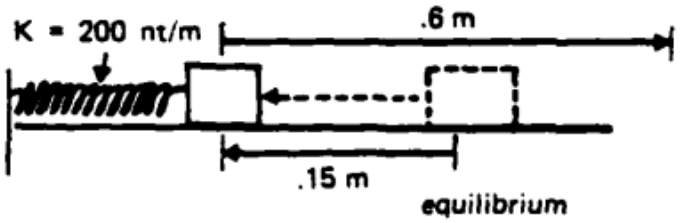
Novice 1: "These deal with blocks on an *incline plane*"

Novice 5: "*Inclined plane* problems, coefficient of *friction*"

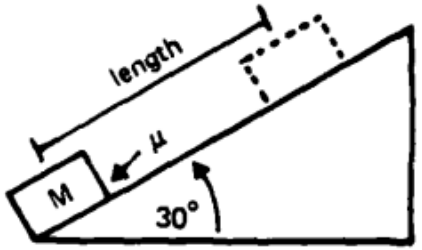
Novice 6: "Blocks on *inclined planes* with angles"

Diagrams Depicted from Problems Catergorized by Experts within the Same Groups

Problem 6 (21)



Problem 7 (35)



Experts' Explanations for Their Similarity Groupings

Expert 2: "*Conservation of Energy*"

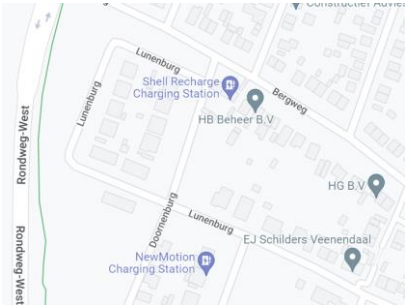
Expert 3: "*Work-Energy Theorem*. They are all straight-forward problems."

Expert 4: "These can be done from energy considerations. Either you should know the *Principle of Conservation of Energy*, or work is lost somewhere."

Chi et al (1981)

How to organise knowledge for problem solving (1)?

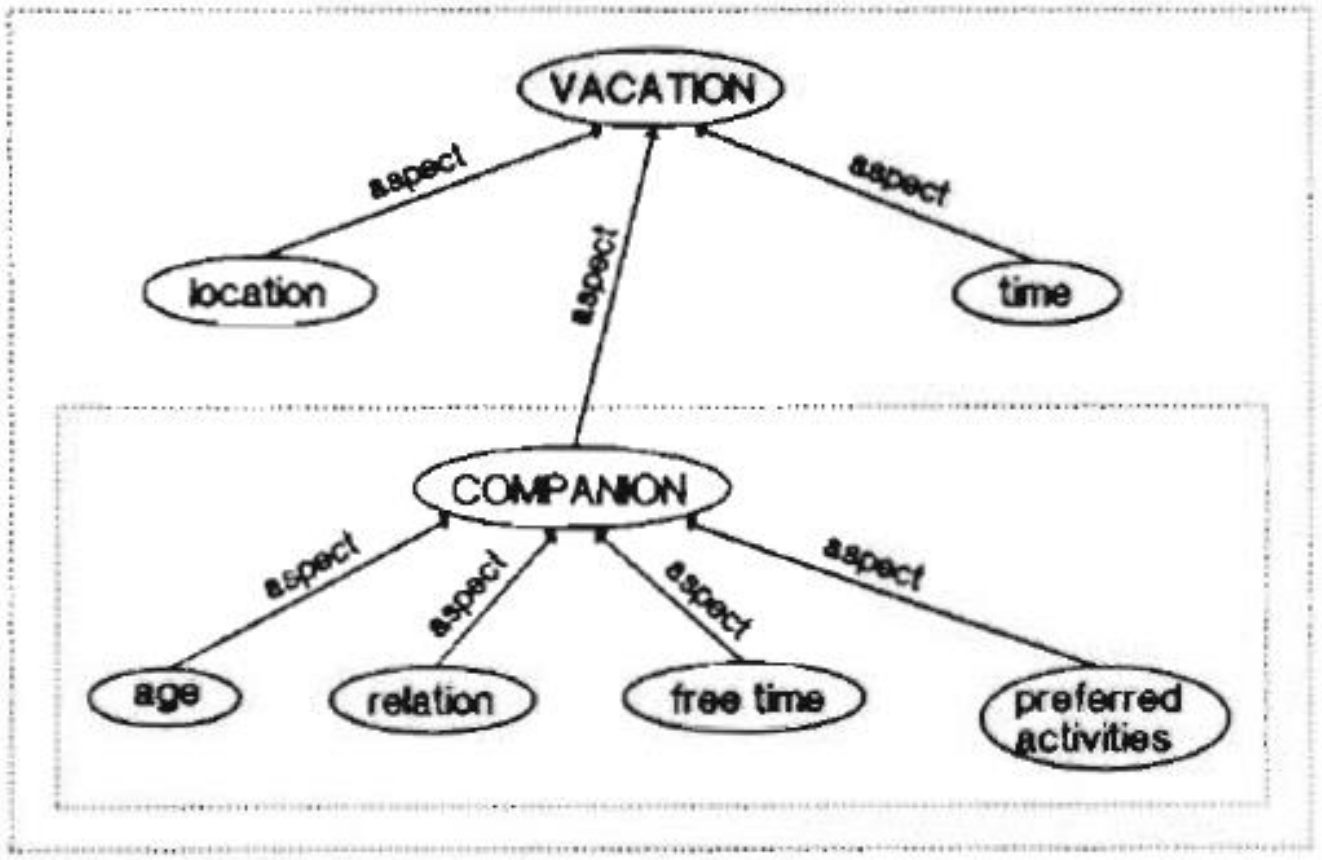
Hierarchical organisation facilitates remembering and problem-solving



