Advancements in Intelligent Support for Collaborative Learning
From Well-Thought-Out Group Formation to Effective Peer Interactions

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Who am I ?
Hi I’m Seiji! I’m a Brazilian
Love sports
Friendship...
Challenges ...
Undegrad in Computer Science at the University of Sao Paulo
Ph.D. in Information Engineering
2 years as a Research Fellow at Carnegie Mellon University, USA
Back to Brazil at USP since 2011
92,792 students

Undergraduate programs
58,204 students
  *International 1,692

Visiting 5,041

Graduate programs
29,547 students
  *International 1,587

Master’s 14,149
Doctorate 15,398
Faculty
6,008

Full time work dedication
5,230
(87.05%)

Academic Titles
(PhD or higher)
5,964
(99.27%)

Technical-Administrative Staff
17,450
USP

USP Ranking

QS World University Rankings 2019: 118
The Times Higher Education BRICS & Emerging Economies 2018: 14
Ibero American SCImago Institutions Rankings (SIR) 2018: 1
CWUR World University Rankings 2018: 77
U.S. News Best Global Universities 2019: 148
SÃO CARLOS
Team
Advancements in Intelligent Support for Collaborative Learning
From Well-Thought-Out Group Formation to Effective Peer Interactions

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Takeaway Message:

1. Take a **real world problem** that is hard to solve
2. **Organize the knowledge** from different sources
3. Build an **ontology**
4. **Hide the ontology** behind a model that people can understand
5. Apply the model and the ontology to **solve the problem**
The field of Computer-Supported Collaborative Learning - CSCL dedicates to study about how technology can be used to support collaborative learning and its processes (Stahl et al., 2006)
**Context**

**Individual Learning**
- Students work individually toward an academic goal;
- More structured;
- Teacher plays an active role during the learning process;
- Individual assessment;
- ...

**collaborative Learning**
- Students work in groups toward a common academic goal;
- Less structured;
- Teacher plays a supportive role during the learning process;
- Individual and group assessment;
- ...

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*Figures:*
- Students work individually.
- Students work in groups.
The field of Computer-Supported Collaborative Learning - CSCL dedicates to study about how technology can be used to support collaborative learning and its processes (Stahl et al., 2006).

Despite of the potential benefits of Collaborative Learning, this approach is only beneficial when there is an adequate design and orchestration of its scenarios (Hernández-Leo et al., 2011; Dillenbourg, 2013; Pietro et al., 2018)
The Problem

- These activities are too complex and time consuming
- They also require specific knowledge and skills
How to increase the chances of successful collaborative learning (CL)?
How to provide intelligent support to design and carry out collaboration?
Knowledge to design effective collaboration is distributed across several learning theories and best practices.

They do not share the same terminology, assumptions and expectations and can be even contradictory!

In fact, Only 35% of the current CL technology rely on pedagogical knowledge.

Can we organize this pedagogical knowledge and build an infrastructure to use it adequately?
Approaches to Represent Pedagogical Knowledge

- Script-based
- Pattern-based
- Ontology-based
• Script-based Solution
  – Set of components to describe an collaborative learning activity
  – Focus on components
  – Way of communicating CL expertise
  – Human-interpretable notations
  – Scripts are hard-coded in computational tools
<table>
<thead>
<tr>
<th>Name</th>
<th>MURDER Script</th>
<th>Universanté Script</th>
<th>ArgueGraph Script</th>
<th>Social Script</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants</td>
<td>An even number of participants</td>
<td>Participants from at least two nations with at least as many participants per nation as there are case descriptions</td>
<td>An even number of at least four participants (works best with 20–30 participants) and a tutor</td>
<td>An amount of participants that must be divisible by three</td>
</tr>
<tr>
<td>Activities</td>
<td>a) relaxing, focusing; b) reading, monitoring comprehension; c) summarizing, explaining; d) monitoring, giving feedback; e) elaborating; f) reviewing, reflecting</td>
<td>a) analyzing and elaborating the case; b) summarizing and explaining; c) analyzing, comparing and relating new information to personal prior knowledge; d) giving feedback and critiquing; e) problem solving</td>
<td>a) justifying opinions and constructing arguments; b) comparing, evaluating, and elaborating; c) negotiating and constructing arguments; d) explaining and justifying opinions; e) summarizing and making connections</td>
<td>a) applying theoretical concepts to cases and constructing arguments; b) critiquing (initially scaffolded with prompts for eliciting clarification, identifying conflicting views and constructing counter-arguments)</td>
</tr>
<tr>
<td>Roles</td>
<td>A summarizer and a listener</td>
<td>None</td>
<td>None</td>
<td>An analyst and two critics</td>
</tr>
<tr>
<td>Resources</td>
<td>Learning material with a small number of text passages</td>
<td>Case descriptions from at least two themes, with at least two case descriptions per theme.</td>
<td>One questionnaire for each participant and another copy for each small group. One argument sheet per questionnaire item.</td>
<td>Three case descriptions</td>
</tr>
<tr>
<td>Groups</td>
<td>Pairs</td>
<td>Theme groups, case groups and national groups</td>
<td>Class group and pairs</td>
<td>Case groups</td>
</tr>
</tbody>
</table>

