

No more LOGIN !

Which tools facilitate classroom orchestration?

schmountz

Pierre Dillenbourg



ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

DUET - Dual Eye-Tracking
Pair programming experiment

Low gaze recurrence



P. Jermann, M.-A. Nüssli & P. Dillenbourg
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Supported by the Swiss National Science Foundation
(grants #K-12K1-117909 and #PZ00P_126611)

DUET - Dual Eye-Tracking
Pair programming experiment

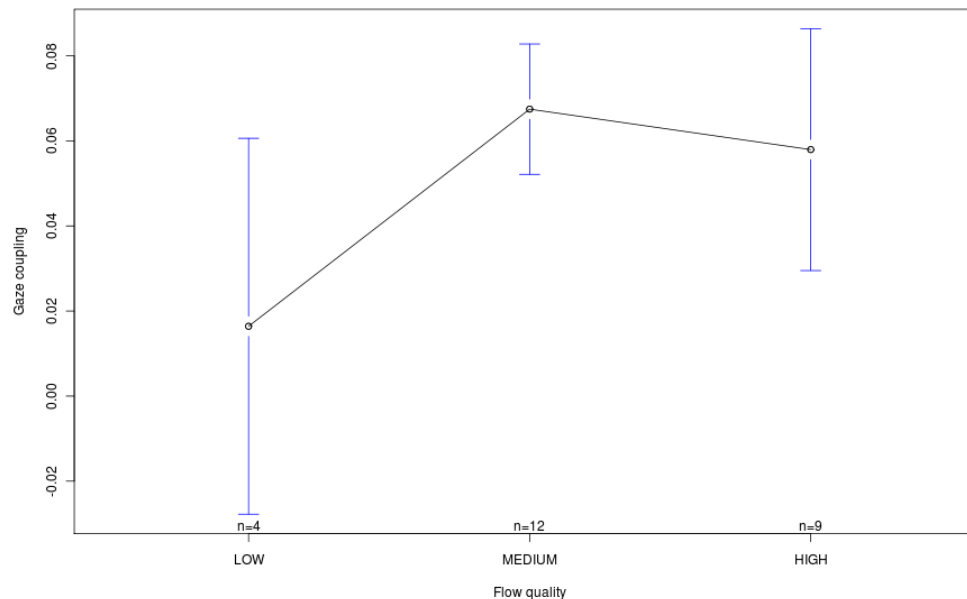
High gaze recurrence



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classroom.

Designing artefacts that would be relevant for any learning task would be as difficult as inventing 'the new table'. Conversely designing an artefact only useful for one specific task (e.g. electrical circuits) would not be convincing, as a school would not buy and install - for instance - a different table for each single course. We therefore target an intermediate scope, that is families of tasks that are present in several (but not all) educational situations, both formal and informal. We hereafter consider three elements that could constitute the basis of a scriptable classroom: desks, lamps and displays.

Desks

A classroom needs some objects to write on and to work around. In our example of scriptable classrooms, the basic element could be a triangular desk designed to be used by a single student (Figure 3). On the surface of the table a LED display is embedded under a thin layer of wood. The LED can be alternatively controlled by a central program, or by a circuit embedded in the table. In addition, the desks are equipped with 3 electrostatic buttons and a RFID reader. These can be used to get input from students, perform a quick search, ask a question, etc. The Desk is also equipped with a tiny microphone array for localized sound detection. Optionally, there are various ways of making the surface of the desk interactive. One possibility is to install pressure sensors under each desk feet. Another one is to use sound propagation inside the material (temporal reversal of acoustic waves technologies (Ing & Fink 1998) permitting to turn common objects into acoustic screens). However, our vision is not that a future desk should include all possible sensors but instead a reduced set of multi-purpose elements that enable the scenarios we present here.

Each desk has three connectors that permit to connect it to another desk (see figure 3). The connector provides both low-voltage power and acts as a serial bus, permitting to exchange data and commands in a network of desks (see figure 4, for an early prototype of the electronic circuits permitting such a network).

Connected desks can form various types of configurations. Figure 5 shows a classroom configurations using 36 tables. Figure 6 shows how the same number of tables can be used to form various kinds of individual and group tables for 2, 4 or 6 students. Figure 6 shows two examples of larger configurations adapted to roundtable discussions involving the entire class.

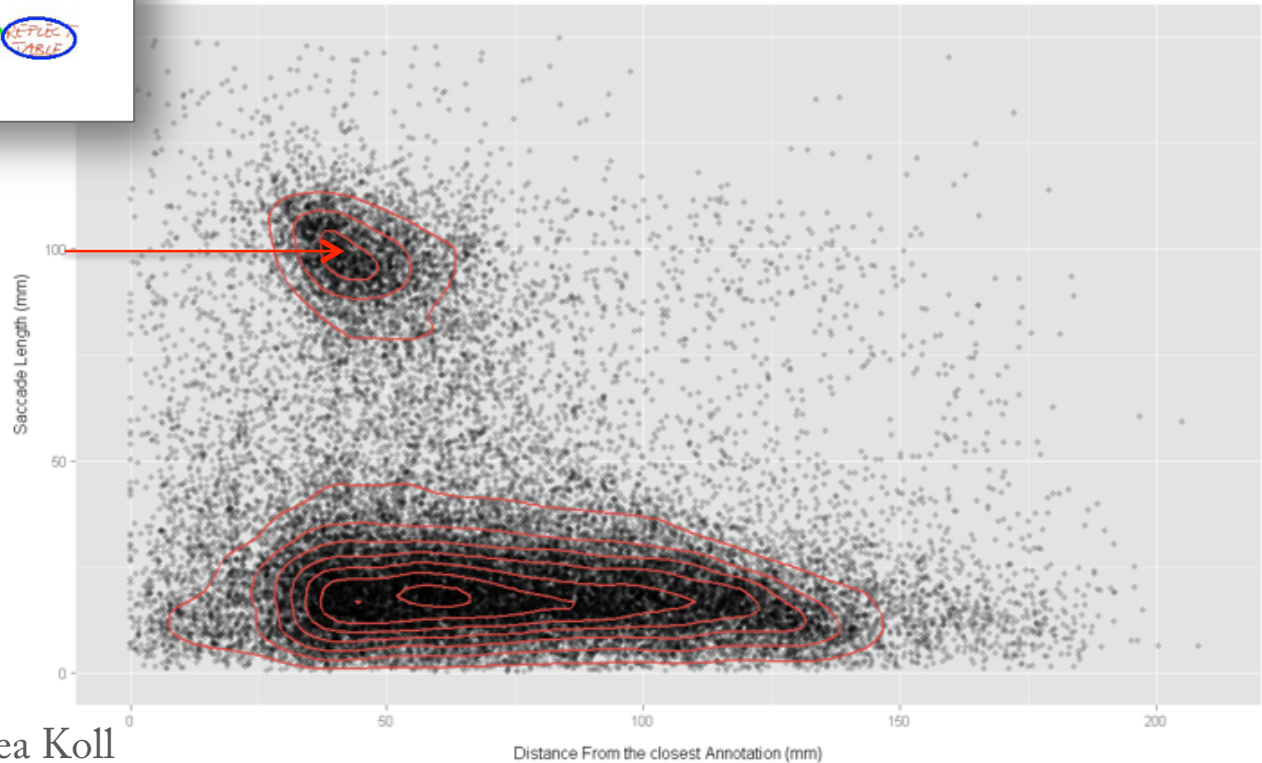
The embedded LED array on each desk can be used for a broad variety of purposes. Figure 7 shows various examples of these possible uses, illustrating both retroactive and anticipative design of interactions. One example of retroactive design is to provide feedback about the on-going conversations dynamics occurring around the table. This can be done for instance by displaying the amount of speech each participant has produced (figure 7a) or identifying who speaks with whom

A.N. Other, B.N. Other (eds), Title of Book 00-00.
© 2003 Sense Publishers. All rights reserved.

FAMILIES OF TASKS

ASSEMBLY TABLE

REFLECTIVE TABLE

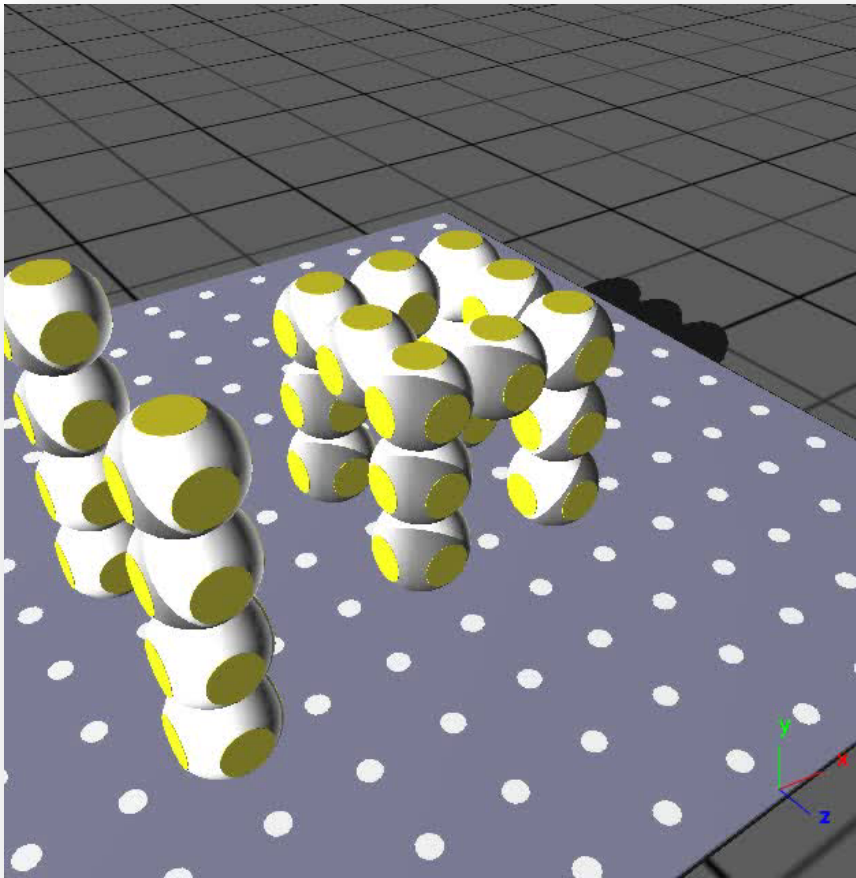




EPFL Rolex Learning Center





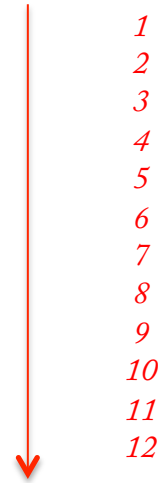


Roombot



Ranger

Gadgets that 'work well' = *dbr* (5,20)



~~orchestration load = *f* (design)~~

schmountz



Vocational education : Dual system : Logistics assistants (warehouse)



KOSMOS 200
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77

KOSMOS 200

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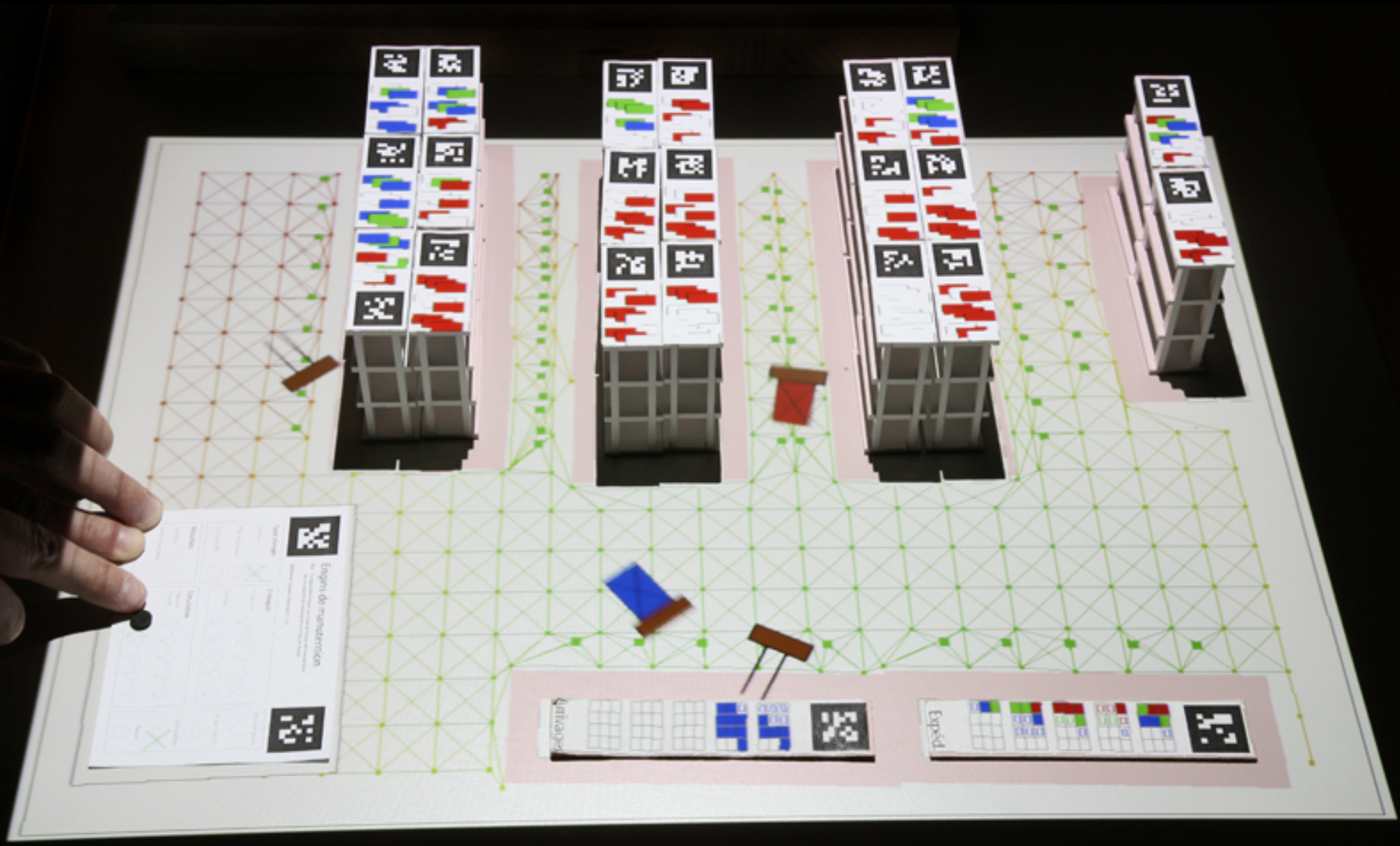
KOSMOS 100
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KOSMOS 100

KOSMOS KAEFER-ART NR. 1 INHALT: 5 STK. MADE IN CHINA
KOSMOS KAEFER-ART NR. 2 INHALT: 5 STK. MADE IN CHINA
KOSMOS KAEFER-ART NR. 3 INHALT: 5 STK. MADE IN CHINA
KOSMOS KAEFER-ART NR. 4 INHALT: 5 STK. MADE IN CHINA
KOSMOS KAEFER-ART NR. 5 INHALT: 5 STK. MADE IN CHINA

Roboter-Kafer
KOSMOS KAEFER-ROBOTER ART NR. 658014 INHALT: 5 STK. MADE IN CHINA
KOSMOS KAEFER-ROBOTER ART NR. 658015 INHALT: 5 STK. MADE IN CHINA