Ausubel, 1968; Reif & Heller. 1982; De Jong & Ferguson, 1992; Reif, 2008; Giere, 2010

How to organise knowledge for problem solving (2)?

Schematic organisation facilitates problem-solving (schema = variable-value structure)



Minsky, 1974; Barselou, 1992; Nokes et al, 2010; Wimsatt, 2007; Ohlsson, 2011; Thagard, 2012

How to organise knowledge for problem solving (3)?

Question based organisation

Question agenda of developmental biology

The question of differentiation. A single cell, the fertilized egg, gives rise to hundreds of different cell types … Since every cell of the body (with very few exceptions) contains the same set of genes, how can this identical set of genetic instructions produce different types of cells? How can a single cell … generate so many different cell types?

The question of morphogenesis. How can the cells in our body organize themselves into functional structures? …

The question of growth. … How do our cells know when to stop dividing? How is cell division so tightly regulated?

The question of reproduction. … How are germ cells set apart from the cells that are constructing the physical structures of the embryo, and what are the instructions in the nucleus and cytoplasm that allow them to form the next generation?

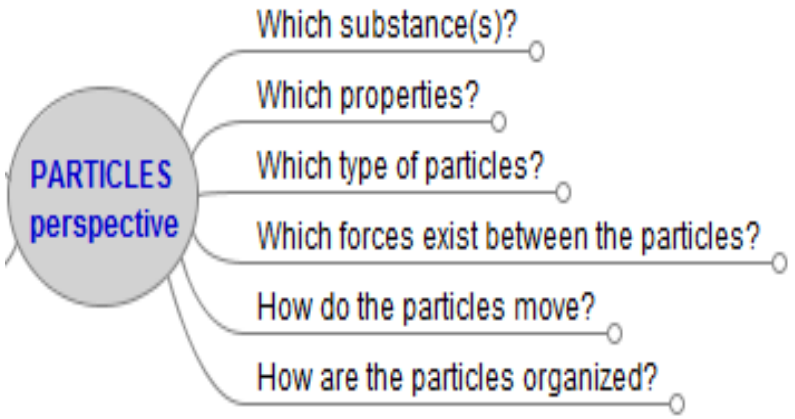
The question of regeneration. Some organisms can regenerate their entire body. … there are some cells in our bodies—*stem cells*—that are able to form new structures even in adults. How do the stem cells retain this capacity and can we harness it to cure debilitating diseases?

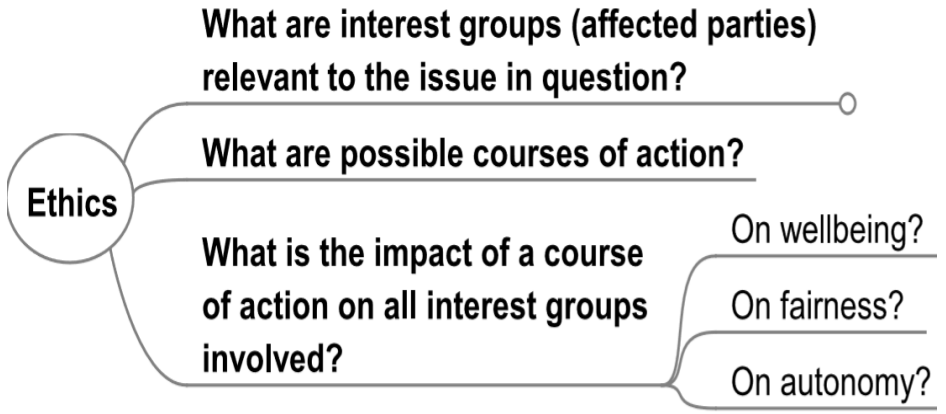
The question of evolution. … How do changes in development create new body forms? Which heritable changes are possible, given the constraints imposed by the necessity that the organism survive as it develops?