Problems with previous approach

1. Human-interpretable notations
2. Too complex & ambiguous
3. There is not a common vocabulary to describe them
4. Different point of views, levels of aggregation, perspective and emphasis
5. Scripts are hard-coded in computational tools
• Pattern-based Solution
  – Description of classroom best practices
  – **Focus on the flow** of the collaborative activities for promoting desired educational objectives
  – Way of communicating CL expertise
  – **Computer-interpretable** notations (IMS-LD)
Example


Jigsaw flow using IMS-LD

- **Role**
  - Educator
  - Experts group
  - Jigsaw group

**Act, role-part**
- Problem and sub-problem formulation

**Act, role-parts**
- Activity control
- Individual study of a sub-problem
- Sub-problem discussion

**Act, role-parts**
- Activity control
- Problem discussion
- Solution proposal

- Collaborative design of a computing system, each subsystem is assigned to each expert
- Discussion forum and collaborative conceptual map tool
Computer-based support to orchestrate collaboration


Problems with previous approach

1. Limited framework to describe pedagogical approaches
2. IMS-LD is designed for individual learning
3. There is not a common vocabulary or formal way to describe collaboration flows
4. Computers cannot reasoning over IMS-LD
5. No support for intelligent authoring, group formation or interaction analysis
• Ontology-based Solution
  – Formal infrastructure to represent pedagogical knowledge
  – Focus on representation and generalization
  – Way of communicating CL expertise
  – Computer-understandable notations (OWL, RDF-S)
  – Knowledge base is shareable across humans and machines
What is an Ontology?

- A *formal explicit specification* of objects and relations in the target world used to share a common understanding within a community and to build models/frameworks about target objects (Mizoguchi, 2003; 2004)

Example of Ontology representation

University

State university

Professor role

Professor

Human

Part-of

Is-a

Part-of

USP

Seiji

Professor role

Instance

Human
Example of Ontology representation: Ontology of Bicycle

context

role concept

basic concept

role holder

vehicle

super

is-a

sub

wheel role

wheel

p/o 1..

rider role

rider

person

bicycle

super

is-a

sub

frame role

frame

p/o 1

pedal role

pedal

p/o 1

handlebar role

handlebar

p/o 1

front wheel role

front wheel

p/o 1

rear wheel role

rear wheel

p/o 1

color

Color

a/o 1

weight

weight

a/o 1

city cycle

p/o 1

front role

carrier

sport cycle

p/o 1

front wheel role

front wheel[2]

sport wheel

p/o 1

rear wheel role

rear wheel[2]