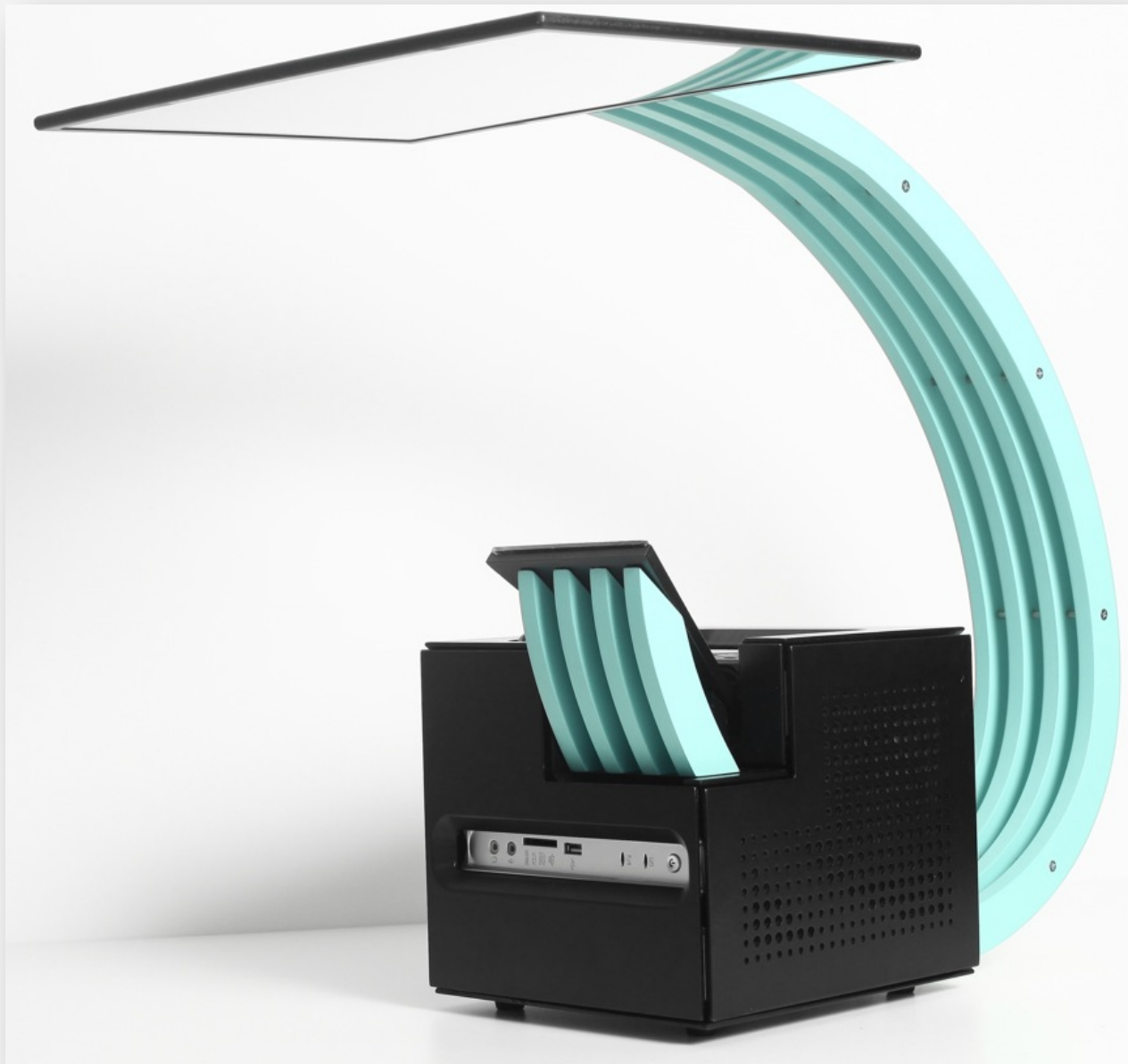
KOSMOS GEHEIM-PERISKOP ART NR. 658618 INHALT: 5 STK. MADE IN CHINA

Elektron-Kochtopf



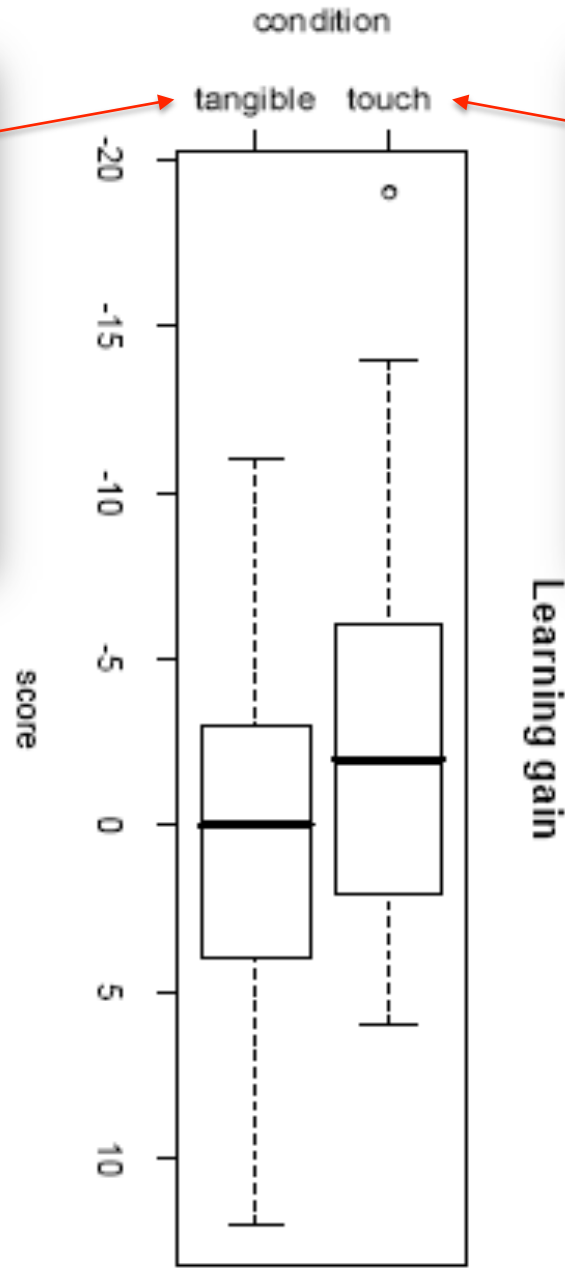
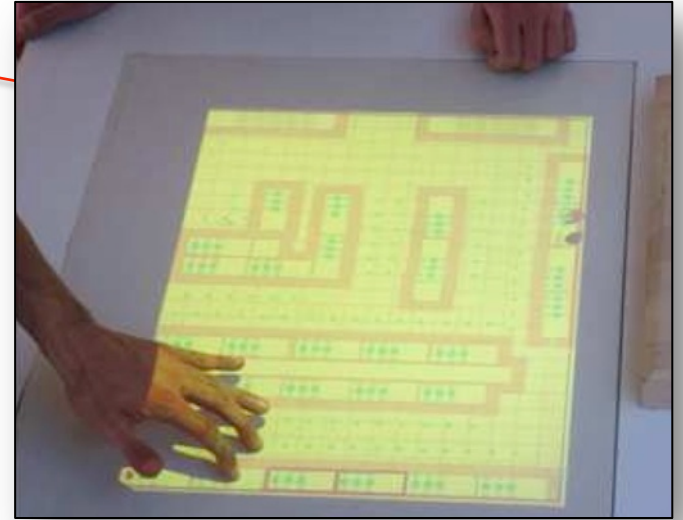
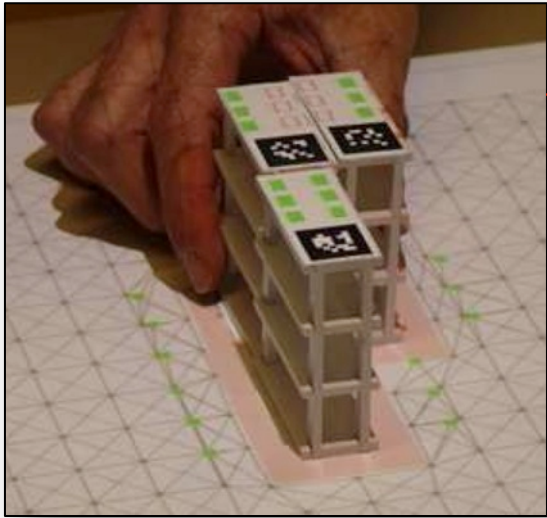
The TinkerLamp

Guillaume Zufferey, Patrick Jermann



The logo for Simpliquity features a stylized circular icon on the left, composed of two concentric rings in shades of green and grey. To the right of the icon, the word "Simpliquity" is written in a clean, grey, sans-serif typeface.

Simpliquity



$$F(1,37) = 6.68, p < .05$$

Gerbeur

20 étages

surface brut de stockage: 2400 m^2
 degré d'utilisation (1): 83%
 surface net de stockage: 68 m^2 $23\% = 45 \text{ m}^2$ 15 étages.

20 m

14 m 60

13 étages

14.15

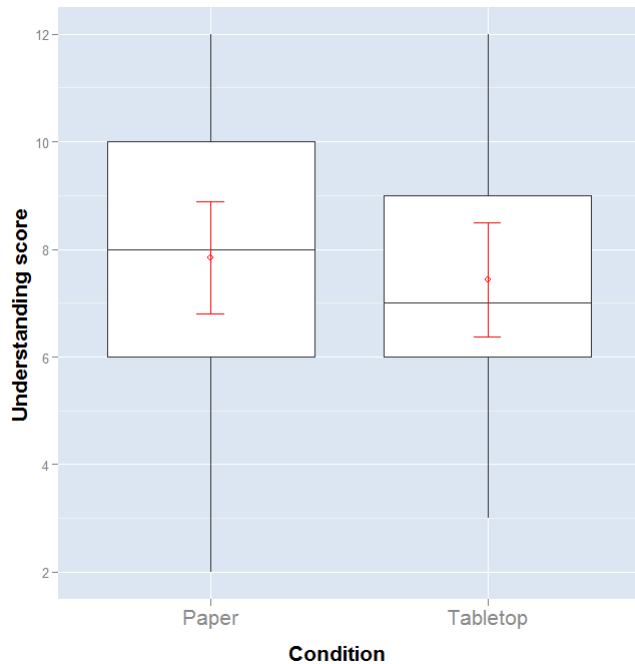
SB = 288 m^2
 SBST = 244 m^2
 Degré 1 = 86%
 SN = 50 m^2

Degré 2 = 14%
 Degré 3 = 20%

surface net de stockage / brut = 23%
 net de stockage / brut de stockage = 28%
 = 15%
 = 19%
 = 13%

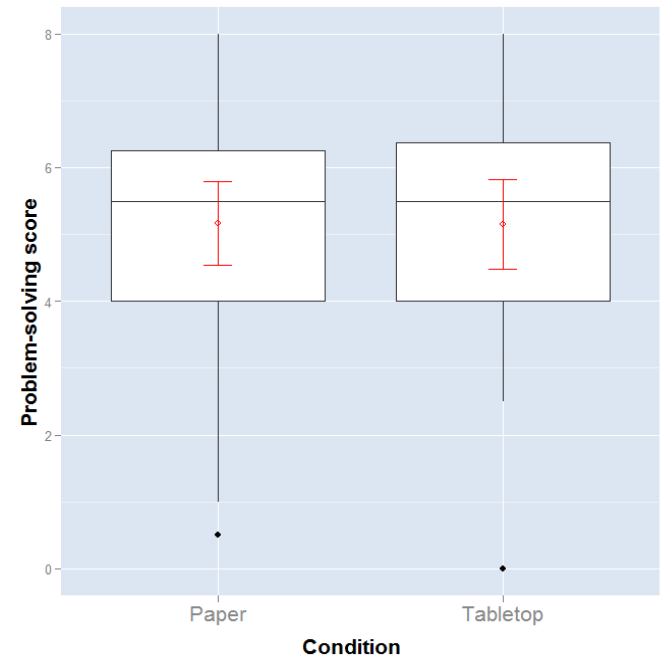


No sign. effect in
understanding



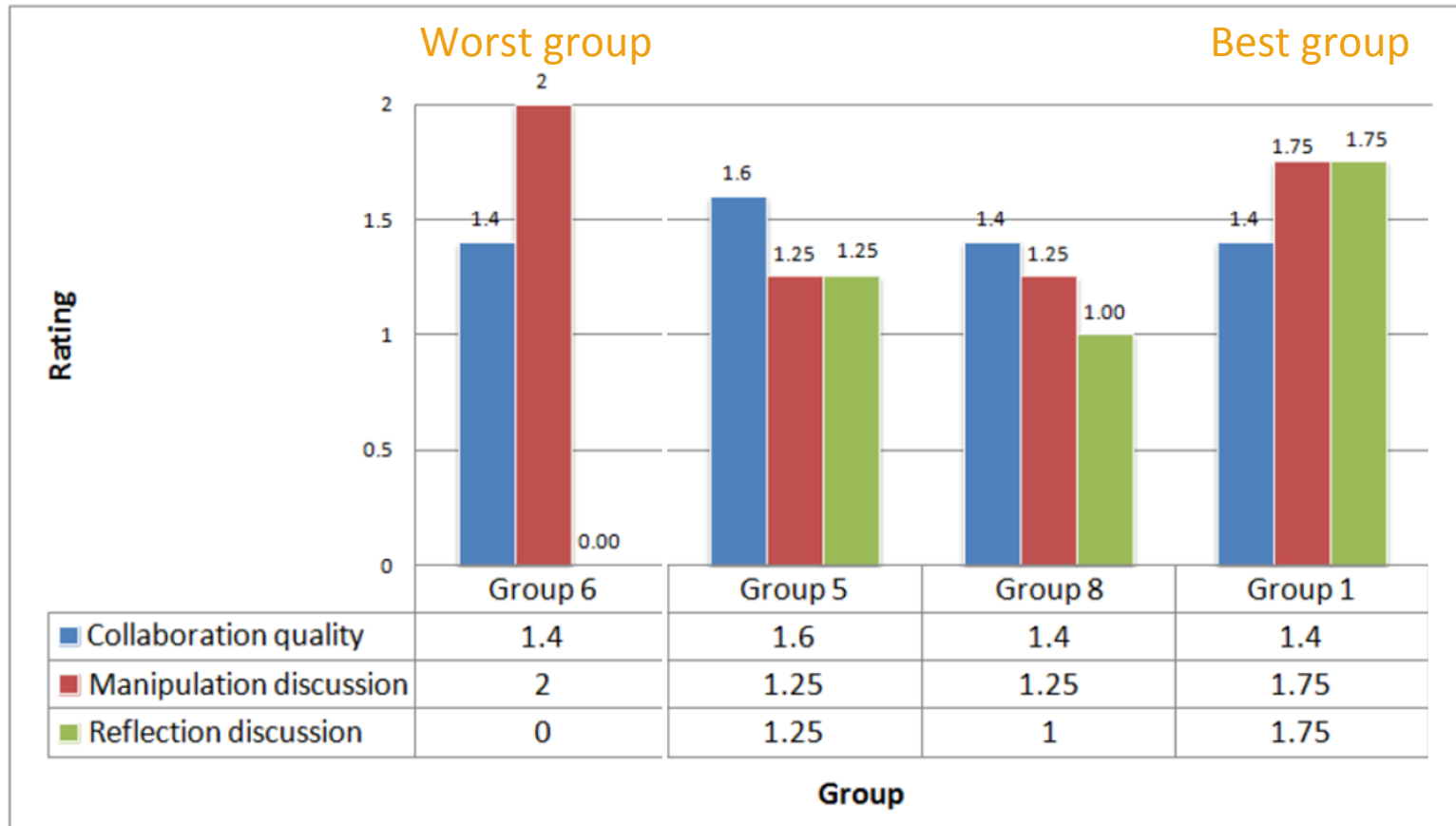
mean = 7.84 vs. mean = 7.43
 $F(1,14) = .25; p > .05$

No sign. effect in
problem-solving



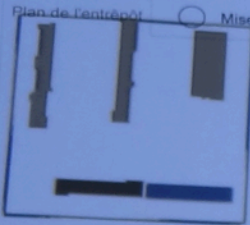
mean = 5.16 vs. mean = 5.15
 $F(1,14) = .06, p > .05$

“Manipulation temptation”!



Fiche Simulation
Repartition des surfaces de stockage

Chariot élévateur Gerbeur Mat r...



Surface brute 25 m²
Surface brute stockage 24 m²
Surface nette stockage 21 m²

Sauver



SIMULATE



- Run a simulation of the current layout.
- Ask the students to predict before running...