The question of environmental regulation. The development of many (perhaps all) organisms is influenced by cues from the environment that surrounds the embryo or larvae. … How is the development of an organism integrated into the larger context of its habitat? (Gilbert, 2010: 2–3)

Chi et al, 1981; Rescher, 2001; Kuipers, 2007; Hintikka, 2007; Love, 2013; Brigandt, 2015

Perspectives are a way to organise knowledge

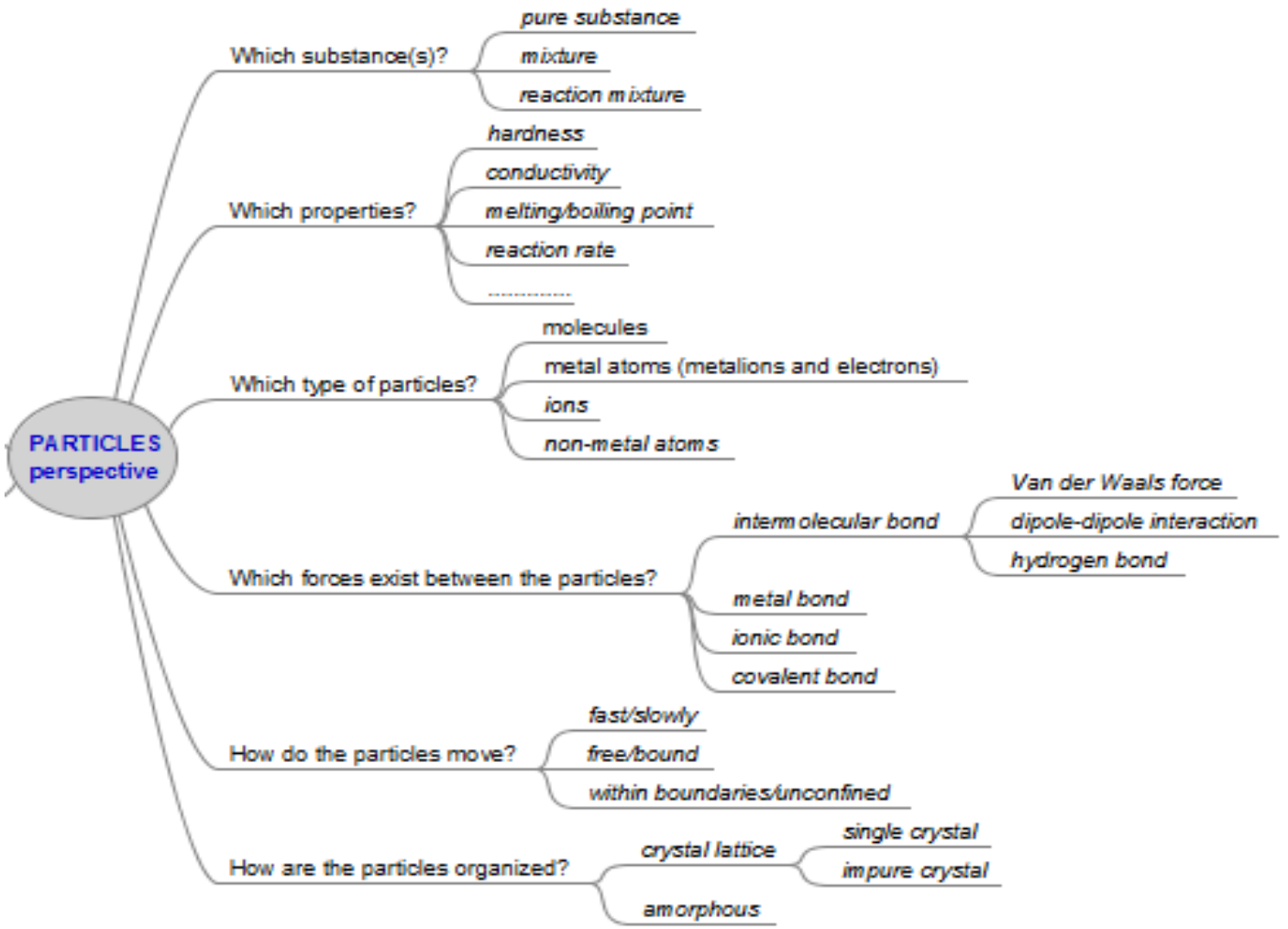




Perspectives as branching trees

Abstract schema underlying the particle perspective

The **properties** of **substances** can be explained by the nature of the **particles** of which it consists, the **forces** between them, and the **movement** and **organization** of those particles



Perspectives for organising knowledge

Structure

Perspectives integrate

✓Hierarchical organisation

✓Schematic organisation

✓Question based organisation

Function

❑**Remembering**

❑**Well-structured problem solving**

❑**Ill-structured problem solving**

✓ Asking questions

✓ Developing answers

✓ Testing answers

✓ Making connections (within and between domains)

✓ Making responsible choices

✓ Learning how to learn

Janssen & Verloop, 2003; Janssen & Van Berkel, 2015; Janssen, 2017; Janssen et al, 2019; Janssen et al, 2020; Landa et al, 2021; Otter, van den, et al, 2021; Boer, et al, 2021

Some examples of perspectives from Leiden University

Biomedical perspective

How does a disease originate and how can it be treated?

- What are the complaints/ symptoms?
- How often, where and with whom does it occur?
- How does it normally function?
- What is going wrong?
  - Psychosocially
  - Physical damage
  - Pathogens
  - Auto-immune responses
  - Genetics
  - Nutrient deficiency
- How can it be treated?
- How can it be prevented?

Nelleke Gruis

LUMC

Some examples of perspectives from Leiden University

Perspective for European Law

How to arrange free selling and buying for businesses and comsumers in the EU?