sport wheel
Example of Ontology representation:
Ontology of Bicycle in OWL

```xml
<owl:Class rdf:ID="Vehicle">
  <rdfs:label>Vehicle</rdfs:label>
  <rdfs:subClassOf rdf:resource="#Any" />
</owl:Class>

<owl:Class rdf:ID="sport_cycle">
  <rdfs:label>sport_cycle</rdfs:label>
  <rdfs:subClassOf rdf:resource="#bicycle" />
</owl:Class>

<owl:Class rdf:ID="city_cycle">
  <rdfs:label>city_cycle</rdfs:label>
  <rdfs:subClassOf rdf:resource="#bicycle" />
</owl:Class>

<owl:Class rdf:ID="bicycle">
  <rdfs:label>bicycle</rdfs:label>
  <rdfs:subClassOf rdf:resource="#Vehicle" />
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:cardinality rdf:datatype="http://www.w3.org/">
        <owl:onProperty rdf:resource="#has_body_color" />
      </owl:cardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#has_body_color" />
      <owl:allValuesFrom rdf:resource="#Color" />
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```
My Contribution

Use ontological engineering to describe formally meaningful information contained in theories.

Pedagogical knowledge

Use ontologies to support the development of ontology-aware systems.

Run experimental studies to:
- propose group formation;
- design group activities;
- estimate benefits, etc.

Users
- Teachers and students

Theory aware intelligent systems

Ontological structure

Why does the learner want to interact with other learners?
Formalizing Collaborative Learning

Smaller group
part of the whole

Interaction

Whole group

L_A

L_B

L_C
Formalizing Collaborative Learning

Sub-group goal

Strategy A

Individual goal

Role

Strategy B

Whole group goal

Role

Role

Individual goal

Individual goal

L_A

L_B

L_C
Formalizing Collaborative Learning

- Learning Strategies
- Learning Goals
- Group Goals
- Roles

\[ \text{W}(L) \text{ goal } \{L_A, L_B\} \]

\[ Y \leq I \text{-goal } (L_B \leq L_A) \]

\[ \text{Strategy A} \]

\[ \text{Strategy B} \]

\[ \text{W}(L) \text{ goal } \{L_A, L_B, L_C\} \]

\[ \text{I goal } (L_A) \]

\[ \text{I goal } (L_B) \]

\[ \text{I goal } (L_C) \]
Formalizing Collaborative Learning

Learning by Apprenticeship

Learning by Guiding

Spread of a skill

Y<=I - goal (L_A <= L_B)

Y<=I - goal (L_B <= L_A)

W(L)-goal({L_A, L_B})

Knowledge Acquisition:
(accretion, tuning, …)

Cognitive Skill Development
(cognitive, associative, …)

Knowledge sharing

Tutor

Tutee

Role

I-goal(L_A)

I-goal(L_B)

I-goal(L_C)

W(L)-goal({L_A, L_B, L_C})
Formalizing Collaborative Learning: Ontology
Formalizing Collaborative Learning: Instances

Interaction Patterns for Learning Theories proposed by Inaba et al. 2003

- Cognitive Apprenticeship
- Peer Tutoring
- Anchored Instruction
- LPP
- Cognitive Constructivism
- Observational Learning
- Distributed Cognition
- Sociocultural Theory
- Cognitive Flexibility Theory

Ontological framework

Influential I_L event

Instructional event

Instructor

Instructional action

Action

Benefits for the Instructor

I-goal

L event

Learning event

Learner

Learning object

Learning action

Benefits for the Learner

I-goal

Influential I_L Event

Learning Event

Institutional Event

Learner

Role

Learning goal (L_A)

action_LA

Instructor

Role

Learning goal (L_B)

action_LB
Development of cognitive skills (rough-cognitive stage)

Learning by apprenticeship

Learning by guiding

Spreading of a skill

Development of meta-cognitive skills (Associative stage)

Cognitive Apprenticeship Theory

Formalizing Collaborative Learning: Example
Formalizing Collaborative Learning: Example
This ontology-based approach solves several problems to formalize and apply pedagogical knowledge$^{1,2,3}$

OK. But let’s be realistic …
Almost nobody can understand this ontology
Takeaway Message:

1. Take a **real world problem** that is hard to solve
2. **Organize the knowledge** from different sources
3. Build an **ontology**
4. **Hide the ontology** behind a model that (some) people can understand
5. Apply the model and the ontology to solve the problem
# Learner’s Growth Model

<table>
<thead>
<tr>
<th>I-goal</th>
<th>Graphical Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition of Content-Specific Knowledge</td>
<td></td>
</tr>
<tr>