Arrivage

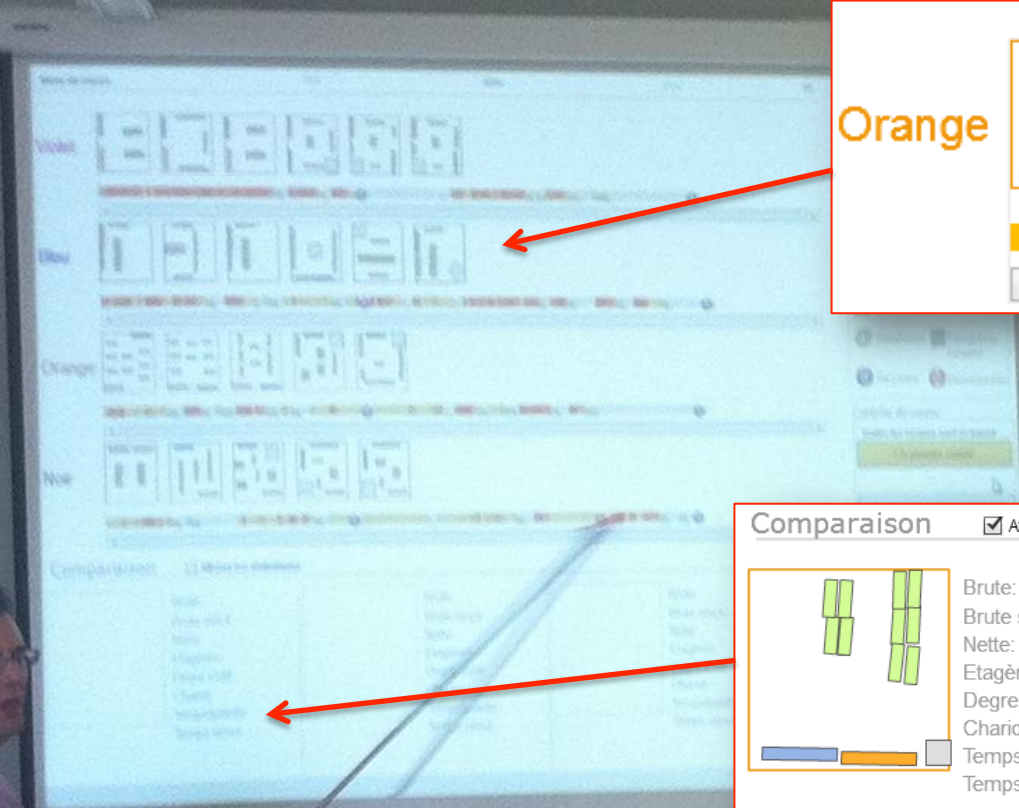


PAUSE CLASS



CLASS

- Pause all the actions (simulation, building model, etc.) in the whole class

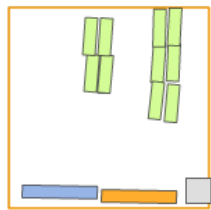


Orange

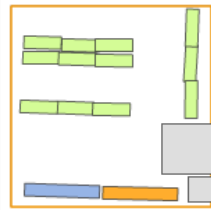


Comparaison

Afficher les statistiques



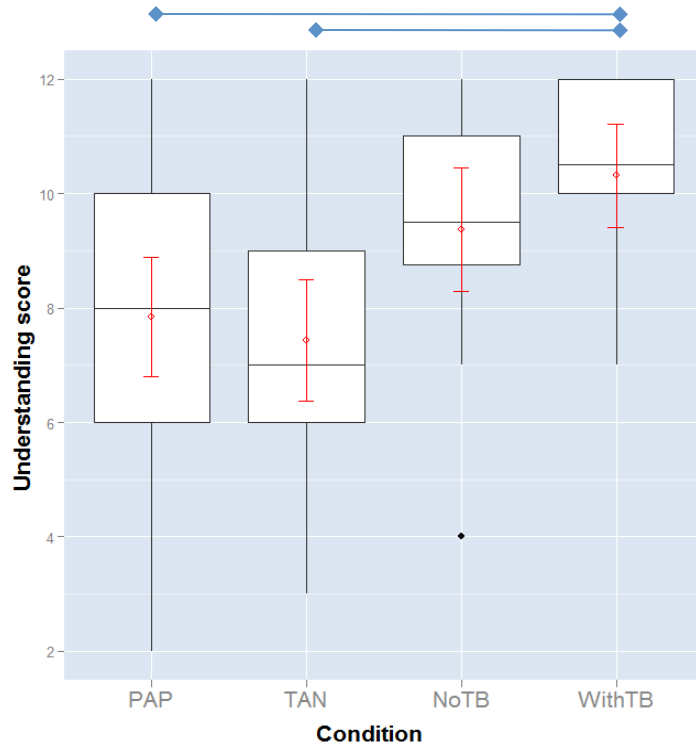
Brute: 256m2
 Brute stock.: 236m2
 Nette: 30m2
 Etagères: 12
 Degré d'util.: 12.6%
 Chariot: gerbeur
 Temps/palette: 115s
 Temps simul.: 0:13:49



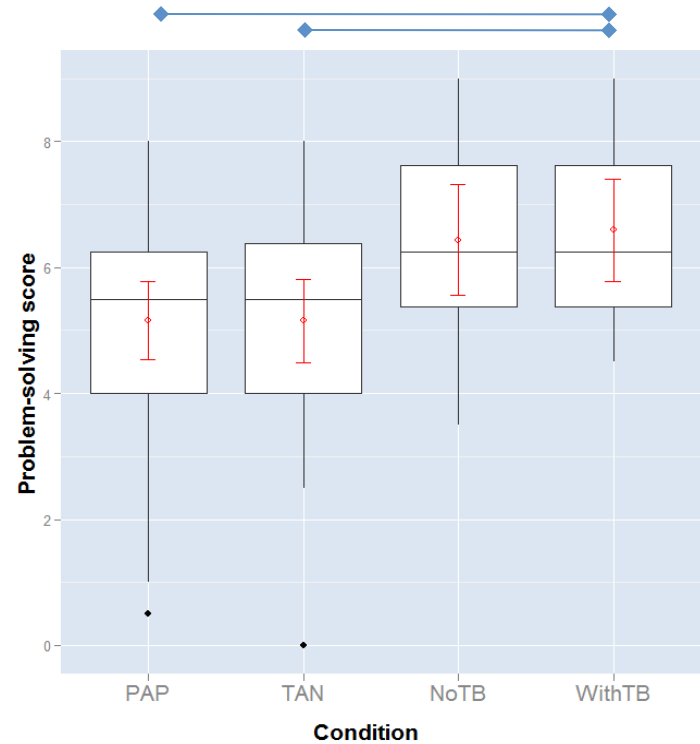
Brute: 256m2
 Brute stock.: 220m2
 Nette: 36m2
 Etagères: 12
 Degré d'util.: 16.4%
 Chariot: gerbeur
 Temps/palette: 130s
 Temps simul.: 0:23:40

Post-test

Sign. effect in understanding



Sign. effect in problem-solving



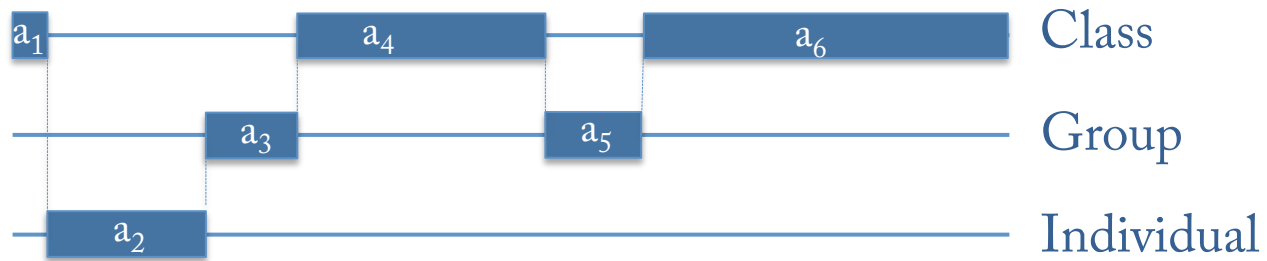
Measures	Warehouse study's conditions		Evaluation of TinkerLamp 2.0 conditions	
	Paper/pen	TinkerLamp 1.0	TinkerLamp 2.0 WithTinkerBoard	TinkerLamp 2.0 NoTinkerBoard
<i>Understanding score</i>	7.84(2.85)	7.43(2.82)	9.38(2.03)	10.31(1.70)
<i>Problem-solving score</i>	5.16(1.70)	5.15(1.78)	6.44(1.65)	6.59(1.53)



Merci DBR,
but why does it work ?



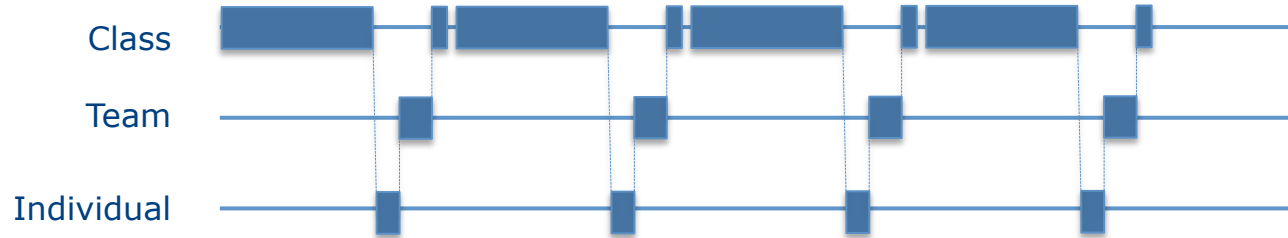
[Step 1] A simple notation...



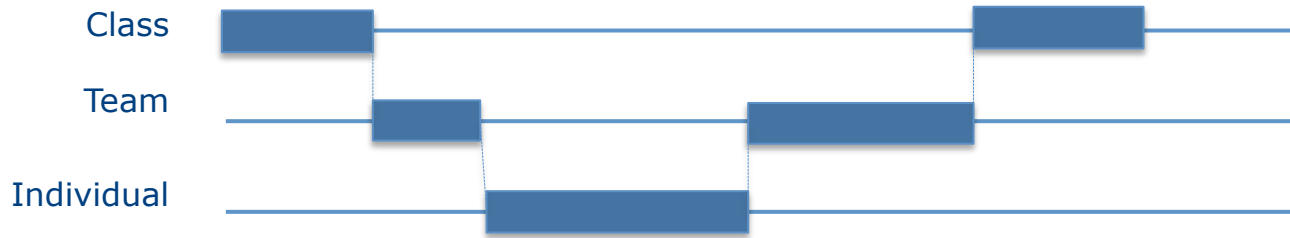
Orchestration is the real-time management of multi-plane multi-layer activity graphs that maximize constraints satisfaction and minimize entropy



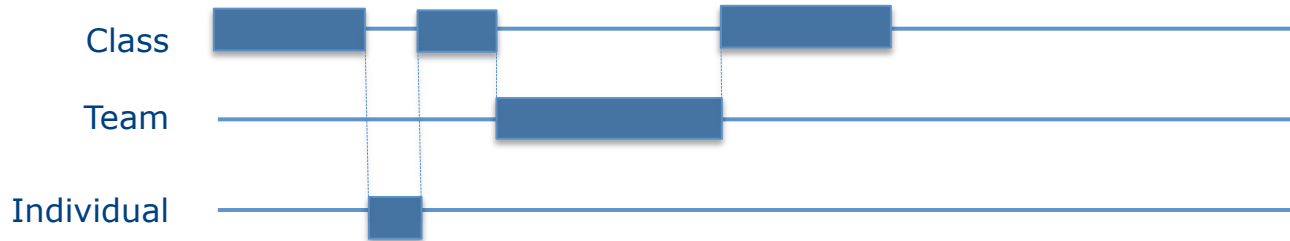
Standard lecture



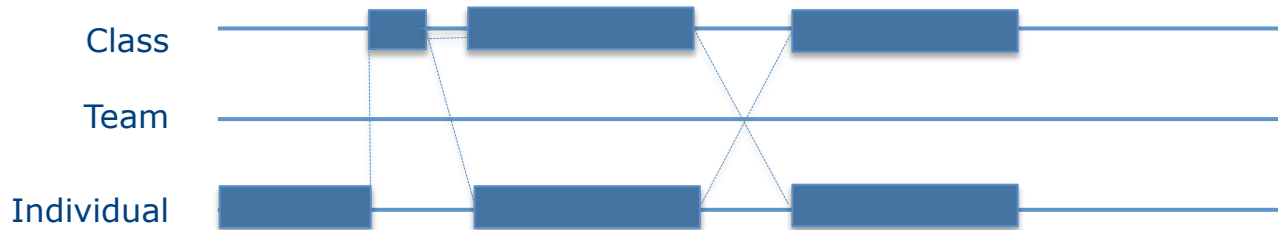
Kiclers+ Lecture
(Mazur's PeerTutoring)



PBL



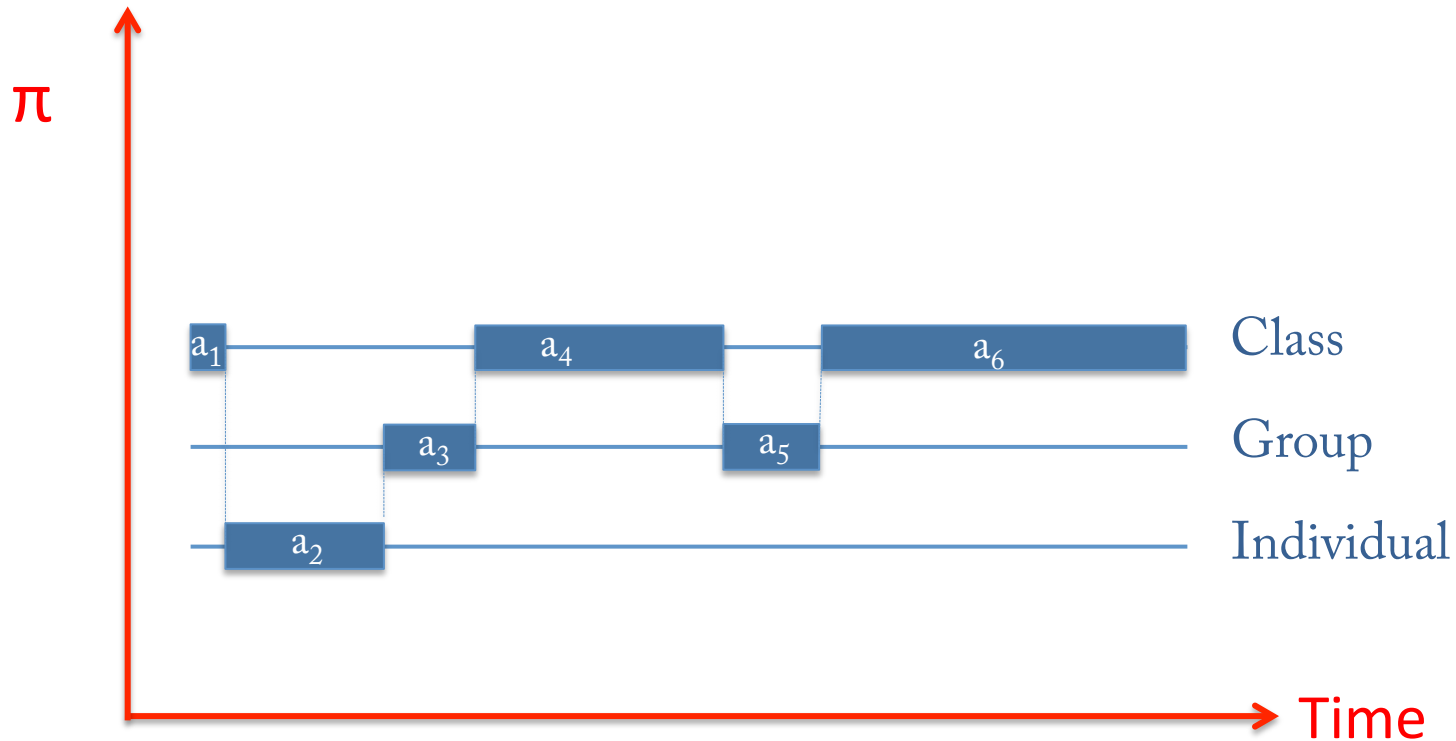
Discovery learning
(Gijlers & de Jong)

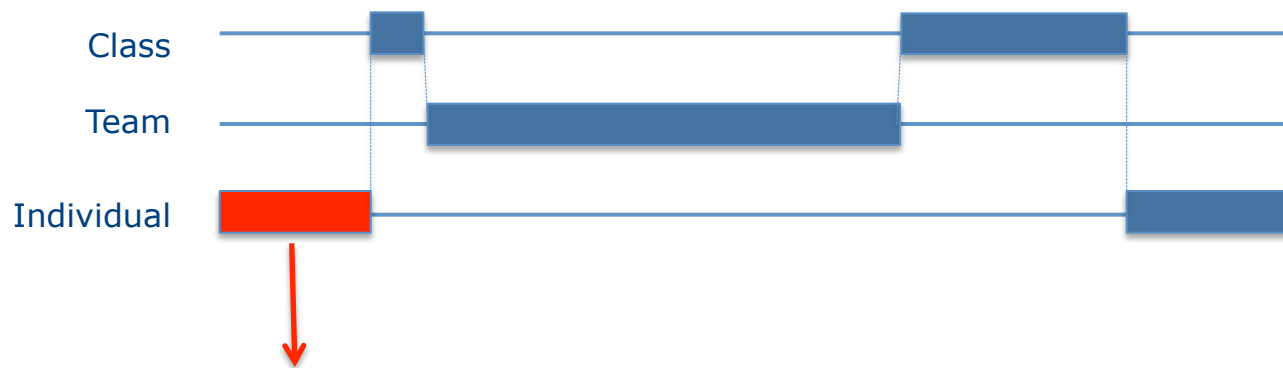


Sub-classes

[Step 1] An **integrated** learning scenario can be modeled as a **directed graph** :

- vertices are learning activities a_i (...)
- edges represent dataflow (...)
- embedded on $\pi \times t$ (...)