- How to prevent that EU member states obstruct free movement of production factors?
  - Goods?
  - Services?
  - People (citizens and labor)?
  - Capital?
- How to prevent that businesses complicate buying and selling?

Armin Cuyvers

FdR

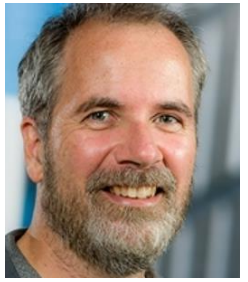
Perspective for European Law

Sjef Barbiers

FGW

Linquistic perspective

Harald van Mill & Frans Rodenburg **FWN**



Markus Davidsen

FGW

Perspectives for building portfolios

- Mathematical (basic) perspective
- Statistical perspective
- Ethical perspective

Religious perspective

LERVO-update

Een perspectiefgerichte benadering van het vakgebied Levensbeschouwing en Religie

JAN BOLLEMAAT, MARKUS DAVIDSEN, JAN VAN DIJK, MICHAËL VAN DER MEER

Four bachelor courses of molecular genetics

FWN

Jaar	BSc1
Vak	Moleculaire Genetica 5 EC
Periode	Blok 1 – September-Oktober
Coordinat	Remko Offringa

Historisch overzicht
celcylcus en stadia van mitose
term: chromosoom, centromeer, telomeer, chromatide
asexuele voorplanting
sexuele voorplanting, levenscycli (kort)
meiose, stadia, cross over, genetische variatie
Mendel versus Darwin
Monohybride kruising: Wetten van Mendel
Termen: gen, locus, allel, homo-/heterozygoot
Testkruising, dominant, recessief
Di-, polyhybride kruising: Mendel wetten
onvolledige dominantie/haplo-insufficiency
Co-dominantie, conditionele allelen, pleiotropie
Epistasie, kwantitatieve genen
Stamboomanalyse bij de mens
Historie: chromosoom theorie van overerving
Genetische notatie
Morgan: geslachtsgekoppelde eigenschappen fruitvlieg
geslachtbepaling: verschillende systemen
Overerving geslachtsgekoppelde genen
X-chromosoom inactivatie: lapjeskat
Koppeling: testkruising, recombinatie, genetische kaart
X2- toets uitleg
aneu-/polyploidie: oorzaak en gevolg
imprinting (kort), cytoplasmatische genen (kort)

Modelorganismen voor ontdekkingen
Historie: Griffith, Avery, Hershey-Chase,
Structuur DNA: regels Chargaff, Franklin/Watson & Crick
fosfodiester binding, waterstofbrug
Dubbele helix --> chromatine: metafase chromosoom
DNA replicatie: semiconservatief, mechanisme;
leading/lagging, okazaki, DNA polymerases, vork,
topoisomerases, snelheid: prok vs euk.,
betrouwbaarheid, fouten & repair
telomeren bij eukaryoten
historie: Beadle & Tatum: 1 gen – 1 eiwit, Dogma Crick
RNA vs DNA opbouw, eiwit vs RNA genen
transcriptie vs translatie, transcriptie mechanisme
transcriptie initiatie prok.: -10 -35, sigma factor
transcriptie terminatie prok.
RNA polymerase I, II en III
transcriptie initiatie euk: -25 TATA en -70
algemene en specifieke transcriptiefactoren
RNA processing: 5'CAP, poly A, splicing: exon en intron

alfa-aminozuren: structuur kort uitgelegd, maar geen detail
peptide binding: condenstatie/hydrolyse
historie: Sanger, Nirenberg: generieke genetische code
translatie: tRNA, aa-tRNA-synthetases
ribosomen: prok vs euk, werking A,P,E site, GTP
translatie start: SD seq prok. , CAP bij Euk
translatie stop
prok. vs euk.: polysomen, polycitronisch RNA (operon)
Prok.: Tryp en Lac operon: repressor, operator, CAP
LacZ: alfa-complementatie,
Euk.: enhancer, transcriptiefactoren, mediatorcomplex
Weefselspecifieke expressie door TFs
Transcriptiefactoren: GR als voorbeeld kern import belangrijk
Chromatine structuur: histon modificatie (kort)
Epigenetica/imprinting (kort met als voorbeeld histon acetylering en DNA methy
Splicing/alternatieve splicing,
eiwitvouwing, eiwitafbraak: proteasoom
eiwitaktiviteit: modificatie/localisatie
wildtype/mutant, reversie/revertant
verlies-/winst-van-functie
puntmutaties: transitie/transversie, missense, stil, nonsense
insertie, deletie,
Oorzaak mutaties: replicatie: slippen--> eerder tautomerie
deaminatie (gemethyleerde C hotspot), transpositie: retro en DNA transposons
Chromosoommutaties
Mutagens: baseanalogen, EMS, ethidiumbromide
Straling
DNA schadeherstel: BER, NER, mismatch repair, recombinatie
Gevolg DNA schade --> kanker: (proto)oncogenen.
(Ontdekking van) restrictie enzymen/modificatie: methylering
Gelelektorforese: ethidiumbromide, restrictiekaart plasmide
knippen/plakken
cloneren: vector: plasmide, lacZ, cloonbank: BAC/YAC
genomisch DNA bank, cDNA, reverse transcriptase, cDNA bank
identificatie clone: hybridisatie/PCR (uitleg techniek)
Termen: Southern/Northern/Western
Detectie van een SNP (voorheen RFLP/Southern), nu met PCR
DNA fingerprinting met PCR: microsatelieten.
RNA expressie: RNA gel --> RT-PCR, in situ hybridisatie.
Eiwitexpressie/-detectie: Western blot
DNA sequencing: Sanger: didexoy, radioactief/fluorescent
Next generation: PAC-BIO & Nanopore (kort genoemd, in het kader van genon
Genoomsequenties: map-based vs shotgun
Verschillen in genoomgrootte en aantal genen.
Voorbeelden van genoomonderzoek:
Fylogenomica, genetische variatie in gewassen, ancient DNA,
personalized medicine
Retrotransposons en genoomgrootte
Genfamilies: eiwithomologie --> genduplicatie en subfunctionalisatie
exon shuffling
Genetische modificatie in planten en dieren: methoden
Klonen van organismen:
Planten: regeneratie/somatische embryogenese
Dieren: embryosplitsing, Gurdon: kerntransplantatie: Dolly, Copy Cat
Therapeutisch klonen: (pluripotente) stamcellen,

