Is “primary - secondary knowledge” framework refutable?

Tanguy, F.\(^a\)\(^b\), Foulin, J-N.\(^a\), Sakdavong, J-C.\(^b\), & Tricot, A.\(^b\)

\(^a\)Laboratory of psychology «Health and Quality of life» EA 4139
Bordeaux Segalen University

\(^b\)Laboratory «Work and Cognition», CNRS UMR 5263, CLLE
Toulouse University
Principles of evolutionary educational psychology (Geary, 2005, 2007)

Cognitive Load Theory  
A learning situation objective
Principles of evolutionary educational psychology (Geary, 2005, 2007)

- For 200 000 years
  - Acquisition by adapting to the environment, in an implicit way.
  - Communicating, living in groups, giving meaning to one’s environment, etc.
  - Knowledge classified in different specific domains

- For 10 000 years
  - Recent appearance in our species
  - No brain evolution in view of acquiring secondary knowledge by an adaptation process
  - Teaching acquisition in an explicit way
  - Reading, counting, studying, learning the physical sciences, etc.

Institutional knowledge

A learning situation objective
Attention
Working memory
Effort and strategies
Long Term Memory
Primary knowledge
Secondary knowledge
Expertise
Lowest Expertise for a beginner
HYPOTHESIS

No attempt in validating Sweller’s global theory (2008)
Main contribution of this research

Lowest Expertise for a beginner
Learning to categorize living species

Classical categorization in biology

Vertebrates
- Mammalia
- Fish

No evolutionary history

Phylogenetic classification

Vertebrates
- Mammalia
- Fleshy member

Evolutionary history

Primary knowledge

Secondary Knowledge on phylogensis

Learning to categorize living species
Hypothesis from the first series of study  
based on the first section of the global teaching/learning theory  
*(Sweller, 2008)*

<table>
<thead>
<tr>
<th>Prior assessments</th>
<th>Manipulation of the Likert scale</th>
<th>Manipulation of the MERS scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation and self efficacy are assessed before the experiment, Initial knowledge pre-test</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge type</th>
<th>Primary Knowledge based</th>
</tr>
</thead>
</table>
| Experiment | Experiment I  
150 participants of 6th grade  
(11.6 years old)  
| Experiment II  
90 participants of 6th grade  
(11.7 years old)  
| Experiment III  
90 participants of 6th grade  
(11.4 years old)  |

<table>
<thead>
<tr>
<th>Categorization complexity material</th>
<th>Very simple</th>
<th>Simple</th>
<th>Complex categorization</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Learning phase</th>
<th>No Guidance</th>
<th>Adaptative guidance</th>
<th>Strong guidance</th>
</tr>
</thead>
</table>
| | 10 living-non living  
2 categories | 10 plants  
5 categories | 10 animals  
18 categories |

<table>
<thead>
<tr>
<th>Testing phase</th>
<th>Applying knowledge</th>
<th>Conceptualization about the categories</th>
<th>Knowledge transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 new living-non living</td>
<td>8 questions</td>
<td>5 living, non living, artificial non living</td>
</tr>
<tr>
<td></td>
<td>8 new plants</td>
<td>8 questions</td>
<td>5 animals</td>
</tr>
<tr>
<td></td>
<td>8 new animals</td>
<td>8 questions</td>
<td>5 plants</td>
</tr>
</tbody>
</table>
**Hypothesis from the first series of study**

based on the first section of the global teaching/learning theory

*(Sweller, 2008)*

**Prior assessments**
Motivation and self efficacy are assessed before the experiment, Initial knowledge pre-test

<table>
<thead>
<tr>
<th>Knowledge type</th>
<th>Primary Knowledge based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Experiment I</strong></td>
</tr>
<tr>
<td></td>
<td>150 participants of 6th</td>
</tr>
<tr>
<td></td>
<td>grade</td>
</tr>
<tr>
<td></td>
<td>(11.6 years old)</td>
</tr>
<tr>
<td></td>
<td>Very simple</td>
</tr>
<tr>
<td><strong>Strong guidance</strong></td>
<td><strong>total help</strong></td>
</tr>
<tr>
<td>From worked examples</td>
<td></td>
</tr>
<tr>
<td><strong>Adaptative guidance</strong></td>
<td><strong>With corrective feedback</strong></td>
</tr>
<tr>
<td><strong>No guidance</strong></td>
<td><strong>No help</strong></td>
</tr>
<tr>
<td>Simple final correction</td>
<td></td>
</tr>
</tbody>
</table>