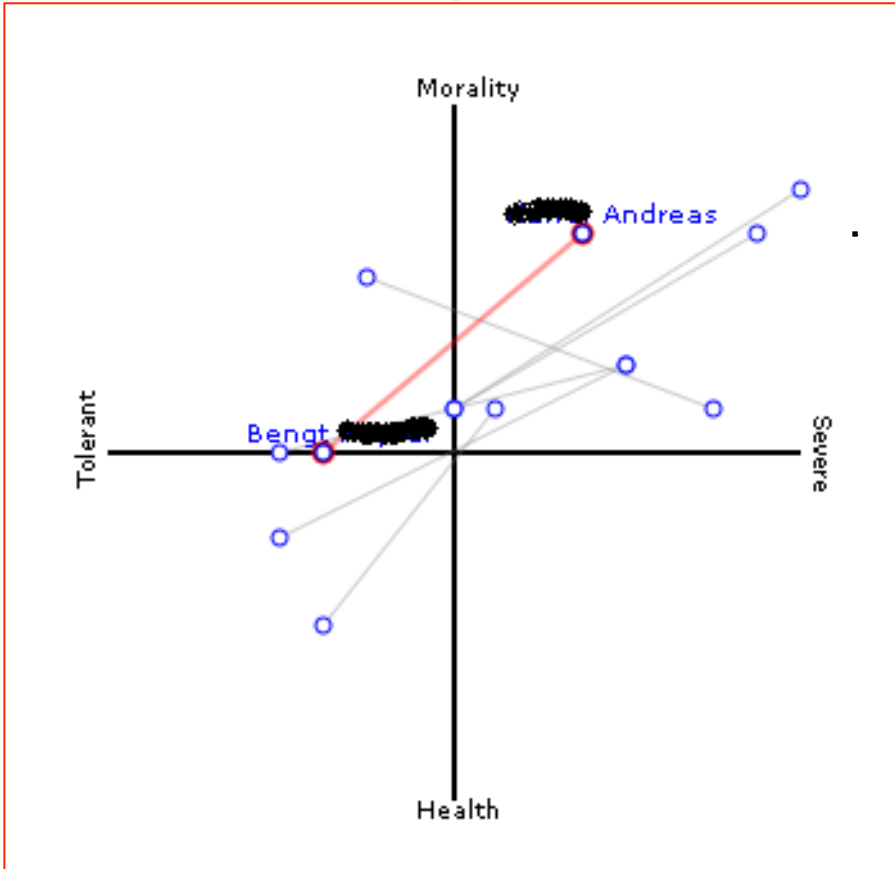
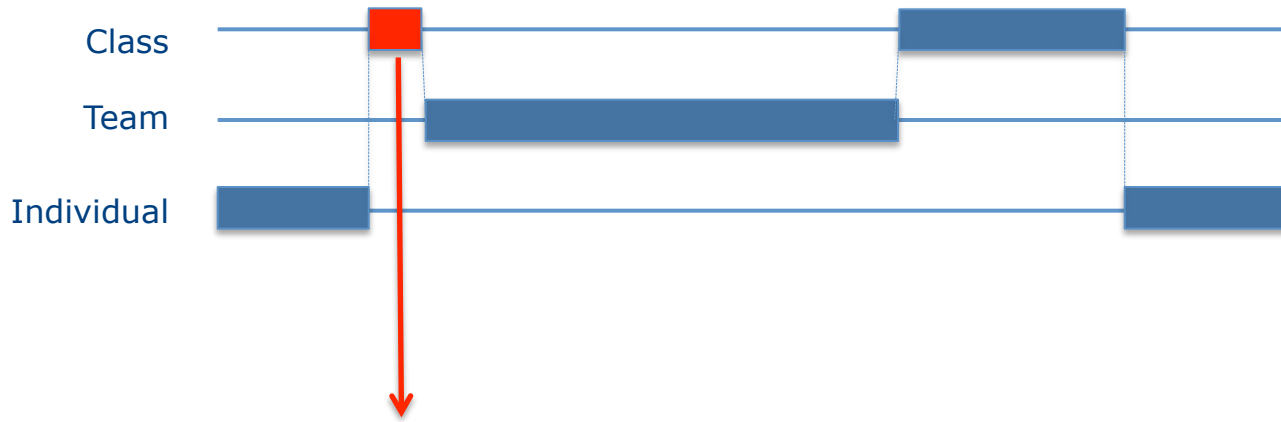
Question 1

Question: *In large city marathons, should drug testing be applied to participants that finish two hours after the winner?*

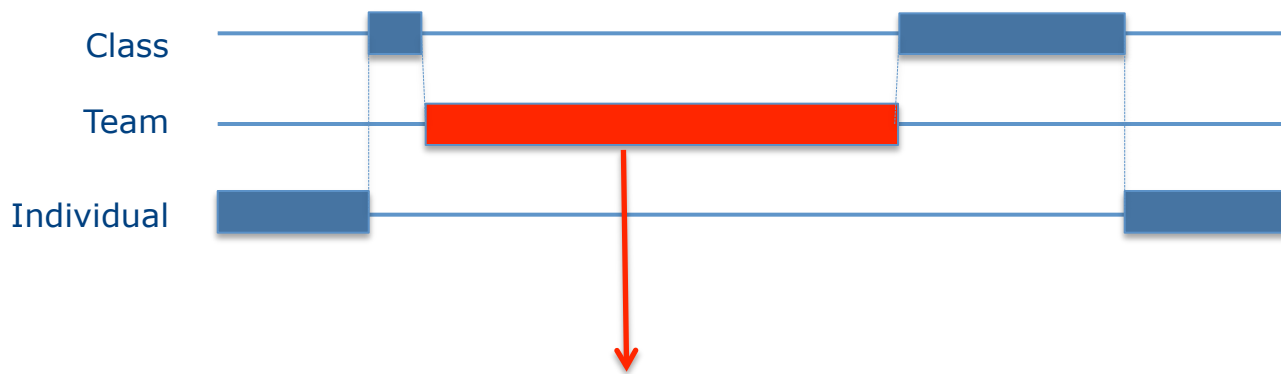
- Answer:**
- Yes, because cheating should always be punished
 - Yes, because any runner taking drugs damages her health
 - No, because they run for themselves, not for rankings
 - No, because people have also the right to smoke and to drink alcohol

Enter your arguments: I believe in individual freedom

ArgueGraph



ArgueGraph



Question 1 :

Question: *In large city marathons, should drug testing be applied to participants that finish two hours after the winner?*

Answer:

- Yes, because cheating should always be punished
- Yes, because any runner taking drugs damages her health
- H No, because they run for themselves, not for rankings
- B No, because people have also the right to smoke and to drink alcohol

Bengt ~~XXXXXXXXXX~~

None

Harrer ~~XXXXXXXXXX~~

For the people that are not relevant for the result lists, it's their own responsibility if they risk damage to their health. Yet, still they are cheating the other clean runners. To require a test from every amateur (while

Enter your arguments:

We consider self-responsibility an important quality for sportlers. Yet, it does not apply to participants getting prize or medals.

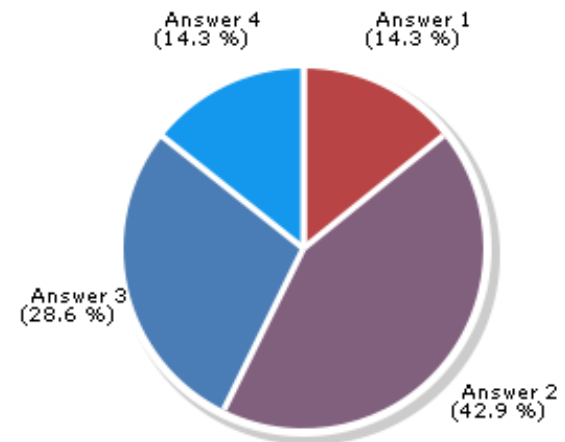
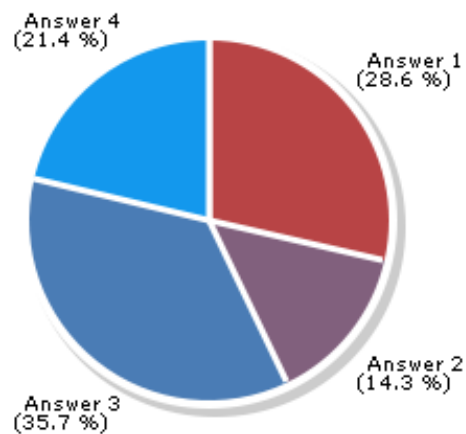


Question: In large city marathons, should drug testing be applied to participants that finish two hours after the winner?

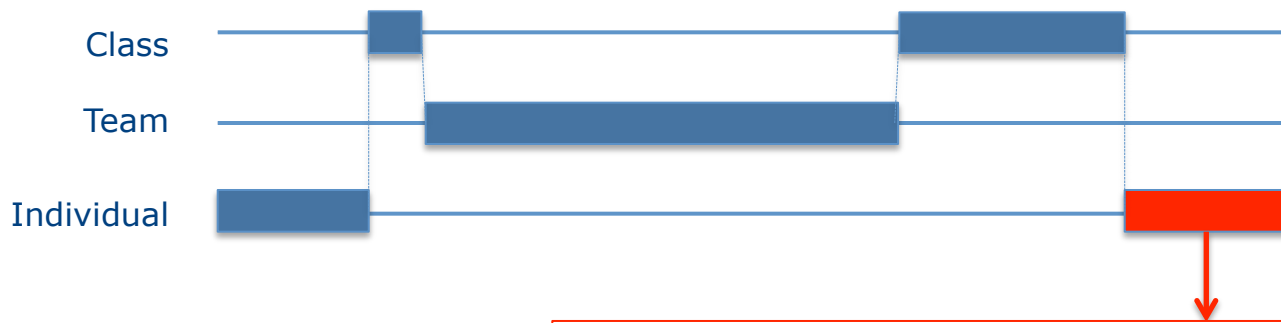
- Possible answers:**
- 1) Yes, because cheating should always be punished
 - 2) Yes, because any runner taking drugs damages her health
 - 3) No, because they run for themselves, not for rankings
 - 4) No, because people have also the right to smoke and to drink alcohol

Solo

Duo



ArgueGraph



Question 1 : *In large city marathons, should drug testing be applied to participants that finish two hours after the winner?*

Your answer and synthesis of known arguments :

Reminder

Individual :

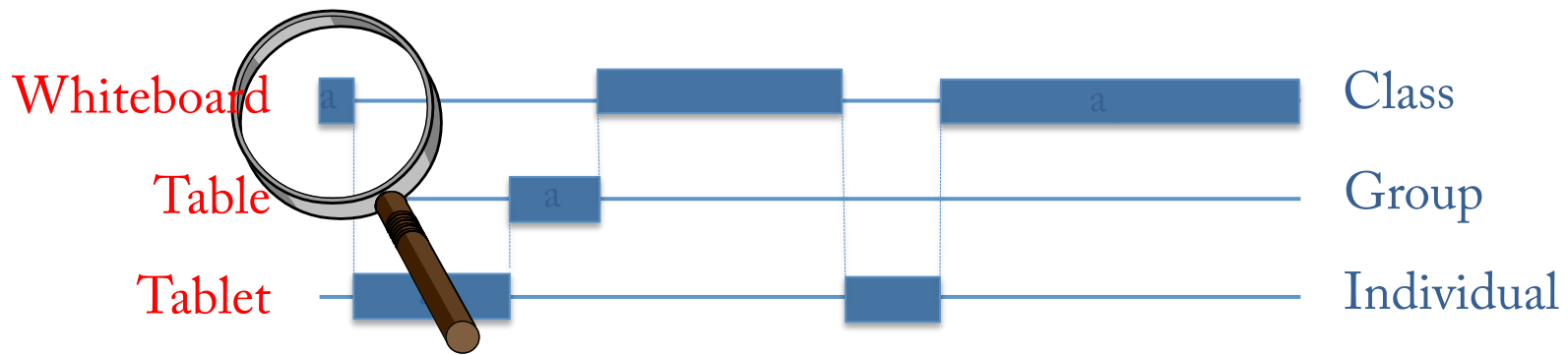
Your arguments :

None

Individual arguments of students :

- No one would ever make the effort to run a marathon without being on drugs. *from [redacted] Nils*
- Someone who is two hours late this time could be the winner next time and the run before; in addition, it does not exclude drug use *from Frank [redacted]*
- For the people that are not relevant for the result lists, it's their own responsibility if they risk damage to their health. Yet, still they are cheating the other clean runners. To require a test from every amateur (while probably almost all of them are clean) would setup a system of total control and non-trust. *from [redacted] Andreas*
- Cheating should always be punished but in particular when it is useless. *from Pierre [redacted]*
- Even though a person runs a marathon for herself, she should be in favor of banning the use of drugs and willingly take the test *from Pantelis [redacted]*
- You should make sure that the winners do not use drugs. No need to test the losers who are rather running for themselves. *from Armin [redacted]*

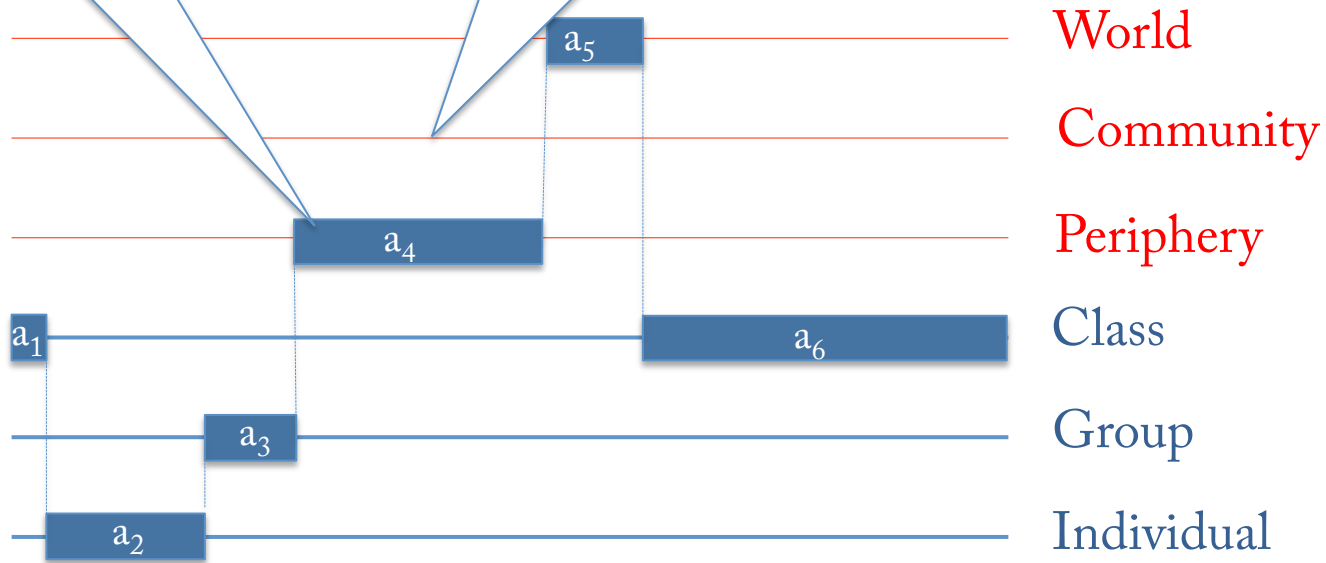
ArgueGraph



Pedagogical integration + Technological integration

Stable relationship: other classes, parents, director, ...

Event specific relationship: museum guide, butcher, ...