<td>Nothing</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Accretion</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Tuning</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Restructuring</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Development of Skills</td>
<td></td>
</tr>
<tr>
<td>Nothing</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Rough-cognitive</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Explanatory-Cognitive</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Associative</td>
<td><img src="#" alt="Graph" /></td>
</tr>
<tr>
<td>Autonomous</td>
<td><img src="#" alt="Graph" /></td>
</tr>
</tbody>
</table>

[Rumelhart D.E. and Norman, D.A., 1978]

[Anderson, J. 1982]
Learner’s Growth Model (LGM)

LGM is a graph that represents all possible transitions in learner’s development.

A learning theory shows some possible transitions in the LGM graph.
Facilitating Visualization with LGM

**Learning by Apprenticeship**
in Cognitive Apprenticeship

**Learning by Guiding**
in Cognitive Apprenticeship

**Learning by Discussion**
in Legitimate Peripheral Participant (LPP)

---

**Stages of Skill development**
- nothing (0)
- rough cognitive stage (1)
- explanatory cognitive stage (2)
- associative stage (3)
- autonomous stage (4)

**Stages of Knowledge acquisition**
- nothing (0)
- accretion (1)
- tuning (2)
- restructuring (3)

---

learning by apprenticeship

learning by guiding

Learning by Discussion
Learning by apprenticeship in *Cognitive Apprenticeship*

Learner plays an *apprentice role* following the *learning events*.
Cognitive Apprenticeship
Learning by Apprenticeship

[Stages of Skill development]
nothing (0)
rough cognitive stage (1)
explanatory cognitive stage (2)
associative stage (3)
autonomous stage (4)

[Stages of Knowledge acquisition]
nothing (0)
tuning (2)
restructuring (3)
accretion (1)

[Interactions]
1. Setting up the learning context
2. Demonstrating how to solve a problem
3. Clarify the problem
4. Monitoring
5. Notifying how the learner is
6. Instigating thinking
7. Requesting problem’s details
8. Showing a solution
9. Affirmative reaction

GMIP: Growth model improved by Interaction Patterns
Cognitive Apprenticeship
Learning by Apprenticeship

The dashed ellipses mean that the interaction on the top/left must be followed by another interaction bottom/right.

The ellipses mean that the interaction on the top/left will be followed by another interaction bottom/right and vice-versa (cycle)
GMIP: Growth model improved by Interaction Patterns

The model offers a solution to create theory-aware tools that help to design CL activities

**CHOCOLATO**: Concrete and **Helpful** Ontology-aware Collaborative Learning Authoring Tool

- Group Formation
- Learners
- Meaningful results
- Effective Groups
- Theories
- Ontologies

**Sequence of activities**

- **CL Design**
- Interaction Analysis

**Why does the learner want to interact with other learners?**

**What activity does the group want to do?**

**How does the group change its state?**

**How does the learner change his/her state?**

**Prim ary focus (P)**

**Secondary focus (S)**

- \( S \leq P \) - goal
- \( P \leq S \) - goal

**I-goal**

**I-role**

**You-role**

**I-goal (I)**

**Y \leq I** - goal

**Behavior**

**k./cog. state**

**Goal state**

**GROUP**

**What activity does the group want to do?**

**How does the group change its state?**

**Why does the learner want to interact with other learners?**

**GROUP**

**GROUP**

**GROUP**
MARI – Main Adaptive Representation Interface

Path of different theories
MARI – Main Adaptive Representation Interface
Search for theories

Search Results
MARI – Main Adaptive Representation Interface

Search for theories

Initial stage → Final stage

Search Results
Development of meta-cognitive skills

Learning by Apprenticeship

Master R << Learning by Apprenticeship$1-role$Imitator R

Imitator R << Learning by Apprenticeship$1-role$Imitator R

Guide R << Learning by Apprenticeship$1-role$Guide R

L-goal (l) << Learning by Apprenticeship$1-goal$ (l)

Development of Cognitive Skill (Cognitive stage)

Development of Cognitive Skill (Associative stage)

Development of Metacognitive Skill (Cognitive stage)

Development of Metacognitive Skill (Associative stage)

Learning Strategy << Learning Theor$Learning Strategy