**Measures in each phases**
Performance / Cognitive load

- **Performance / Cognitive load**
  - **Knowledge transfer**
    - 5 living, non living, artificial non living
    - 5 animals
    - 5 plants

- **Computer teaching device**
  - Initial learning / Post-test/ Transfer
Study I: Living-Non living categorization

These pebbles are Non living
Study II: plants categorization

Strong guidance

Possède des fleurs et des graines

Graines dans un fruit feuilles aplaties

Angiospermes

Graines dans un cône (pomme de pin) Feuilles généralement en aiguilles

Conifères

A une tige et des feuilles

Possède des racines

Fougères

Ne possède pas de racines

Mousses

N’a ni tige, ni feuille

Algues

Identifier un végétal

Possède des fleurs et des graines

Ne possède ni fleurs ni graines

Possède des racines

Fougères

Ne possède pas de racines

Mousses

N’a ni tige, ni feuille

Algues
Identifier un végétal

Possède des fleurs et des graines

Graines dans un fruit
feuilles aplaties

Angiospermes

Graines dans un cône (pomme de pin)
Feuilles généralement en aiguilles

Conifères

Ne possède ni fleurs
ni graines

Possède des racines

Fougères

N’a ni tige, ni feuille

Ne possède pas de racines

Mousses

A une tige et des feuilles

Algues

Recommencer
l’exercice

Passer à l’exercice suivant
Study III: animals categorization
Sweller’s hypothesis seems to be confirmed: explicit guidance is not an efficient way of acquiring primary knowledge.

These three studies proved to be relevant:
- Knowledge of categorization in the biological world seems implemented
- Folk theory centered on the living, misappreciation of the non living
- Persistent animated conception versus the non animated one in order to categorize living and non living

Hypothesis from the second series of study based on the second section of the global teaching/learning theory (*Sweller, 2008*).

<table>
<thead>
<tr>
<th>Knowledge type</th>
<th>Secondary Knowledge based</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experiment</strong> 75 participants of 6th grade (11.7 years old) per study</td>
<td><strong>Experiment IV</strong></td>
</tr>
<tr>
<td><strong>Phylogenetic classification material</strong></td>
<td>Average</td>
</tr>
<tr>
<td><strong>Learning phase</strong></td>
<td><strong>No Guidance</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Adaptative guidance</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Strong guidance</strong></td>
</tr>
<tr>
<td></td>
<td>Applying knowledge</td>
</tr>
<tr>
<td><strong>Testing phase</strong></td>
<td>Conceptualization about the categories</td>
</tr>
<tr>
<td></td>
<td>Knowledge transfer</td>
</tr>
</tbody>
</table>

**Prior assessments:** Motivation and self-efficacy are assessed before the experiment, initial knowledge pre-test.

**Manipulation of the Likert scale**

**Manipulation of the MERS scale**
Hypothesis from the second series of study
based on the second section of the global teaching/learning theory (Sweller, 2008)

<table>
<thead>
<tr>
<th>Prior assessments</th>
<th>Manipulation of the Likert scale</th>
<th>Manipulation of the MERS scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motivation and self efficacy are assessed before experiment, Initial knowledge pre-test</td>
<td>Secondary Knowledge based</td>
<td>Secondary Knowledge based</td>
</tr>
<tr>
<td>Knowledge type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 participants of 6th grade (11.7 years old) per study</td>
<td>10 plants</td>
<td>10 animals</td>
</tr>
<tr>
<td>Phylogenetic classification material</td>
<td>8 attributes</td>
<td>8 attributes</td>
</tr>
<tr>
<td>Strong guidance</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>total help</td>
<td>The same like study II</td>
<td>The same like study III</td>
</tr>
<tr>
<td>From worked examples</td>
<td>Computer teaching device</td>
<td></td>
</tr>
<tr>
<td>Adaptative guidance</td>
<td>Initial learning / Post-test/ Transfer</td>
<td></td>
</tr>
<tr>
<td>With corrective feedback</td>
<td>Knowledge transfer</td>
<td></td>
</tr>
<tr>
<td>No guidance</td>
<td>Measures in each phase</td>
<td></td>
</tr>
<tr>
<td>No help</td>
<td>Performance / Cognitive load</td>
<td></td>
</tr>
<tr>
<td>Simple final correction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 questions</td>
<td>6 animals</td>
<td>6 plants</td>
</tr>
</tbody>
</table>
Materials (Study IV)