Jaar	BSc2
Vak	Moleculaire Biologie 4 EC
Periode	September
Coordinator	Paul van Heusden
Docenten	Paul van Heusden, Sylvia de Pater

College	Practicum
Gen/Open Reading Frame/structuur mRNA	LabBuddy
Restrictie enzymen	Restrictie afbraak
Recombinant DNA	Agarose gelelectroforese
terminal transferase	PCR
DNA bibliotheek	Zuiveren PCR fragment
cDNA synthese	ligeren
phage lambda	plasmide isolatie
cosmiden	E. coli transformatie
oppikken genen uit DNA bibliotheek	Yeast two-hybrid
PCR	Gisttransformatie (LiAc)
Southern blot	Southern blot
hybridisatie	Basic Bioinformatics (Blast, calculate MW/Iep)
labelen van probes	labjournaal
Random primed DNA synthesis	Verslag schrijven
Digoxigenin labeling	
Nick translation	
Polynucleotide kinase	
Northern blot	
Western blot	
RFLP	
Cloning vectors (pUC plasmiden)	
Single-stranded DNA synthesis	
Blue white screening	
DNA sequencing (dedeoxy)	
Transcription vectors	
Site-directed mutagenesis	
DNA ligation	
Ratio vector / insert	
supercoiled	
qPCR	
RT-PCR	
Yeast plasmids	
YAC	
Yeast Two-hybrid	
Yeast as a model organism	
Yeast structural genomics	
DNA array technology	

Jaar	BSc2
Vak	Systeembiologie 3 EC
Periode	December
Coordinator	Paul van Heusden
Docenten	Paul van Heusden, Arthur Ram, Vera van Noort, Young Choi

College	Werkcollege
Genomic architecture Yeast	Metabolic pathways in yeast
Genomics	Transcriptomics yeast
Transcriptomics	Cytoscape
Metabolic pathways	Mass spec data analysis
Proteomics/2D gel electrophoresis	Mathematical modeling
Mass Spectometry (classical, MALDI-TOF, ESI)	
Introduction of Metabolomics : what to expect from metabolomics (Choi)	
Principal component analysis	
Data analysis Mass Spectroscopy	

Jaar	Bsc2
Vak	Moleculaire Microbiologie 6 EC
Periode	Blok 1 September Oktober
Coordinator	Arthur Ram
Docenten	Arthur Ram, Joost van den Brink, Vera van Noort, Peter Punt, Mark Arentshorst

functionele analyse van genen
mutanten en complementatie groepen
knock outs maken
recombinatie en ku70
aspergillus mutanten
aspergillus transformatie
protoplateren en heterokaryons
reinstrijken
methodes voor mutagenese
mutant identificatie via genoom sequencen en complementeren

sec
tat
Type I-IV

ER=GOLGI-vesicles
microtubuli en kinesin
CopII en Rabs

regulatie mbv transcriptie factor
positieve regulatie (mal-regulon)
negatieve regulatie / repressie (arg-regulon)
negatieve regulatie / inductie (lac-regulon)
attenuatie

verschillen pro vs euk
RNA processing
gene expressie
chromatine structuur HAT/HDAC
transcriptie fatoren (gal4)
regulatie van enzyme productie in Aspergillus
enzyme network
transcriptie factor
transcriptie factor bindingsplaats
co-regulatie

pimaire en secondaire metaboliten
citroenzuur productie
penicilline productie
werkingsmechanism penicilline

Quorum sensing
two component systems
V. fisheri fisheri LuxR
Biofim formation
antimicrobial peptides

fungal biotech
enzymes for biomass degradation
protein production
multicopy strains
protease mutants screening
antibody production
itaconic production
metabolic engineering
deletion/overexpression