Cognitive Apprenticeship

MARI – Main Adaptive Representation Interface
MARI – Main Adaptive Representation Interface

Learning by Apprenticeship

Setting up learning context

Receiving information

 Ontology

Giving information

Development of cognitive skills (rough cognitive stage)

Development of meta-cognitive skills (Associative stage)

Learning by Guiding

Learning by Apprenticeship

Master

Apprentice

L_A

L_B

Giving information

Receiving information
Takeaway Message:

1. Take a **real world problem** that is hard to solve
2. **Organize the knowledge** from different sources
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4. **Hide the ontology** behind a model that (some) people can understand
5. Apply the model and the ontology to **solve the problem**
CHOCOLATO: Concrete and Helpful Ontology-aware Collaborative Learning Authoring Tool

Learners

Group Formation

Effective Groups

Ontologies

Sequence of activities

CL Design

Interaction Analysis

Meaningful results

CHOCOLATO

Why does the learner want to interact with other learners?

How does the learner change his/her state?

What activity does the group want to do?

How does the group change its state?
How to group students?

Student 1

Student 2

Student 3
How to group students?
How to group students?
How to group students?

Student 1

Student 2

Student 3
Theory-Driven Group Formation

Identify which collaborative learning scenarios can help learners to achieve their goals

learning goals

High Performance Group

Y <= I - goal

Learning Strategy IT <= LR

I-goal

Learner

Behavioral role participant

You-role

Learner

Behavioral role participant

I-role

Learner

Teacher’s intention

Can play

Can play

Satisfies

Satisfies

Learning Strategy LR <= IT

I-goal

I-goal

I-goal

I-goal

Learner

Behavioral role participant

Teacher’s intention

G1 ... Gn

L_A

L_B

G1 ... Gn
CHOCOLATO

Knowledge Base
- Learning Objects
- Learner Model
- Ontologies

CL Design Support System

Domain Mapping Support System

Learning Material Support System

Group Formation Support System

Osaka University

Department of Knowledge Systems

Seiji Isotani: My course list | My calendar | My User Account | Logout

Course test 1
MAC110 - Seiji Isotani

Osaka University > MAC110 > Groups > Pedagogical groups > Suggest group formation

Pedagogical groups
Suggest group formation

Select the group goal
- No specific goal
- Creating a solution
- Knowledge Construction
- Knowledge sharing
- Spread of a skill

Select applicable theories
- All theories
- Anchored Instruction
- Peer Tutoring

Topics
Add child | Add brother | Delete
- Topic 3
- Topic 2
- ontology 1
- Topic 1.1
- Topic 1.1.1

Skills
Add child | Add brother | Delete
- skill related to 3
- skill related to 3.1

Knowledge
Add child | Add brother | Delete
- knowledge related to 3

Select the topic, skill/knowledge and students to start the group formation process (only adequate students are shown)

Select an User Role
- All Roles
- Anchor holder role
- Anchored Instructor role

Select Users
- All Students
- Student 14
- Student 15
- Student 16
- Student 17
- Student 18
- Student 19
- Student 20

Start Group Formation

Manager(s) for MAC110: Seiji Isotani

Developed by Information Laboratory, Using Ontologies and Semantic Web Technologies to enhance Clarolino

Groups
Development

- RDF/OWL Parser (ARC2), PHP, Claroline (LMS).
### (a) Created groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>Registered</th>
<th>Max</th>
<th>Edit</th>
<th>Delete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 - Distributed Cognition</td>
<td>6</td>
<td>8</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Group 2 - Peer Tutoring</td>
<td>3</td>
<td>8</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Group 3 - Cognitive Apprenticeship</td>
<td>4</td>
<td>8</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>Group 4 - LPP</td>
<td>4</td>
<td>8</td>
<td>✔</td>
<td>✗</td>
</tr>
</tbody>
</table>

### (b) Users’ details

<table>
<thead>
<tr>
<th>Last name</th>
<th>First name</th>
<th>Profile</th>
<th>Role</th>
<th>Group</th>
<th>Group Tutor</th>
<th>Course manager</th>
<th>Edit</th>
<th>Unregister</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Isotani</td>
<td>Seiji</td>