- Sea lettuce
- Fucus
- Polytrichum
- Polypodium
- Fern
- Pine
- Cedar
- Pulmonary
- Hyacinth
- Oak

Intrinsic cognitive load

Extrinsic cognitive load // Attributes

Intrinsic cognitive load

Global cognitive load

Mental efforts

- Spores
- Roots
- Leaves
- Seeds
- Thallus
- Vegetal
- Pine cone
- Fruit
Materials study IV: strong guidance

Would you like to see the demonstration again

- YES
- NO

To the next position See the whole demonstration from the start I'm down
Materials study IV: adaptative guidance

- Spores
- Leaves
- Thallus
- Vegetal
- Pine cone
- Seeds
- Fruit

- Roots

Message: This is not the right position
OK
Materials study IV: post-test; 8 new plants

Fucus  Sea lettuce  Polytrichum  Eagle fan  Monterey pine  Lotus corniculatus  Oak  Salicornia

Spores  Roots  Leaves  Seeds
Thallus  Vegetal  Pine cone  Fruit
8 questions about the tree of life and phylogenesis

1/ Here is the tree of life between the following vegetals:

- Thalle
- Hormospor
- Polypod
- Polypode
- Drymades
- Thine
- Clado
- Palmen
- Jacinthe
- Chêne

Question 1: The characteristics « vegetal » is shared by all vegetals? True / False / I don’t know.

Question 2: The spore is a characteristic shared by the polypod and the pulmonary? True / False / I don’t know.

Question 3: Oak has closer characteristics from the hyacinth than the pine? True / False / I don’t know.

4/ When two species are closely related, they share a great number of common characteristics? True / False.

5/ A tree of life answers for
   - the history of living creatures
   - relations between living creatures
   - the level of evolution of living creatures

6/ Man, dolphin and bat are closely related because:
   - they appeared at the same period on earth
   - they are all mammals
   - all of them share the same anterior skeleton

7/ Keys of determination answer for
   - the story of living creatures’ histoire des êtres vivants
   - the relationship between living creatures
   - the level of evolution

8/ Man is at the top of the classification because he is the most evolved living creature: True / False
Materials: transfer task; 6 animals

- Panda
- Maki Catta
- Cebus
- Macaque
- Chimp
- Man

Non opposable thumbs
Close nostrils

Hairs
Snout
Nose

Tail
No tail
Nostrils isolated
Studies IV and V: work in the process of initial learning regarding three guidance modalities

**Average number of mistakes**

- No guidance
- Adaptative guidance

**Average number of attempts**

- No guidance
- Strong guidance
- Adaptative guidance

**Average time spent on each attempt**

- No guidance
- Strong guidance
- Adaptative guidance
Scores of success in the three phases of study IV

- **GUIDAGE DIRECTIF**
- **GUIDAGE ADAPTATIF**
- **SANS GUIDAGE**

**Post-test**
- GUIDAGE DIRECTIF: 0.35
- GUIDAGE ADAPTATIF: 0.55
- SANS GUIDAGE: 0.235

**Conceptualization**
- GUIDAGE DIRECTIF: 0.81
- GUIDAGE ADAPTATIF: 0.76
- SANS GUIDAGE: 0.75

**Transfert**
- GUIDAGE DIRECTIF: 0.17
- GUIDAGE ADAPTATIF: 0.19
- SANS GUIDAGE: 0.095

Statistical Tests:
- Post-test: F(2, 72) = 17.32, p < .0001
- Conceptualization: F(2, 72) = 2.17, ns
- Transfert: F(2, 72) = 5.72, p < .0054
Self evaluated cognitive load during the four phases of study IV

- **Apprentissage**
  - GUIDAGE DIRECTIF: 4.52
  - GUIDAGE ADAPTATIF: 4.72
  - SANS GUIDAGE: 5.76
  - $F(2, 72) = 8.88 \ p < .0004$

- **Post Test**
  - GUIDAGE DIRECTIF: 5.3
  - GUIDAGE ADAPTATIF: 3.8
  - SANS GUIDAGE: 6.0
  - $F(2, 72) = 20.49 \ p < .00001$