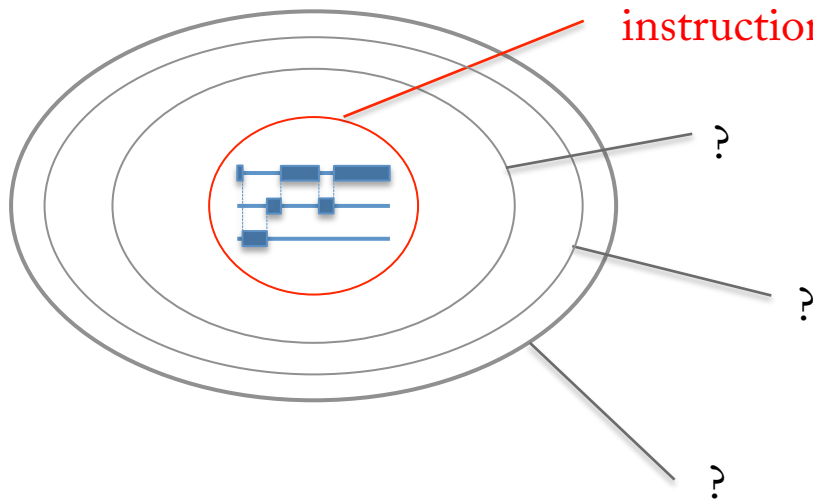
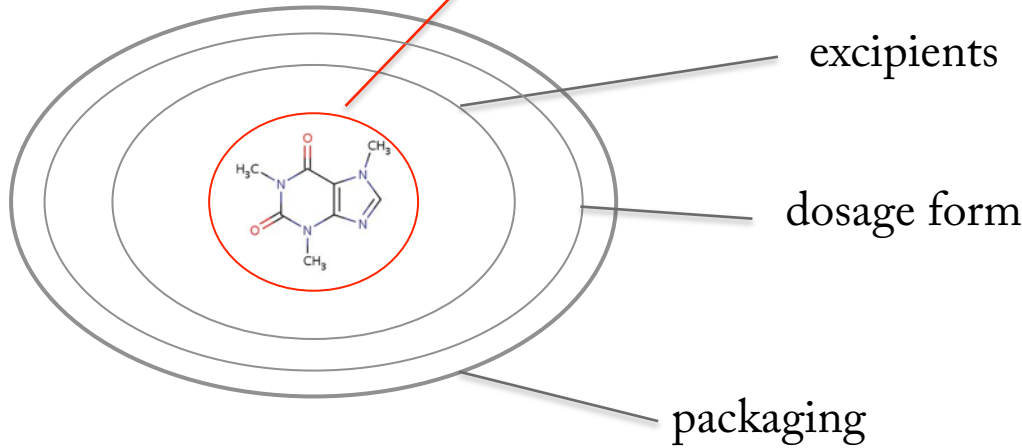


pedagogical + technological integration

[Step 2] How to package Alzheimer pills ?



active substance (pharmaceutics)



Anziadherents

Binders

Pill, tablet, or capsule

Coatings

Specialty tablet like buccal, sub-lingual, or orally-disintegrating

Disintegrants

firm for Listerine Pocketpaks)

Fillers

Liquid solution or suspension (e.g., drink or syrup)

Flavours

Powder for liquid or solid crystals

Inhalants

Natural or herbal plant, seed, or food of sorts (e.g., marijuana such as that found in "special brownies")

Moisturizers

Pastes (Gaglets)

Oral

Oral

Oral

Oral

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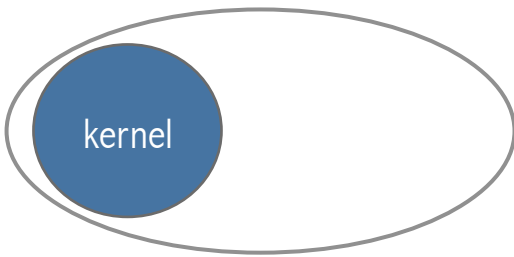
Oral

Oral

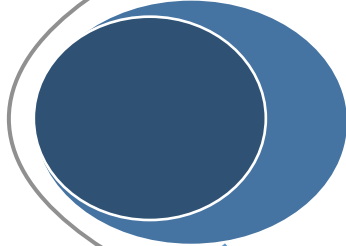
Oral

Oral

Oral



[Step 2] Kernel activities ● are designed from learning theories while orchestration also covers other activities ○, **less directly** related to instructional design, **but should nonetheless be technically integrated.**



Debriefing activities
(designed but undetermined)

re-visit

homework

copy

Nom complet: *Rossio Eddy*
Classe: *4/2/1*

A. Analyse de 4 entrepôts

Regardez le meilleur plan d'entrepôt de chacun des 4 groupes de la classe.

1. Quel plan est le meilleur en ce qui concerne:

- Surface brute: 1
- Surface nette: 2
- Nombre de étages: 2
- Degré d'utilisation: 2
- Temps par palette: 3

2. Quel plan est le meilleur en général? Pourquoi?

4. Malgré le degré d'utilisation plus bas que celui de 2, le 4 a un local amorce, on fait moins de temps/palette avec des amorce plus rapides et on a une surface nette qui est considérablement plus grande que celle du 3, qui utilise judicieusement des "contre-poids" qui occupent plus de place.

B. Comparaison avec votre entreprise.

Discutez de ces questions avec votre superviseur et écrivez vos explications.

1. Le meilleur plan vous avez choisi (question A.2) est-il similaire au plan de votre entreprise (degré d'utilisation, mise en place, etc.) en place. On a plus d'angles (matériaux, contre-poids, ascenseurs) et plus de surface, et on est une entreprise de production donc moins de degré d'utilisation par rapport au stock.

2. En général, lequel de ces 4 plans est le plus proche de votre entreprise (degré d'utilisation, mise en place, etc.) de 2, en comparant avec une de nos halles. On a remarqué que la mise en place des étagères est assez ressemblante si l'on déplace les quais perpendiculairement aux deux files d'étagères horizontales. Pour prélever la marchandise dans les étagères, on utilise un préparateur de commandes au lieu des chariots élévateurs.

3. En général, lequel de ces 4 plans est le plus différent de votre entreprise (degré d'util., mise en place, etc.) de 3, car les quais se trouvent au centre de l'entrepôt, on a plus d'étagères et plus le plan est difficilement comparable à nos halles de logistique.

➤ 90% (54/60) done

➤ 82% discussed with supervisor



Surfaces de stockage

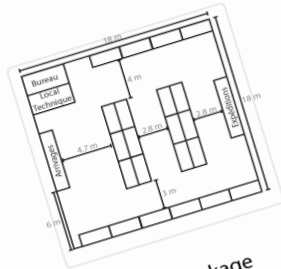
Le stockage

1

- 1) Implantez l'entrepôt dont le plan est dessiné sur la figure ci-contre.



Entrepôt



- 2) Reportez les valeurs des surfaces de stockage dans les cases prévues de la feuille de travail ci-contre.
Que pensez-vous du degré d'utilisation de cet entrepôt?



Surfaces de stockage

Surf. brute = largeur x hauteur = x = m²

Surf. brute de stockage = Surf. brute - locaux annexes = - = m²

Surf. nette de stockage = Surf. brute de stockage - Allées de circulation = - = m²

Surf. nette de stockage = Nombre d'étagères x Surf. d'une étagère = x = m²

Degré d'utilisation = $\frac{\text{Surf. nette de stockage}}{\text{Surf. brute de stockage}}$ = %

Comment pourriez-vous l'augmenter? Pourquoi est-ce important?



Exploitation

- 3) Simulez 30 minutes de travail avec 1 gerbeur, et reportez les valeurs dans les cases prévues ci-contre.
Combien faudrait-il de gerbeurs pour sortir 100 palettes en 1 heure?

A votre avis, quel est le type de chariot le plus efficace dans cet entrepôt?

Chariots élévateurs

Type

Gerbeur

Mat rétract.

Contrepoids

Nombre

1

2

3

4

5

ABC: oui non

Heure:

Par jour:

Palettes sorties:

Article 1:

Article 2:

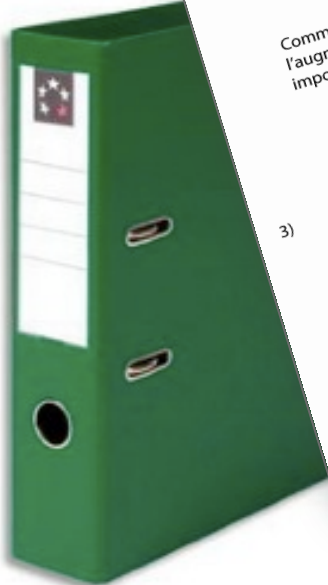
Article 3:

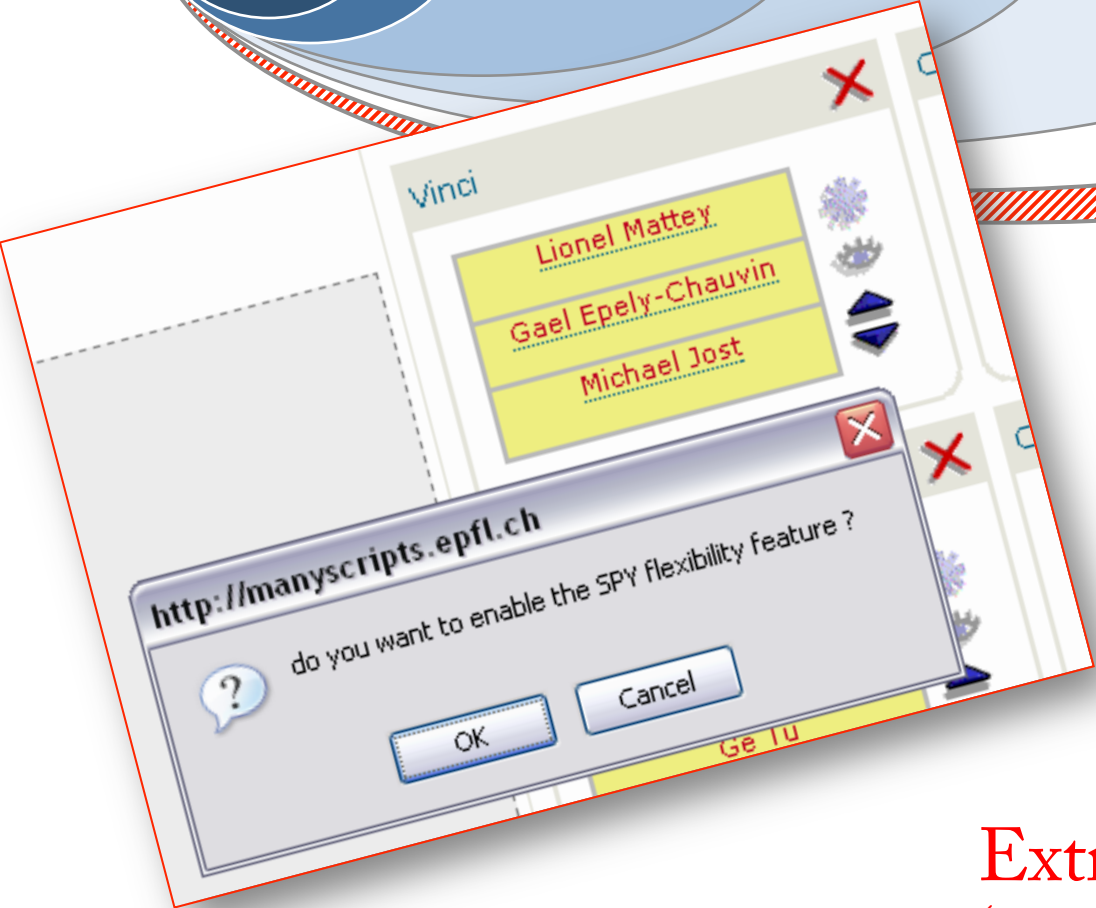
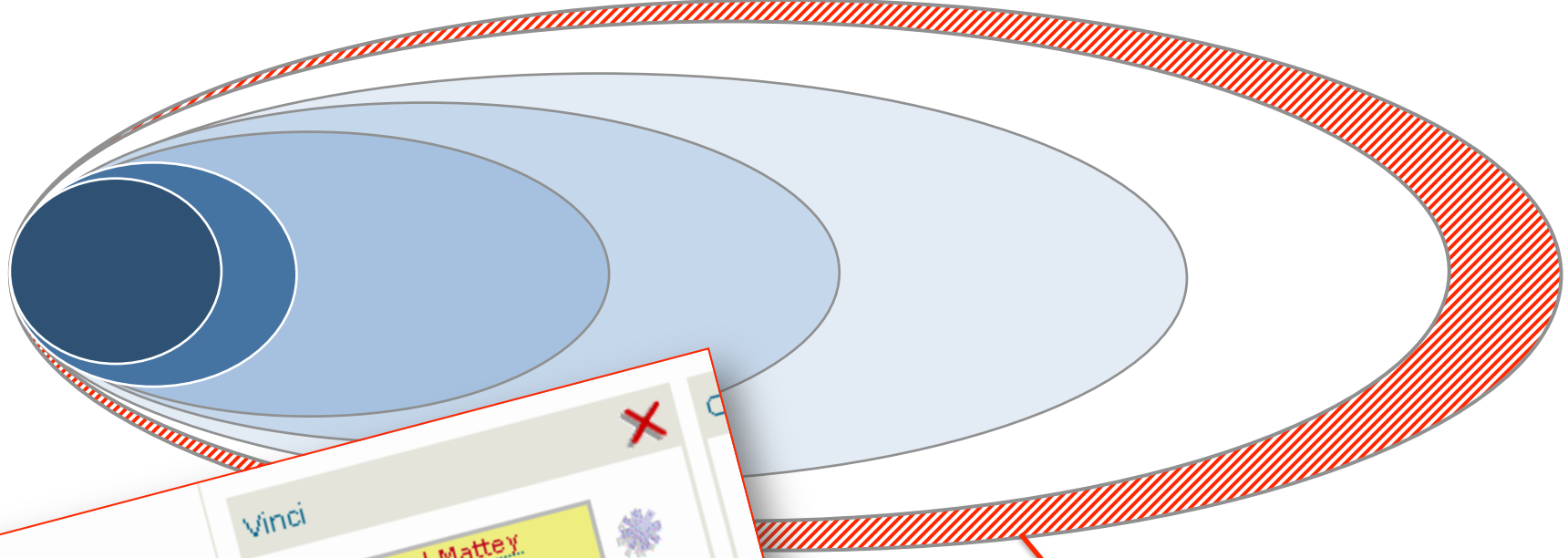
Temps moyen par palettes (sec.):



Login
Move tables
Distribute

Logistics activities
(not designed but necessary)





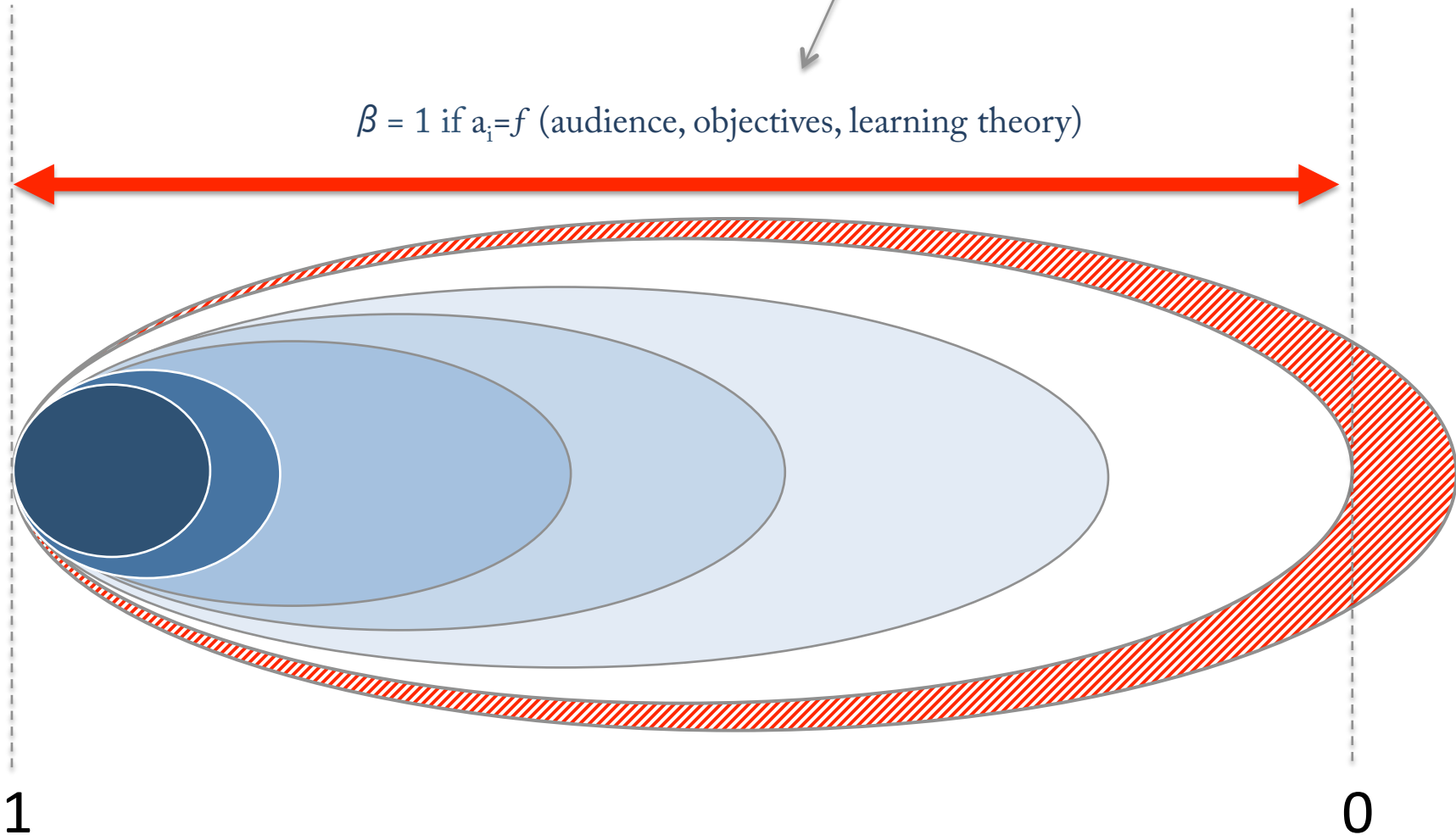
Sick / drop-out
Network failure
Eureka !
Fire
Crane

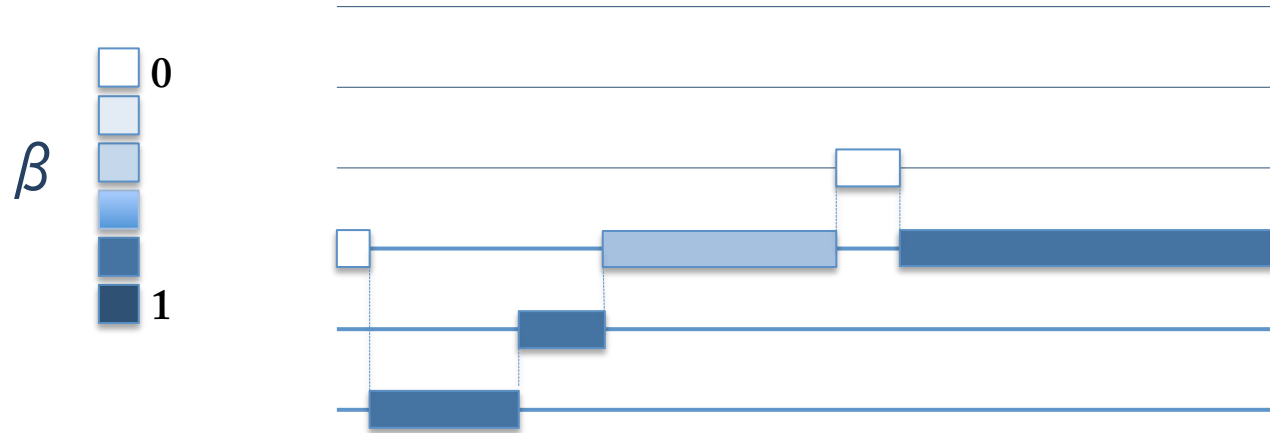
Extraneous events
(unavoidable)

[Step 2] Kernel activities are designed from learning theories while orchestration also covers other activities, less directly related to instructional design.