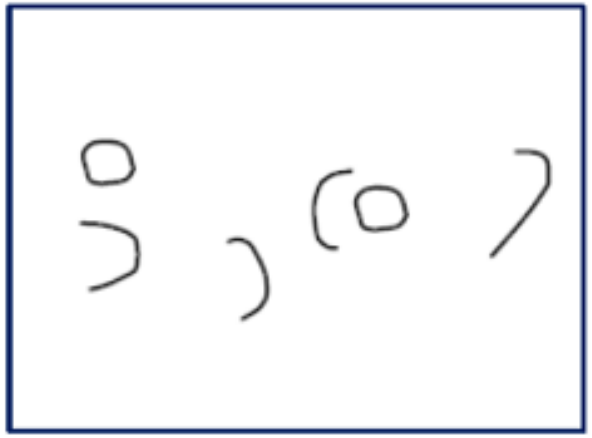
Molecular genetic perspective

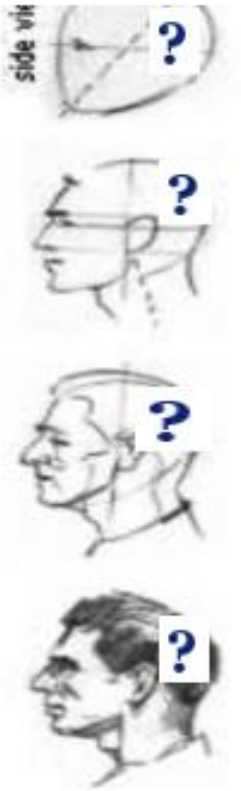
Transforming school subjects into perspectives

Deel 2

Schoolvakken in perspectief

What to teach (2)? Sequencing content





Atomistic sequencing

- Decompose a complex whole into pieces
- Teach it piece-by-piece
- Part-task practice

Hinders meaning making and problem solving

Holistic sequencing

- Progressive differentiation (expanding the perspective)
- Driven by interesting/relevant problems (whole tasks)

Facilitates meaning making and well- and ill-structured problem solving

Reigeluth, 2007;
Kirschner & Merrienboer, 2017
Janssen et al, 2019

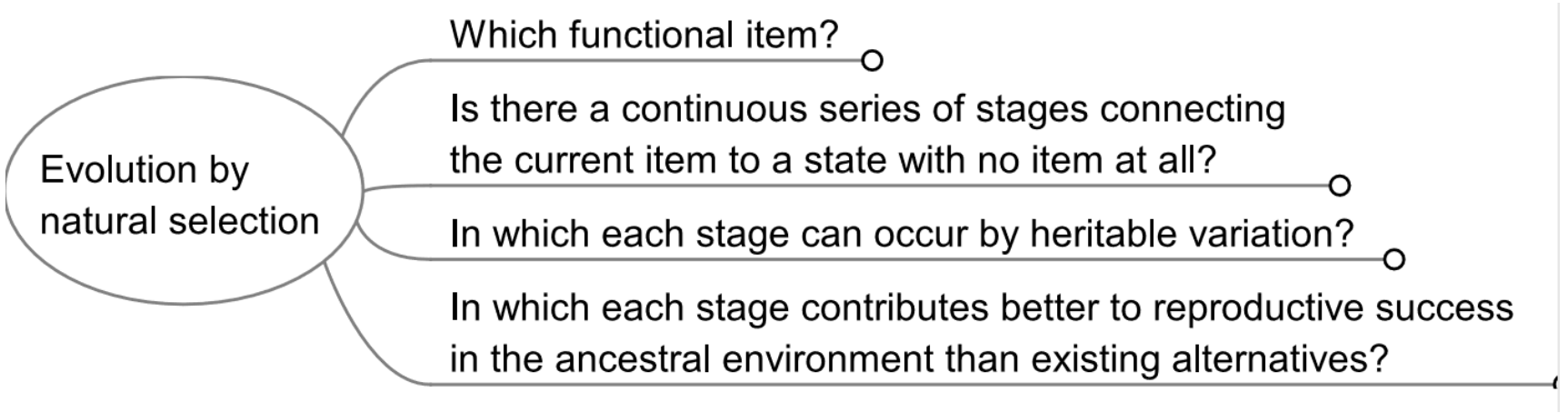
Complex question

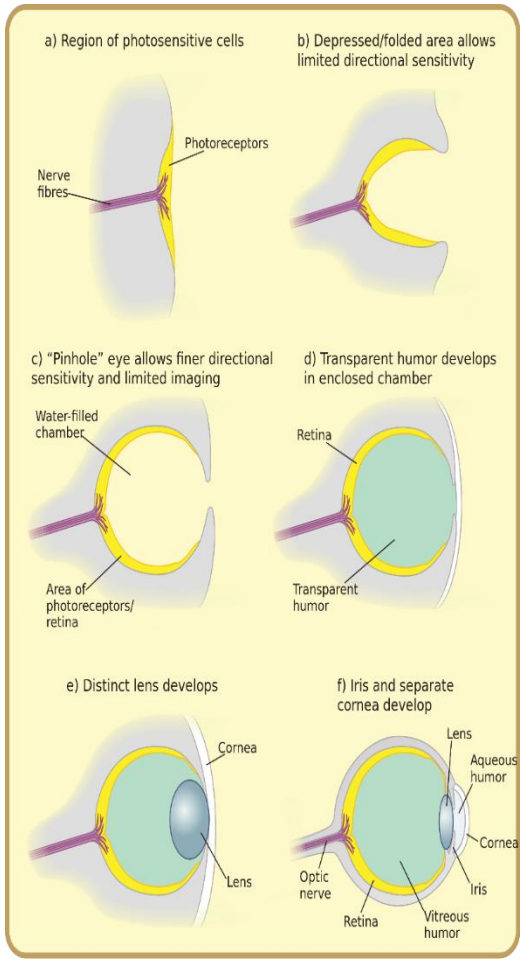
Why legs not wheels?