<td>Manager</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>2</td>
<td>Student 1</td>
<td>User</td>
<td>Peer Tutee</td>
<td>Group 2 - Peer Tutoring (35)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>3</td>
<td>Student 10</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>4</td>
<td>Student 11</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>5</td>
<td>Student 12</td>
<td>User</td>
<td>Peer Tutor</td>
<td>Group 2 - Peer Tutoring (35)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>6</td>
<td>Student 13</td>
<td>User</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>7</td>
<td>Student 14</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>8</td>
<td>Student 15</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>9</td>
<td>Student 16</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>10</td>
<td>Student 17</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 1 - Distributed Cognition (34)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>11</td>
<td>Student 18</td>
<td>User</td>
<td>Master</td>
<td>Group 3 - Cognitive Apprenticeship (36)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>12</td>
<td>Student 19</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 4 - LPP (37)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>13</td>
<td>Student 2</td>
<td>User</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>14</td>
<td>Student 20</td>
<td>User</td>
<td>Full Participant</td>
<td>Group 4 - LPP (37)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>15</td>
<td>Student 3</td>
<td>User</td>
<td>Apprentice</td>
<td>Group 3 - Cognitive Apprenticeship (36)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>16</td>
<td>Student 4</td>
<td>User</td>
<td>Apprentice</td>
<td>Group 3 - Cognitive Apprenticeship (36)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>17</td>
<td>Student 5</td>
<td>User</td>
<td>Peripheral Participant</td>
<td>Group 4 - LPP (37)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>18</td>
<td>Student 6</td>
<td>User</td>
<td>Peripheral Participant</td>
<td>Group 4 - LPP (37)</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
<tr>
<td>19</td>
<td>Student 7</td>
<td>User</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>✔</td>
<td>✗</td>
</tr>
</tbody>
</table>
Does it really work in practice?

In vivo studies: PCA

Year 4

Average score of all tasks

Score in the first Test

Year 7

Average score of all tasks

Score in the first Test

Year 8

Average score of all tasks

Score in the first Test

Year 9

Average score of all tasks

Score in the first Test

1st Principal Component

2nd Principal Component

In vivo studies: PCA
Future Directions
Does it really work at scale?
(self-controlled learning environment)
TRABALHO EM GRUPO

Turma: UX DESIGN - 2017A

Formação automática de grupos
Selezione a(s) atividade(s)
Selezione critérios para os agrupamentos:
- Gênero
- Idade
- Perfil

Formação manual de grupos
Para formação de grupos manual, arraste e solte aqui os integrantes do grupo.

Grupos formados
TRABALHO EM GRUPO

Turma: UX DESIGN - 2017A

Marcos  Jessica  Marcos  Jessica  Joana  Rafael  Rafael  Caio  Roberto  Caio  João  Felipe

Formação automática de grupos

Seleciona a(s) atividade(s)

Seleciona critérios para os agrupamentos
- Gênero
- Idade
- Perfil

Grupos: 4
Integrantes: 6

Formação manual de grupos

Para formação de grupos manual, arraste e solte aqui os integrantes do grupo

Grupos formados

Grupo 1: 6
Grupo 2: 6
Grupo 3: 6
Grupo 4: 6
Opening educational data

http://learnsphere.org/
data infrastructure to support learning improvement online
Understand the role of affective states in group formation (and collaborative learning processes)

Reis et al. (2018) Affective states in computer-supported collaborative learning: Studying the past to drive the future. Computers & Education 120: 29-50
Dealing with the demotivation problem when using computer-supported collaboration

Takeaway Message:

1. Take a **real world problem** that is hard to solve
2. **Organize the knowledge** from different sources
3. Build an **ontology**
4. **Hide the ontology** behind a model that people can understand
5. Apply the model and the ontology to **solve the problem**
Advancements in Intelligent Support for Collaborative Learning