‘ β loominess’

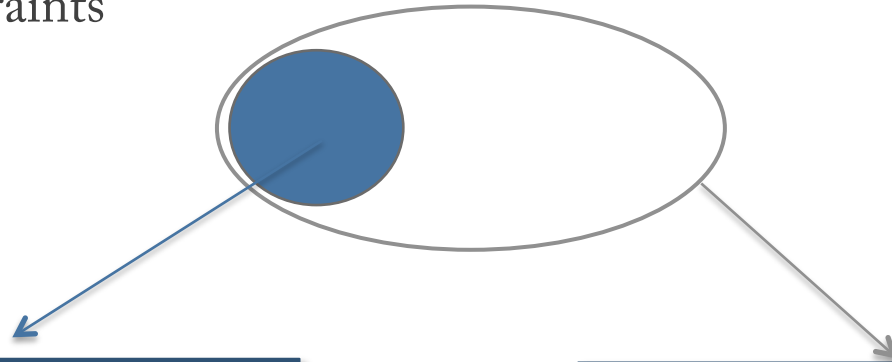
$\beta = 1$ if $a_1 = f$ (audience, objectives, learning theory)





$a_i : (\pi, t, \beta, \underbrace{\text{input, output}^*, \text{tools, resources, instructions, \dots}}_{\text{IMS-LD}})$

[Step 3] The activity graph must satisfy intrinsic as well as multiple extrinsic constraints



Intrinsic constraints

- Students' profiles
- Domain epistemology
- **How people learn**
- Curriculum relevance

Extrinsic constraints

- Time budget (t)
- Time segmentation
- Resources
- Control
- Space
- Costs
- Producing grades
- leaving traces
- Safety
- Teacher's energy
- Teacher's self-image
- School culture
-

Extrinsic constraints

- Time budget (t)
- Time segmentation
- Control
- Resources
- Space
- Costs
- Producing grades
- Leaving traces
- Safety
- Teacher's energy
- Teacher's self-image
- School culture
-



Groups Progression

Students answers:

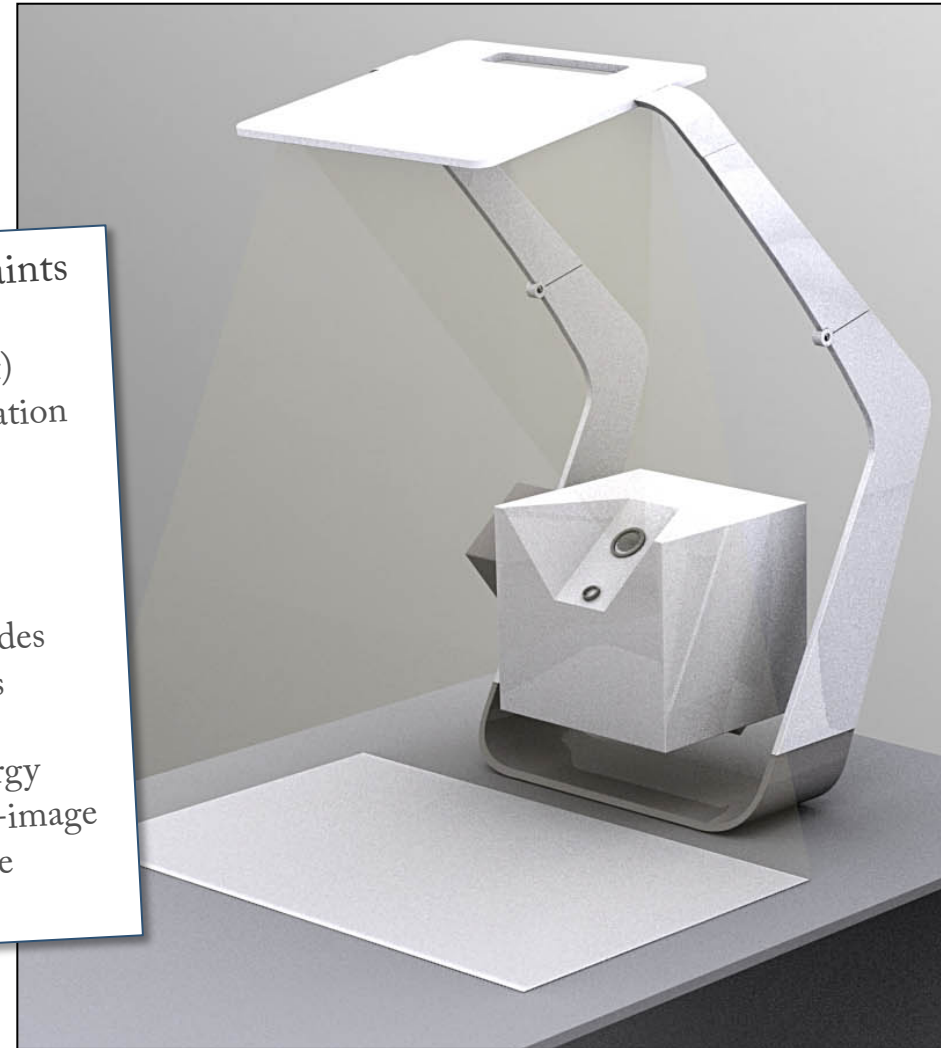
Name	Questions	~Words per questions
Armin [REDACTED]	<input type="text"/> (4/4)	22
Frank [REDACTED]	<input type="text"/> (4/4)	24
Bengt [REDACTED]	<input type="text"/> (4/4)	0
Pierre [REDACTED]	<input type="text"/> (4/4)	11

ByPass

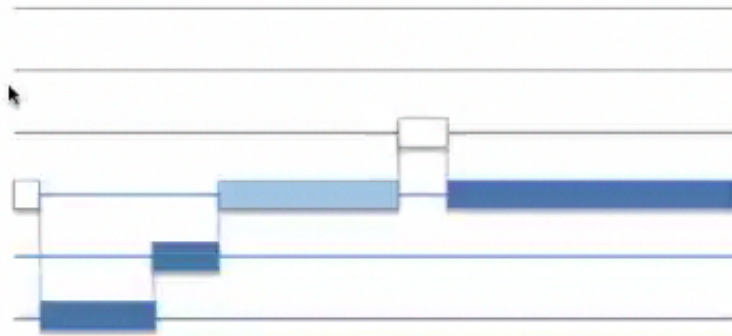


Extrinsic constraints

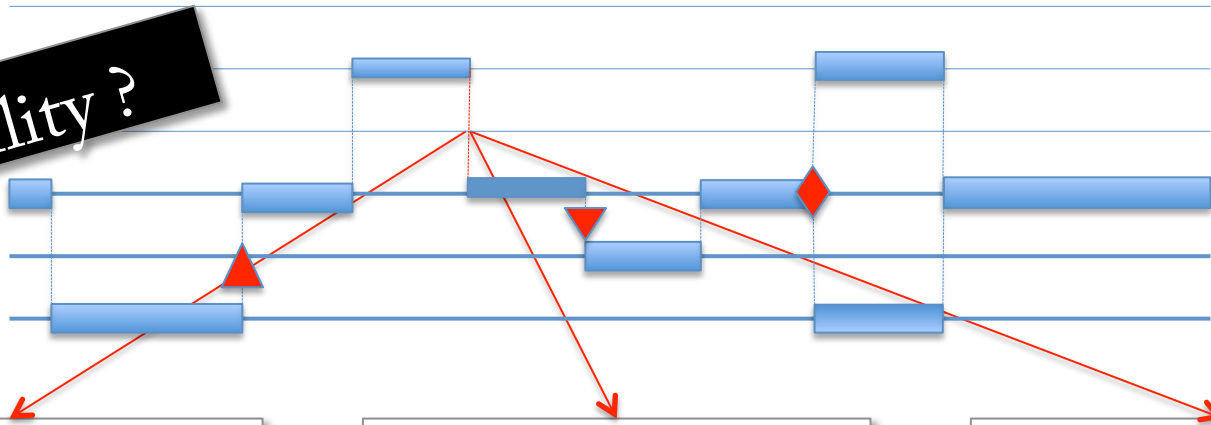
- Time budget (t)
- Time segmentation
- **Control**
- Resources
- Space
- Costs
- Producing grades
- Leaving traces
- Safety
- Teacher's energy
- Teacher's self-image
- School culture
-



[Step 4] The activity graph must be permanently **adapted** to learners' behavior as well as to extrinsic constraints and events.



Flexibility ?



Fiber = $R (a_i \rightarrow a_j)$

Strength = $1 - p (a_j | \neg a_i)$

Elasticity = $f (t_i, t_j)$

time decay

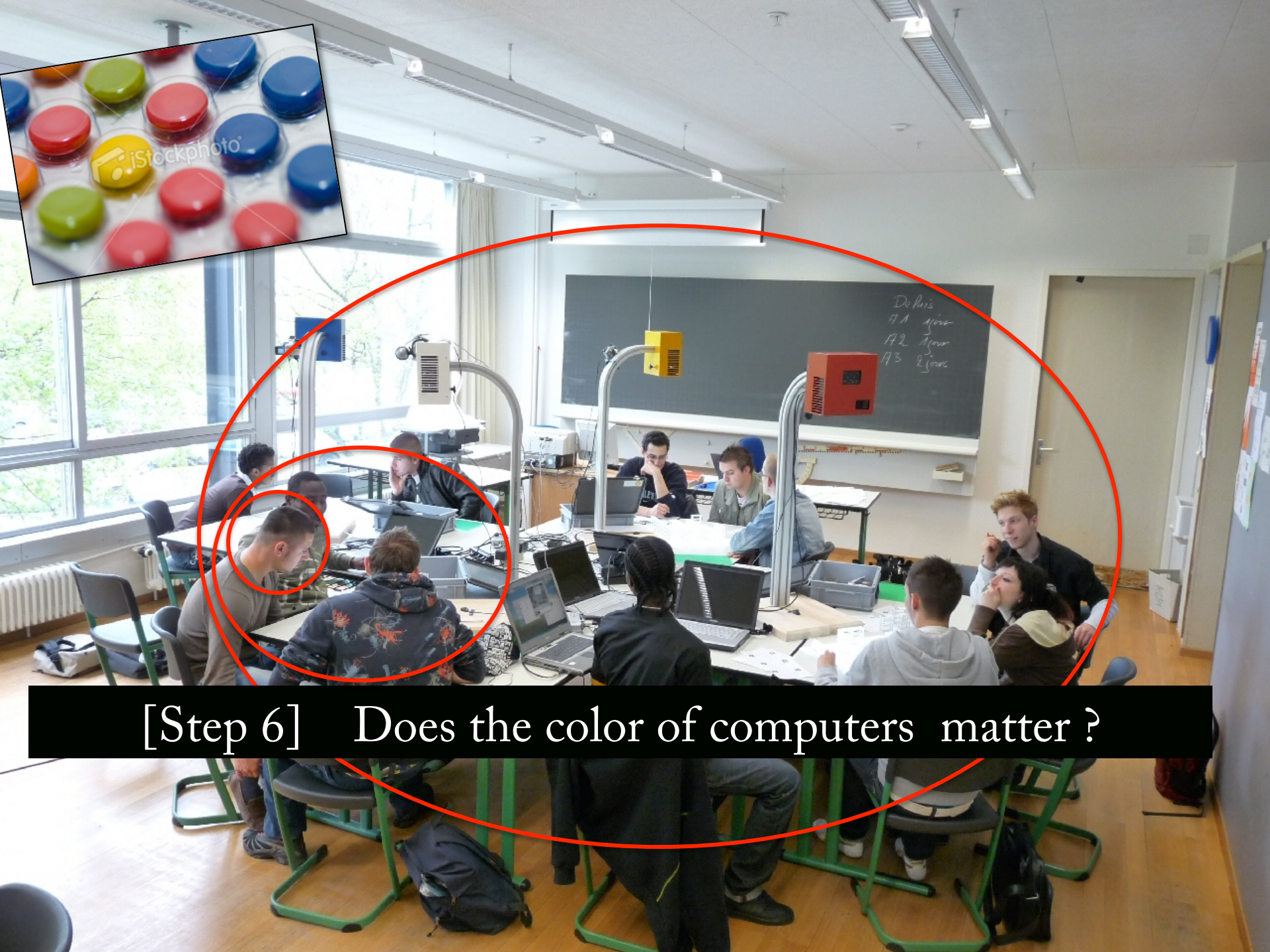
Pre-requisite	students acquire in a_i skills they need for a_j
Advance organizer	a_i pre-activates cognitive structures for a_j
Didactic contract	a_i presents teacher's expectations about a_j
Motivation	a_i motivates learners for a_j
Logistics	a_i sets up the environment for a_j
Dataflow	input (a_j) = f (output (a_i))

Operators input (a_{i+1}) = f (output (a_i))

▲	Aggregation	e.g. collect data for debriefing
▼	Distribution	e.g. JIGSAW set up
	Group formation	e.g. form heterogenous pairs
	Group rotation	e.g. reciprocal teaching
◆	Feedback	input for a_{i+1} is teacher's FB on a_i
	Decision	e.g. level groups

[Step 5 / HCI] A 'flexible workflow' is a paradox that can be addressed by physical 'handles' on digital structures (cf. step 7).



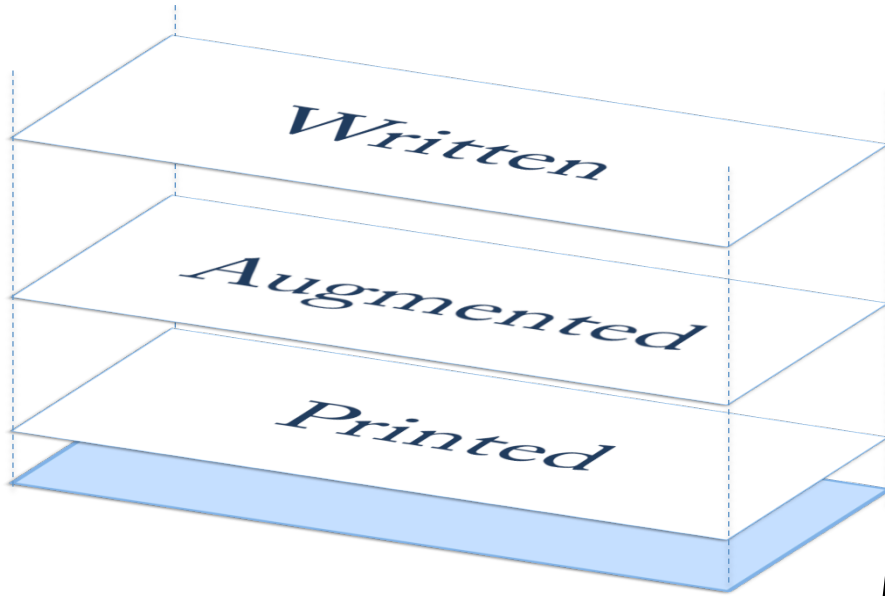


[Step 6] Does the color of computers matter ?

[Step 6] Orchestration is usability when the user is the classroom.

	User	Constraints
Circle 3	Classroom	<i>Discipline, time, energy, reporting...</i>
	<i>Hutchins</i> Cockpit	
Circle 2	Group	<i>Interdependence, WYSIWIS,...</i>
Circle 1	Individual	<i>Cognitive load, pre-requisites,...</i>

[Step 7] The graph expands on information layers: $ag = \pi \times t \times l$



The photograph shows a hand holding a silver marker, writing on a worksheet titled "INDIVIDUAL FIELDWORK SHEET". The worksheet contains the following sections:

- 1. Consider 4 layouts**
Look at the 4 best layouts you and other groups built during the class.
Which one is your favorite? Why?
I like the first one.
Because it is the fastest.
Forklifts can move faster.
- 2. Fill the blanks**
Fill in the blanks in the Prediction column.