Evolutionary perspective
How to explain complex design in nature?

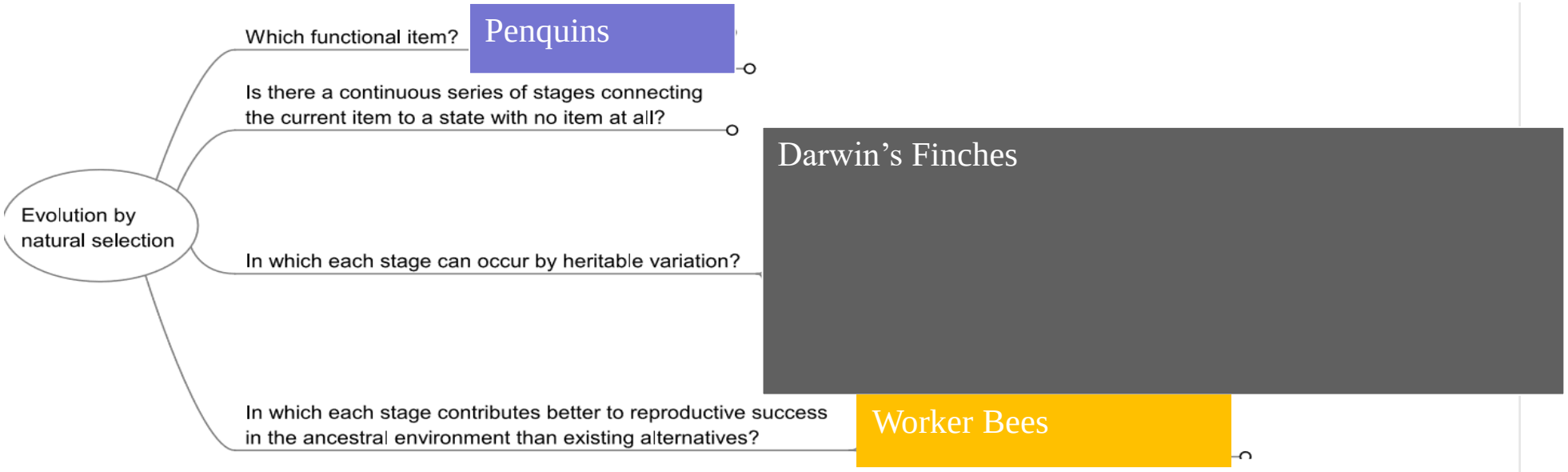
Darwin's answer → cumulative selection

By gradual step-by-step transformations from simple beginnings, sufficiently simple to have come into existence by chance. directed by nonrandom survival and reproduction

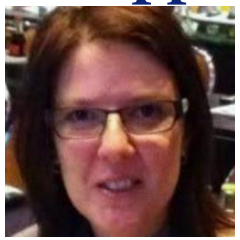




Stepwise expanding the perspective driven by complex questions providing the need or expansion



Mapping questions for teambased learning on a biomedical perspective



Huidkanker (epidemie)

- Wat zijn de klachten/symptomen?
  - Welke vormen zijn er?
    - Hoe verloopt het ziektebeeld?
- Hoe vaak komt het voor?
  - Is er verschil tussen man/ vrouw?
  - Is er verschil tussen leeftijdsgroep?
  - Is er verschil tussen mensens met bepaalde huidskleur?
- Hoe worden de normale functies van de huid vervuld?
  - Hoe beschermt de huid tegen de zon?
    - Hoe wordt pigment geproduceerd?
    - Waarom zijn er huidskleur verschillen?
  - Hoe wordt vitamin D aangemaakt?
- Wat gaat er mis?
- Hoe wordt huidkanker veroorzaakt?
  - Psychosociaal?
    - Wat is de rol van anti-zonnebrand?
    - Is een bruine tint gezond?
      - Wat is de rol van zonnebank gebruik?
  - Fysieke schade?
    - Wat gebeurt er in de cel?
      - Treden er genetische veranderingen op?
        - Hoe detecteer je dit?
      - Zijn er opruimmechanismes?
      - Zijn er herstelmechanismes?
  - Ziekte verwekkers?
  - Voedsel tekorten?
    - Wat is de rol van Vitamine D?
  - Autoimmuun?
  - Erfelijkheid?
    - Wat is onderliggend aan erfelijke huidkanker?
      - Hoe detecteer je dit?
      - Zijn er genetische testen?
- Hoe kan het worden behandeld?
- Hoe kan het worden voorkomen?
  - Zijn er voorlooper stadia?
  - Is er in te zetten op preventie?