From Well-Thought-Out Group Formation to Effective Peer Interactions

Seiji Isotani
Professor
Computing in Education Laboratory
University of Sao Paulo
sisotani@icmc.usp.br
CHOCOLATO: Concrete and Helpful Ontology-aware Collaborative Learning Authoring Tool

CHOCOLATO

Group Formation

Effective Groups

Ontologies

Theories

Learners

CL Design

Sequence of activities

Interaction Analysis

Why does the learner want to interact with other learners?

What activity does the group want to do?

How does the group change its state?

Meaningful results

Common goal

Primary focus (P)

Secondary focus (S)

S <= P

P <= S

Y <= I

Behavior

k./cog. state

Goal state

How does the learner change his/her state?

W(A)

Role

Y \rightarrow I

Behavior

W(L)

Role

Y \rightarrow I

Common goal

Primary focus (P)

Secondary focus (S)

S <= P

P <= S

Y <= I

Behavior

k./cog. state

Goal state

How does the learner change his/her state?
Cluster of utterance-labels

Interaction Patterns

1 2 3 4 5 6 7

Expected interaction

Tagging

protocol with labels

Abstraction of pattern

Recommendations

D1

Comparison

Designer’s intention

Protocol with labels

Learning Group

Idealized by Inaba et al. (2002)

Designing

Designer’s intention

Users (teacher)
Application

Domain dependent Scenario

Domain independent Scenarios

General recommendations

Specific recommendations

Teacher/Designer

Domain specific knowledge

Mapping to fit in our Model

Instantiation to fit the domain

Designer's intention

CHOCOLATO (CL Design system)

CL Theory Ontology

Interaction Patterns for Learning Theories

Domain Independent

Domain knowledge

Domain dependent Resources

Domain dependent Scenarios

Domain dependent Scenario

Domain dependent Resources

Specific recommendations
Framework to design domain-dependent CL scenarios

Learning resources

Knowledge/Skill

GMIP

Domain independent ontologies
boundary

Domain dependent learning objects

Learning state

(a) (b) (c) (d)

LO1

LO2
References

Development of cognitive skills (rough-cognitive stage)

Development of cognitive skills (explanatory-cognitive stage)

Development of meta-cognitive skills (Associative stage)

Learning by apprenticeship

Learning by guiding

Spreading of a skill

Learning by observation

Knowledge Formalization

Formalizing CL
<table>
<thead>
<tr>
<th>I-goal</th>
<th>Definition</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acquisition of Content-Specific Knowledge</td>
<td>To add new knowledge concerning the target domain to existing schemata, to understand it, and then to consider relationship among knowledge, and (re) construct knowledge structure.</td>
<td>[2, 3, 4, 6, 15, 16]</td>
</tr>
<tr>
<td>Accretion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restructuring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Cognitive Skill</td>
<td>To get knowledge concerning cognitive skills such as diagnosing and monitoring, to practice them, and then to refine them.</td>
<td>[16, 18, 23]</td>
</tr>
<tr>
<td>Cognitive stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associative stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomous stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Metacognitive Skill</td>
<td>To get knowledge concerning metacognitive skills for observing self-thinking process, diagnosing it and regulating or controlling of self-activity, to practice them, and then to refine them.</td>
<td>[16, 19, 23]</td>
</tr>
<tr>
<td>Cognitive stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associative stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomous stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Skill for Self-Expression</td>
<td>To get knowledge concerning the skills for externalizing self-thinking process and presenting the learner's self-perspectives, to practice them, and then to refine them.</td>
<td>[3, 21]</td>
</tr>
<tr>
<td>Cognitive stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Associative stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Autonomous stage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Formalizing CL

**Knowledge Organization: learning strategy**

<table>
<thead>
<tr>
<th>Y&lt;=I-goal</th>