	Prediction	Solution
1. Biggest Net surface is layout	4	<input type="checkbox"/>
2. Biggest Raw surface is layout	3	<input type="checkbox"/>
3. Biggest Utilizat. degree is layout	<input type="checkbox"/>	<input type="checkbox"/>
4. Fastest Avg speed is layout	<input type="checkbox"/>	<input type="checkbox"/>

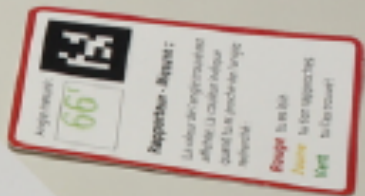
3. Compare with your company
Which one of the 4 layouts is most different to your company. Discuss this issue with your supervisor and write down your answer.

.....
.....
.....
.....
.....
.....
.....

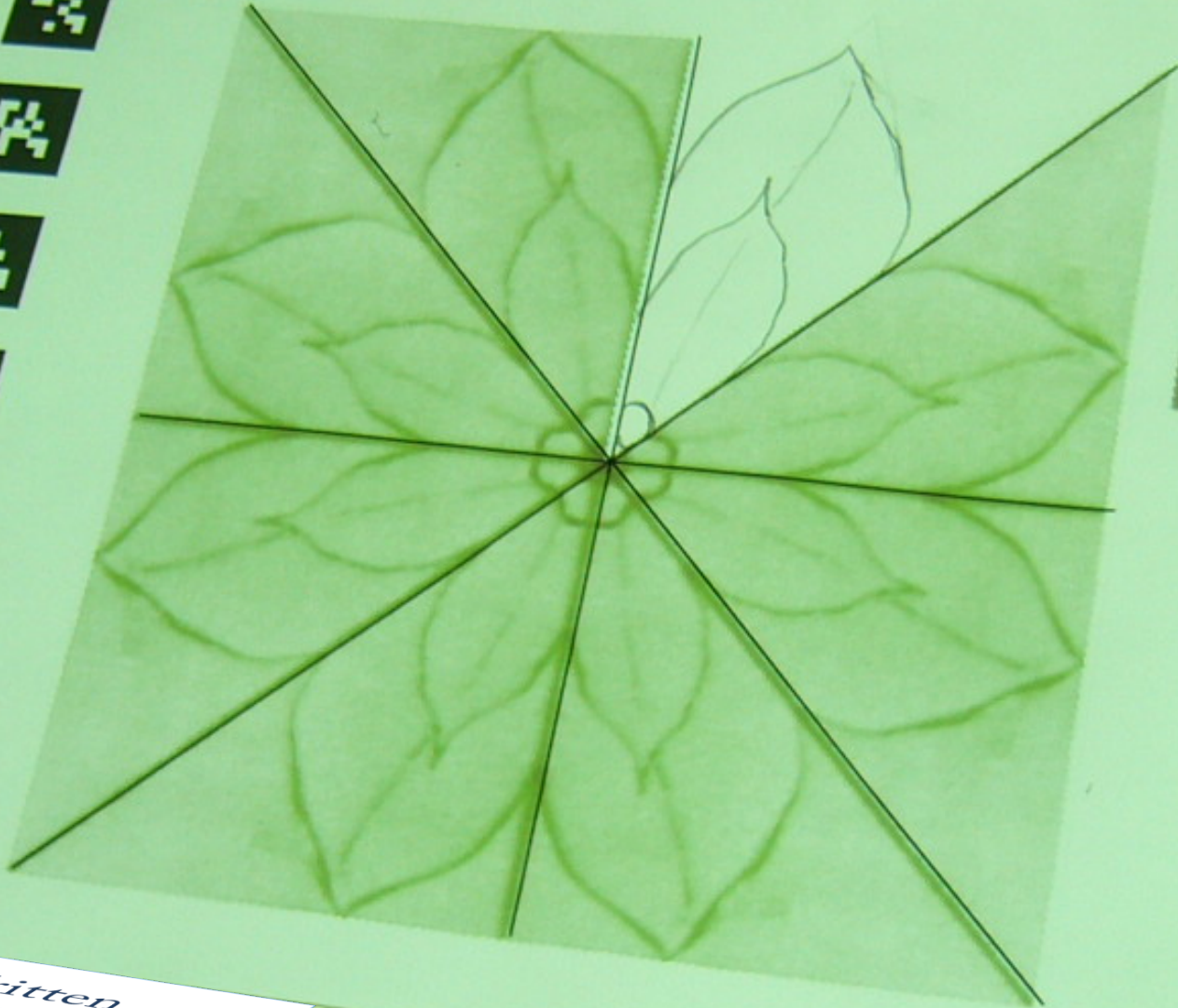
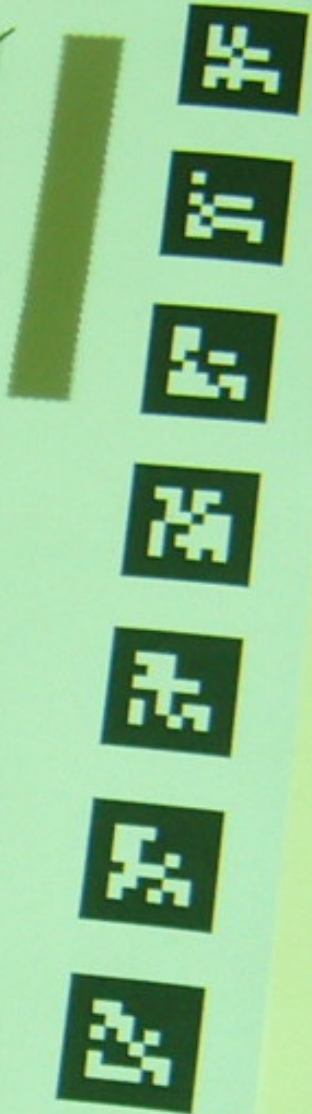
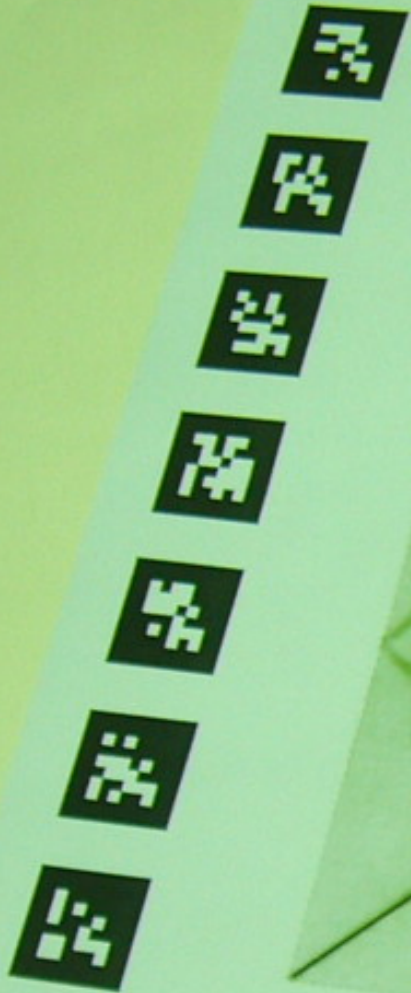
I. Mesure d'angles

- 1) Fais apparaître un trait passant par le point P et faisant un angle de 30° du côté B. Mesure l'angle résultant du côté A et note la valeur trouvée dans la grille, ainsi que la somme des deux angles A+B.
- 2) Refais la même procédure avec un angle de 60° , 90° et 135° . Que peux-tu dire sur la somme des deux angles ?

A	B	A+B
65°	125°	170°
30°	90°	120°
135°		



Written
Augmented
Printed

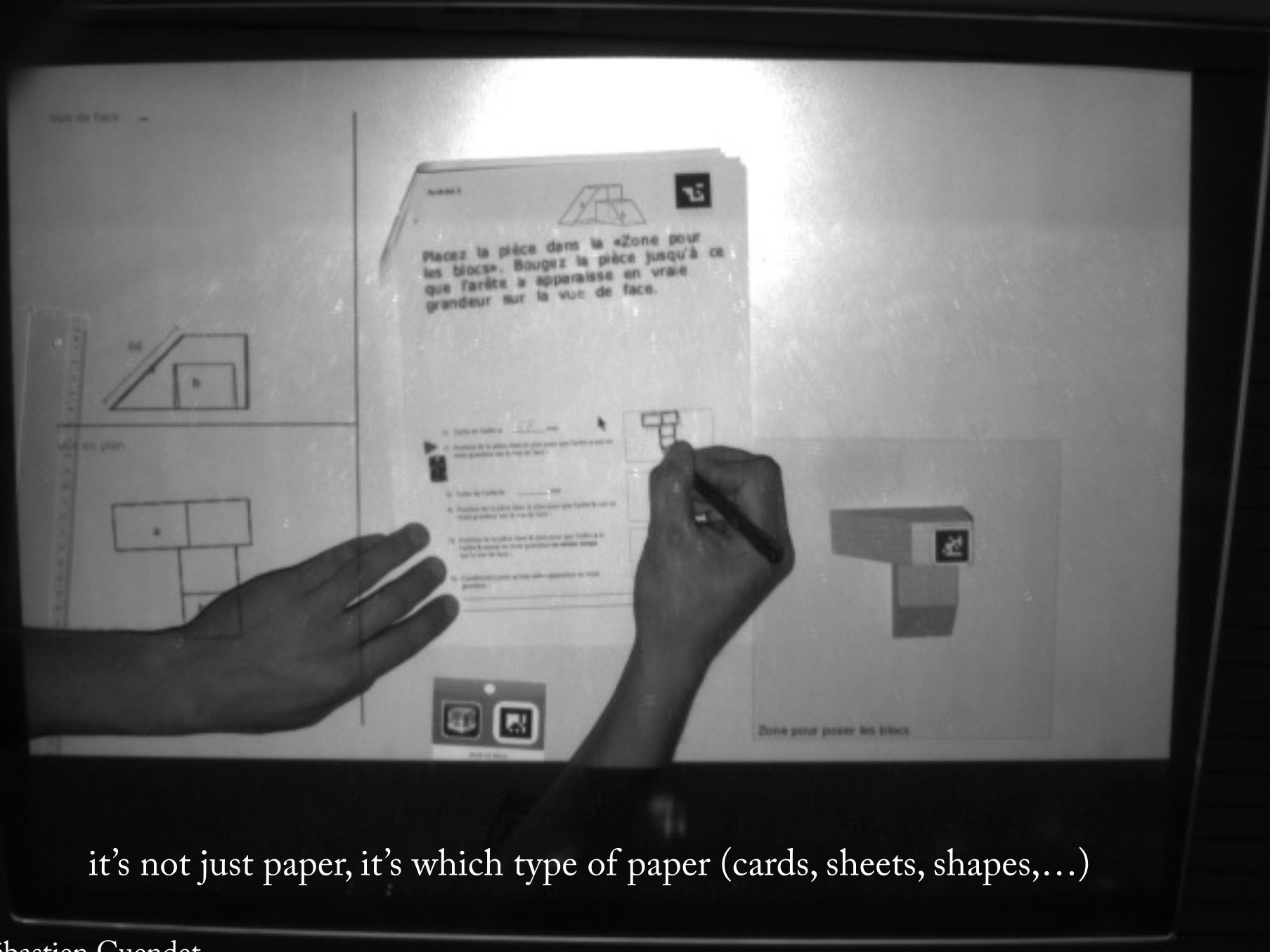


Written

Augmented

Printed

**Augmented reality environment
for the training of carpenters**



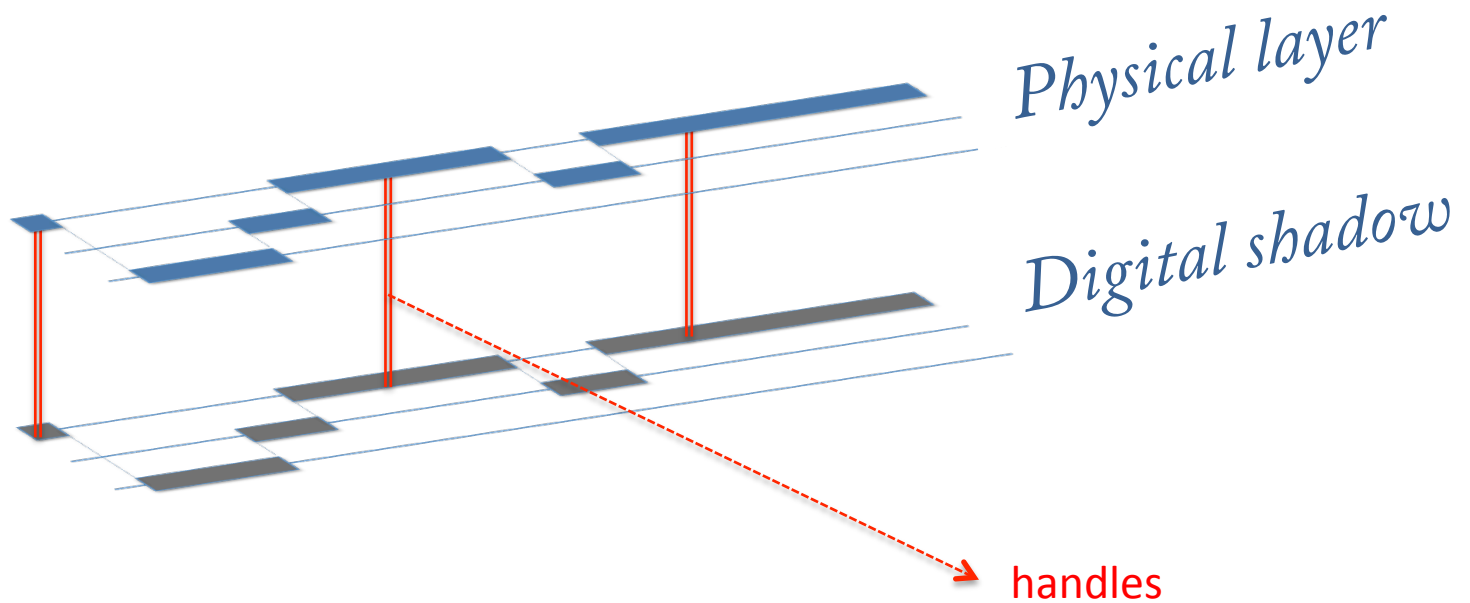
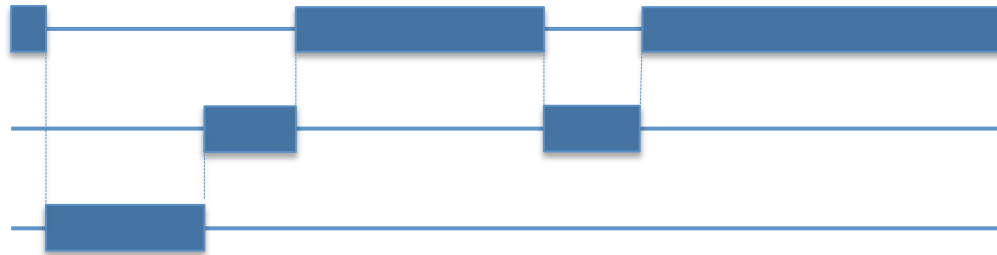
Placez la pièce dans la «Zone pour les blocs». Bougez la pièce jusqu'à ce que l'arête à apparaître en vraie grandeur sur la vue de face.

- 1) Taille de l'arête à ...
- 2) Position de la pièce dans le plan pour que l'arête se voit en vraie grandeur sur la vue de face.
- 3) Taille de l'arête de ...
- 4) Position de la pièce dans le plan pour que l'arête se voit en vraie grandeur sur la vue de face.
- 5) Position de la pièce dans le plan pour que l'arête se voit en vraie grandeur sur la vue de face.
- 6) Position de la pièce dans le plan pour que l'arête se voit en vraie grandeur sur la vue de face.