Vraag 1

Vraag 2

Vraag 3

Vraag 4

Vraag 5

Vraag 6

Vraag 7

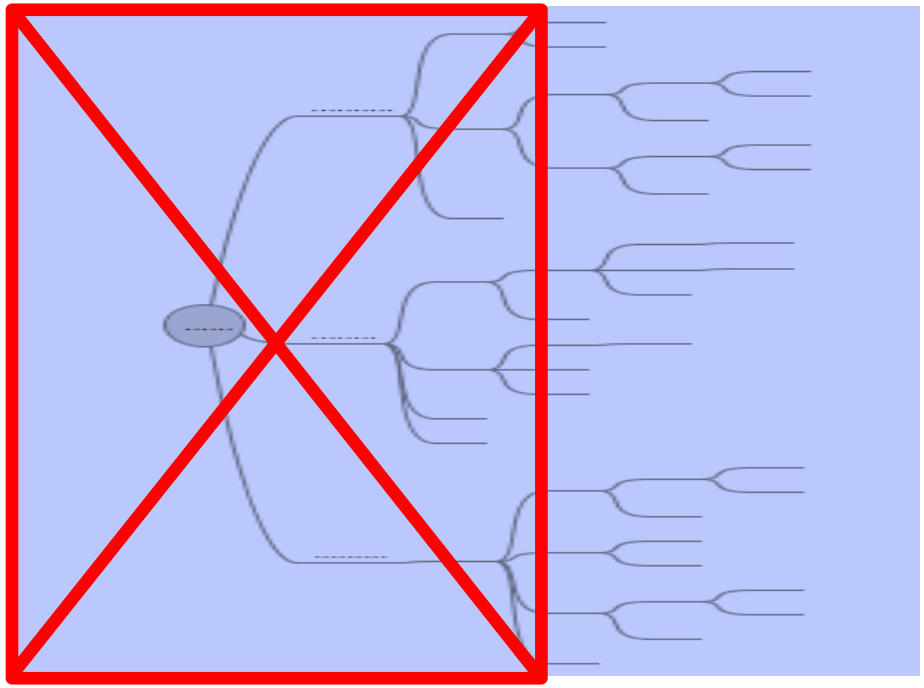
Team based learning 1
Huidkankerepidemie
het probleem

Team based learning 2
Hoe wordt huidkanker veroorzaakt

Team based learning 3
Hoe wordt huidkanker behandeld

Team based learning 4
Hoe kan huidkanker worden voorkomen

Perspectives are essential domain specific tools for developing and organising knowledge. What happens if they are skipped?



- Students lack an advance organiser for meaningful learning
- Students lack powerful thinking tools for well-structured and ill-structured problem solving (both disciplinary and interdisciplinary)
- Students do not learn how to think like .....

Teaching and learning after Covid-19

Take-home message

- Our most important choice is what we try to teach.
- Organise and sequence content as one or multiple expanding perspectives to facilitate well- and ill-structured problem solving.
- Based on this robust backbone additional decisions about methods and media can be made.

Fred Janssen

- Master's degree in Biology
- PhD 'Learning biology by designing'
- ICLON, Leiden Graduate School for Teaching (since 1999)
    - Biology teacher educator (until 2016)
    - Full professor of science education (since 2016)
    - Department head secondary education (since 2018)
    - Senior Comenius Fellow / Leiden Teachers' Academy fellow
    - Scientific director ICLON (since 2022)
    - Focus of my own research program (13 PhD's / 2 Post-docs)

An ecological approach to student and teacher learning

Interfacultair Centrum voor Lerarenopleiding, Onderwijsonderzoek en Nascholing (ICLON)

100+ onderwijsexperts

Opleiden van academische docenten	Professionaliseren en wetenschapsoriëntatie	Onderzoek naar onderwijs
• 1e graads & 2e graads (meerdere trajecten) • 330 studenten • Vakdidactici alfa, bèta, gamma & onderwijskundigen • 18 schoolvakken • Samen opleiden met 9 opleidingsscholen waarbij 90% van alle VO scholen in de regio Zuid Holland zijn aangesloten	• Wetenschapsoriëntatie PO • Wetenschapsoriëntatie VO • VO-HO aansluiting • ONZ netwerk > 60 scholen i.s.m. de faculteiten • Docentprofessionalisering (PO, VO, HO)	• 3 Hoogleraren • 2 UHD's / 5 UD's • 45 lopende PhD projecten / 55 gerealiseerde dissertaties • 240 wetenschappelijke publicaties / 102 professionele publicaties (in de laatste 5 jaar) • Structurele samenwerkingsverbanden en publiceren met met 7 universiteiten uit de top 50 • Nieuwe taak: coördinatie en versterking HO onderzoek

- Goede universitaire, regionale, nationale en internationale verankering
- Opleiden, professionaliseren en onderzoek m.b.t. de gehele keten (po,vo, ho)
- Uitstekende beoordelingen van visitatiecommissies
- Werken vanuit een gemeenschappelijke kennisbasis

ICLON Knowledge base

12 Teaching - Learning principles

For understanding and supporting student and teacher agency development