<th>Definition</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning by Observation</td>
<td>Learning indirectly by observing other learners' learning processes</td>
<td>[2]</td>
</tr>
<tr>
<td>Learning by Self-Expression</td>
<td>Learning by externalizing self-thinking process, such as self-explanation and presentation.</td>
<td>[5]</td>
</tr>
<tr>
<td>Learning by Teaching</td>
<td>Learning by teaching something he/she already knows to other learners</td>
<td>[5,17]</td>
</tr>
<tr>
<td>Learning by being Taught</td>
<td>Learning directly by being taught by other learners</td>
<td>[17]</td>
</tr>
<tr>
<td>Learning by Apprenticeship</td>
<td>Learning by observing other learners' behavior and then imitating it.</td>
<td>[7]</td>
</tr>
<tr>
<td>Learning by Practice</td>
<td>Learning by applying knowledge or skill to a specific problem</td>
<td>[23,24]</td>
</tr>
<tr>
<td>Learning by Diagnosing</td>
<td>Learning by diagnosing other learners' learning or thinking processes</td>
<td>[6,18]</td>
</tr>
<tr>
<td>Learning by Guiding</td>
<td>Learning by demonstrating knowledge or skill to other learners and guiding the learners</td>
<td>[7]</td>
</tr>
<tr>
<td>Learning by Reflection</td>
<td>Learning by rethinking and observing the learner's self-thinking process.</td>
<td>[33,34]</td>
</tr>
<tr>
<td>Learning by Discussion</td>
<td>Learning by discussion with other learners</td>
<td>[10,27,30]</td>
</tr>
</tbody>
</table>
## Knowledge Organization: Role for learners

<table>
<thead>
<tr>
<th>Role</th>
<th>Condition</th>
<th>Predictable benefit (I-goal)</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apprentice</td>
<td>• <em>nothing</em></td>
<td>• Development of cognitive and/or metacognitive skill (cognitive stage &amp; associative stage)</td>
<td>[6]</td>
</tr>
<tr>
<td>Master</td>
<td>• knowing how to use cognitive skill&lt;br&gt;• having experience in using the cognitive skill&lt;br&gt;• having how to use meta-cognitive skill&lt;br&gt;• having experience in using the metacognitive skill</td>
<td>• Development of cognitive and/or metacognitive skill (autonomous stage)</td>
<td>[6]</td>
</tr>
<tr>
<td>Peripheral participant</td>
<td>• knowing how to use cognitive skill&lt;br&gt;• knowing how to use metacognitive skill&lt;br&gt;• not having experience in using the cognitive skill&lt;br&gt;• not having experience in using the metacognitive skill</td>
<td>• Development of cognitive skill (associative stage)&lt;br&gt;• Development of metacognitive skill (associative stage)</td>
<td>[21]</td>
</tr>
<tr>
<td>Full participant</td>
<td>• having the knowledge&lt;br&gt;• having experience in using the knowledge&lt;br&gt;• having related knowledge in the domain&lt;br&gt;• knowing how to use cognitive skill&lt;br&gt;• having experience in using the cognitive skill&lt;br&gt;• having how to use meta-cognitive skill&lt;br&gt;• having experience in using the metacognitive skill</td>
<td>• Acquisition of content specific knowledge (restructuring)&lt;br&gt;• Development of cognitive skill (autonomous stage)&lt;br&gt;• Development of metacognitive skill (autonomous stage)</td>
<td>[21, 25, 28]</td>
</tr>
<tr>
<td>Peer tutee</td>
<td>• not having the knowledge</td>
<td>• Acquisition of Content Specific Knowledge (accretion)</td>
<td>[7]</td>
</tr>
<tr>
<td>Peer tutor</td>
<td>• having the target knowledge&lt;br&gt;• not having experience in using the knowledge&lt;br&gt;• misunderstanding the knowledge</td>
<td>• Acquisition of Content Specific Knowledge (tuning)</td>
<td>[7]</td>
</tr>
</tbody>
</table>
An Theory-based Ontology for CL

- Necessary Condition
  - Knowledge/cognitive state
- Desired Condition
  - Knowledge/cognitive state
- How to collaborate
  - Behavioral Role

CL Scenario

Learning Strategy

- Y<=I-goal
  - I-role
    - Role Holder
    - Learner
  - You-role
    - Role Holder
    - Learner
- I-goal (l)
  - I-goal

CL process

- W(A)-goal
- W(L)-goal

Common goal

How to interact

- Interaction Pattern

Necessary Interaction Activity

- Influential I_L event

Complementary Interaction Activity

- Influential I_L event
Example of Ontology representation

It is incorrect to have the *is-a* relation between “Human” and “Teacher” given that *teacher* is a role played by a *human* in a context (where is the context???).