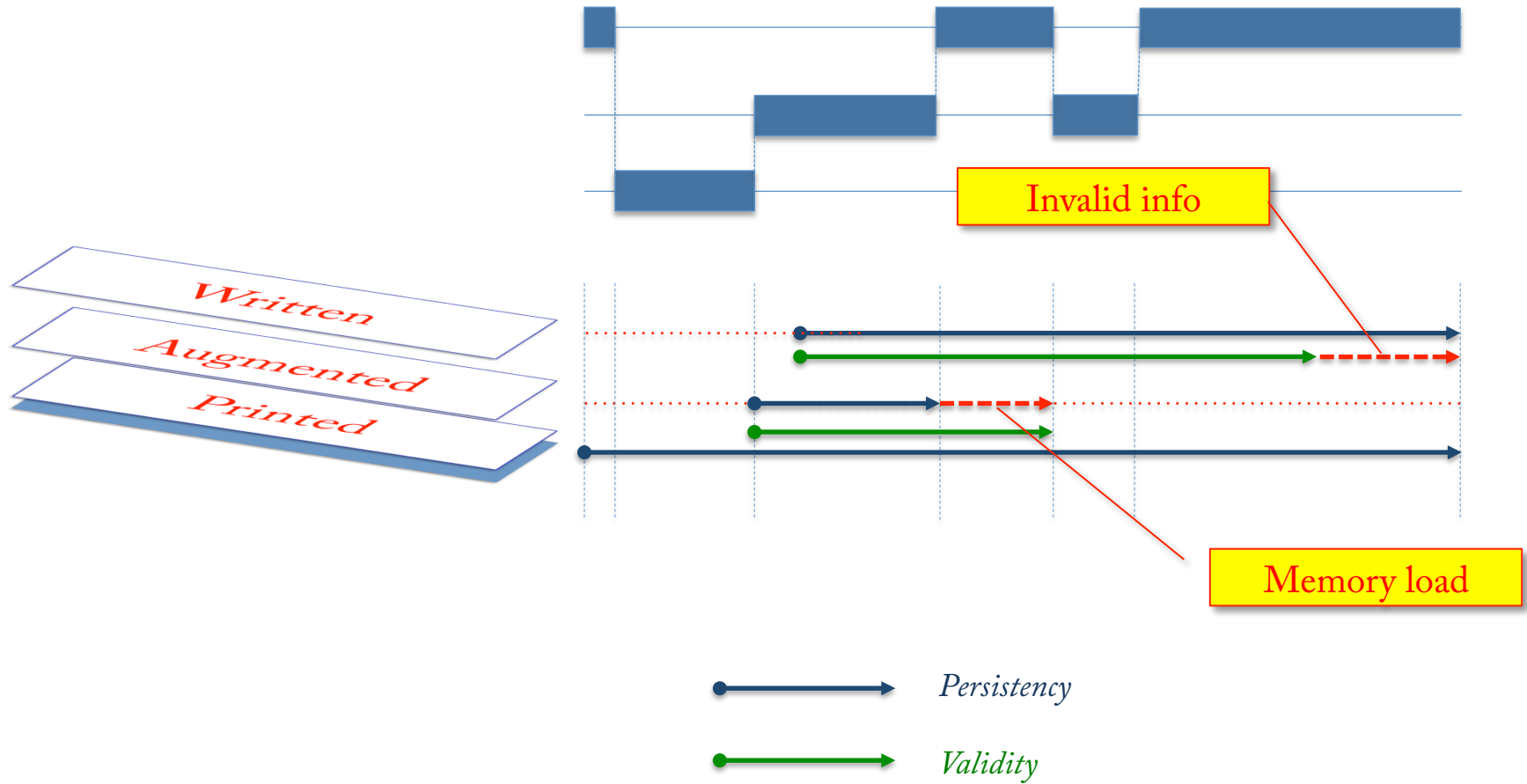


it's not just paper, it's which type of paper (cards, sheets, shapes,...)

[Step 7] An activity graph has 2 layers, physical & digital, which are connected by 'handles'.



[Step 8] Information layers differ in terms of information persistency.



[Step 9] By making visible what would otherwise be invisible, buffers increase persistency of information.



Physics 101: Exercises Session



Problems are delicious



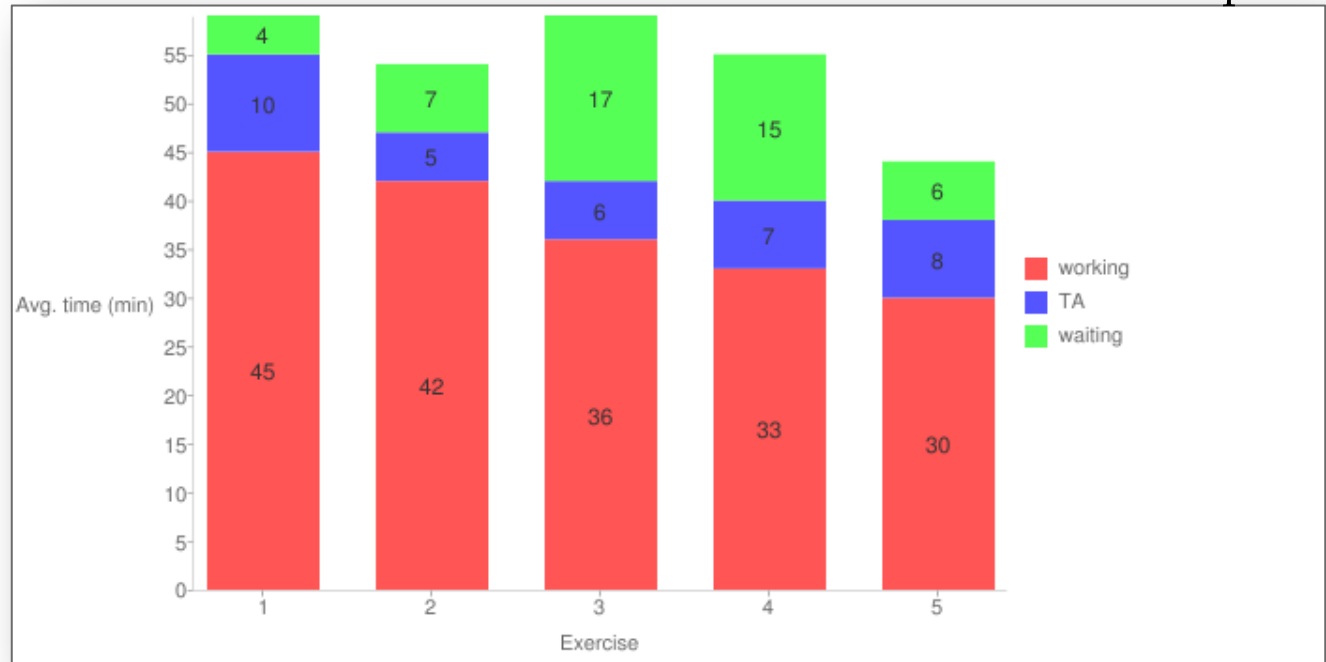
“While Waiting Productivity” LOSS : 62% → 6%

H. Alavi, Olivier Guédât



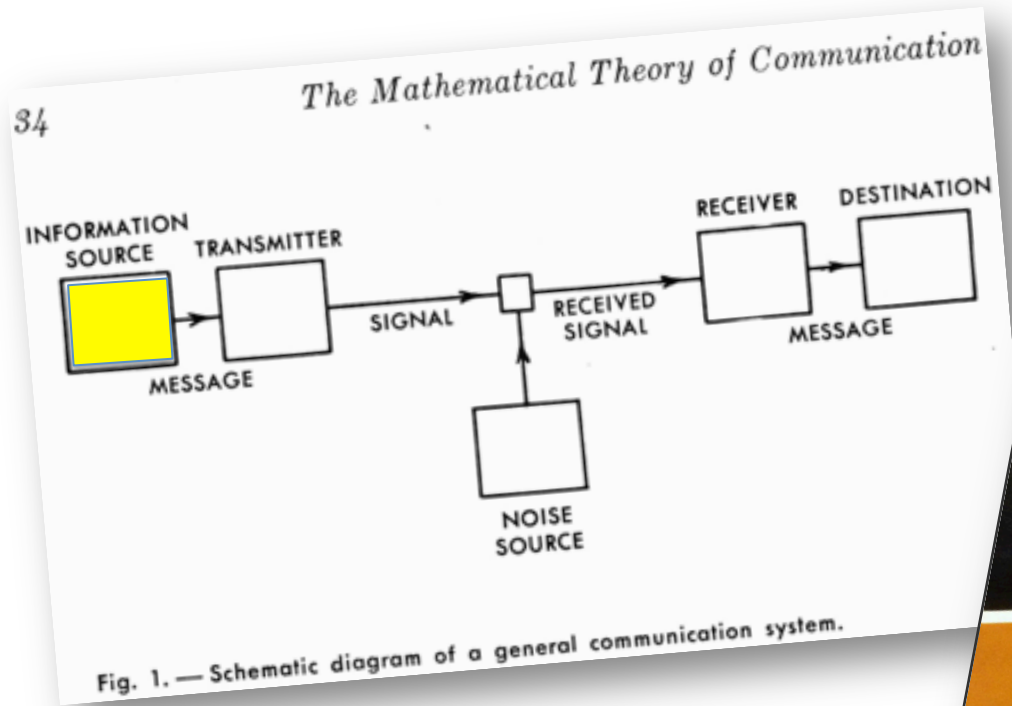
Action buffer

Teacher's cockpit



Reflection buffer

[Step 10] Orchestration requires managing massive flows of information.



[Step 10] Orchestration requires managing massive flows of information.

As it differs from information theory

An emitter is any object or actor in the classroom that display information.

A signal exists if a receiver perceives it

The beat = 1 Hz

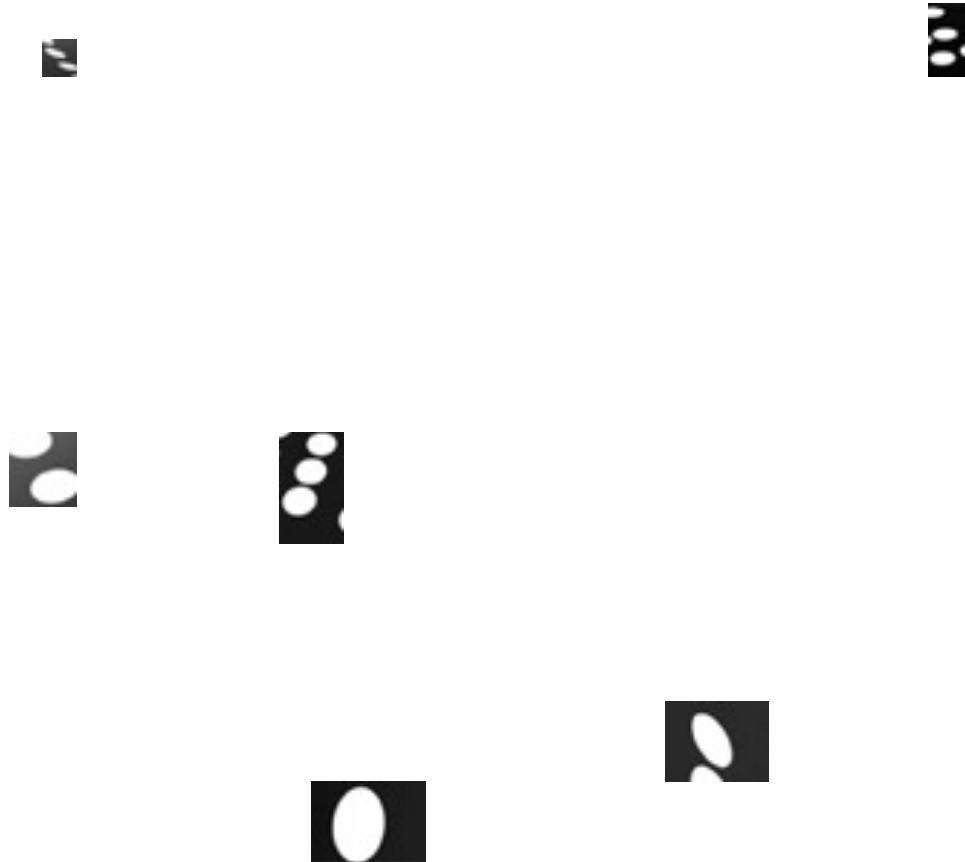
The channels are audio, vision, touch and wires.

The bandwidth is determined by the receiver's capacity (= teacher's cognitive load).

$$22 \times 50 \times 3000 < 10/3$$

By Daniel Schwartz

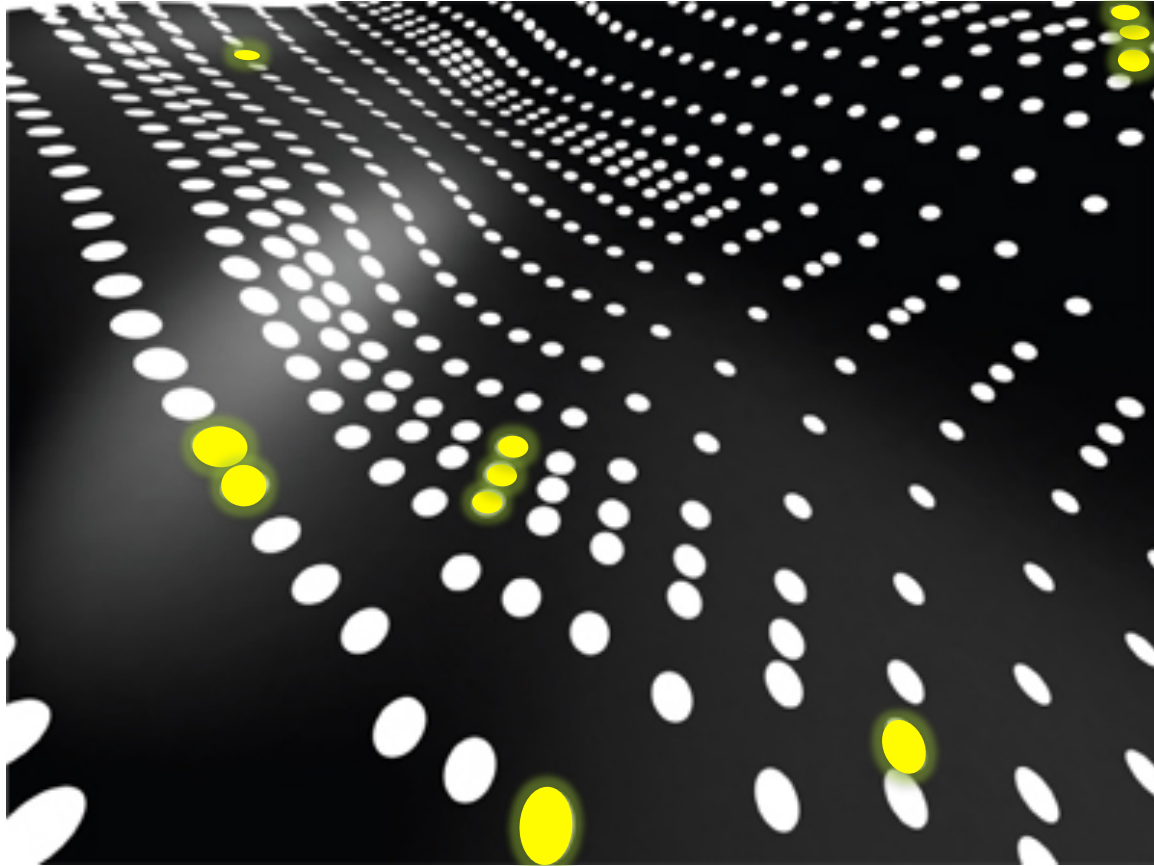
Cognitive Load Theory



Hard to grasp all this discrete information – need to use slow verbal encoding to handle working memory demands.

By Daniel Schwartz

“reveateur”



Same information as before, but now placed in its appropriate spatial context. Rapidly “graspable” without verbal encoding.

[Step 11] The classroom geometry 'chunks' for the teacher *(to be developed)*



[Step 12] Modeling a classroom as an information system (to be developed)

$$ag^0 = f((C, S, T, X), \text{learning-theory}) \quad f = \textit{instruction design}$$

$$ag^t = f'(ag^{t-1}, C^{t-1}(S), T, X) \quad | \quad H(S, C^t) < H(S, C^{t-1}) \quad f' = \textit{orchestration}$$

Orchestration the real-time management of multi-plane multi-layer activity graphs that maximize constraints satisfaction and minimize entropy

$$ag = (V, E)$$

$$V = \{a_i : (\pi, t, \beta, \textit{instruction, resources, \dots}) \wedge \sum_{i=1}^{|V|} t(a_i) = T \}$$

$$E = \{(a_i, a_j) : (\textit{fiber, operator, strength, elasticity}) \mid j > i, \}$$

$$H(C^t(S)) = \sum_{i=1}^{|S|} \sum_{j=1}^{10} (H(s_i, c_j) * (t - \textit{persistency}(c_j, l))) \mid c_j \in \{\textit{activity, attention, understanding, \dots}\}$$



Lantern
(A. Alavi)



WiTeach
(Z. Crivelli)

Design for Orchestration

1. Control
2. Visibility
3. Flexibility
4. Physicality
5. Minimalism
6. Do not target heroes

Summary

1. Graph
2. Bloominess
3. Constraints
4. Flexibility
5. Paradox
6. 3rd circle
7. Layers
8. Persistency
9. Buffers
10. Flows
11. Revelateur
12. Modeling



Education

Orchestration does not replace learning theories. It is a necessary but not sufficient condition for scaling up.



HCI

There is a need for HCI³ in education.



Information theory

Yes, we can.

Orchestration ?

Piaget, Vygotsky & Al Capone



Natacha Ongeloofelijk, Guillaume Zufferey, Patrick Jerman, M.-A. Nüssli, Quentin Bonnard, Hamed Alavi, Sebastien Cuendet Andrea Mazzei, Khaled Bachour, Olivier Guedat, Flaviu Roman, Frédéric Kaplanj, Julia Fink

Daniel Schwartz, Miguel Nussbaum, Frank Fischer, Yannis Dimitriadis, Pierre Tchounikine.

STELLAR NoE, Swiss Leading House for VET technologies, Swiss National Science Foundation