- **Conceptualization**
  - GUIDAGE DIRECTIF: 4.52
  - GUIDAGE ADAPTATIF: 3.64
  - SANS GUIDAGE: 5.92
  - $F(2, 72) = 13.85 \ p < .00001$

- **Transfert**
  - GUIDAGE DIRECTIF: 5.88
  - GUIDAGE ADAPTATIF: 5.76
  - SANS GUIDAGE: 6.36
  - $F(2, 72) = 1.01 \ ns$
Scores of success in the three phases of study V

- **GUIDAGE DIRECTIF**
- **GUIDAGE ADAPTATIF**
- **SANS GUIDAGE**

<table>
<thead>
<tr>
<th>Phase</th>
<th>GUIDAGE DIRECTIF</th>
<th>GUIDAGE ADAPTATIF</th>
<th>SANS GUIDAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Test</td>
<td>0.705</td>
<td>0.475</td>
<td>0.455</td>
</tr>
<tr>
<td>Conceptualization</td>
<td>0.835</td>
<td>0.655</td>
<td>0.59</td>
</tr>
<tr>
<td>Transfert</td>
<td>0.4</td>
<td>0.285</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Statistical tests:
- Post Test: $F(2, 72) = 14.48, p < 0.0001$
- Conceptualization: $F(2, 72) = 14.13, p < 0.0001$
- Transfert: $F(2, 72) = 4.84, p < 0.0107$
Self evaluated cognitive load during the four phases of study V

- **GUIDAGE DIRECTIF**
- **GUIDAGE ADAPTATIF**
- **SANS GUIDAGE**

**Apprentissage**
- **GU**: 4.4
- **AD**: 4.24
- **SN**: 5.8

**Post-test**
- **GU**: 4.96
- **AD**: 6.2
- **SN**: 5.7

**Conceptualization**
- **GU**: 4.92
- **AD**: 4.08
- **SN**: 6.4

**Transfert**
- **GU**: 6.12
- **AD**: 6.2
- **SN**: 7.16

Significance tests:
- **Apprentissage**: $F(2, 72) = 9.57, p < .0002$
- **Post-test**: $F(2, 72) = 4.64, p < .0127$
- **Conceptualization**: $F(2, 72) = 15.35, p < .00001$
- **Transfert**: $F(2, 72) = 3.55, p < .0340$
Guidance and secondary knowledge based on phylogenesis

- **Complex learning**
  - **Motivation**
  - **Attention resources**
  - **Effort**

- **German cognitive load**
- **Intrinsic cognitive load**
- **Extrinsic cognitive load**

- **No guidance**
  - Learning failure
  - - Kirschner et al., 2006
  - - Geary, 2008
  - - Sweller, 2008

- **Explicit guidance**
  - Learning efficiency
  - - Paas et al., 2010
  - - Paas & van Gog, 2006

Sweller’s hypothesis seems to be verified
Effect of guidance on learning based on primary and secondary knowledge

- First attempt in validating Sweller’s global theory (2008)
- Exploratory character of this research

It seems possible to empirically compare primary and secondary knowledge learning

- Guidance seems to be less appropriate for learning primary knowledge
- Guidance seems to be adapted for learning secondary knowledge

Questions raised by this research:
- Self-evaluated cognitive load among pre-teens (Paas et al., 2003)
- Types of knowledge to teach in sciences (Sélosse, 2008; Lherminier, 2008; Orange-Ravachol, 2007).
- Relation between primary and secondary knowledge: primary as a base for secondary knowledge learning
- Collecting student’s initial conceptions
  - Setting the beginning of learning and the guidance script
  - Adapting guidance to the secondary knowledge aimed at and to the learner’s expertise level

Helping someone’s pedagogy

- Drawing up the teaching script of learning: work of an expert to get intrinsic and extrinsic cognitive load under control
Argument for the debate opposing constructivism and guidance learning?

**Sciences:** data lead us to the **efficiency of guidance** 
(Mayer, 2004; Kirschner et al., 2006; Klahr & Nigam, 2004)

**But** learning by problem solving remains the uppermost strategy

Nowadays, do we have to teach knowledge?
Do we have to teach a scientific approach?
Do we have to teach knowledge through a scientific approach?
Thank you for your kind attention.

franck.tanguy33@gmail.com