CS-411 : Digital Education

Chapter 8
Learning analytics
(and Classroom analytics)

P.Dillenbourg

EPFL

What if the learning activity
that you have designed
does not work well for Marco ?

The learner adapts

If you don’t understand the video, play it again but slower

The teacher adapts

If students don’t understand the lecture, re-explain

The system adapts

If students don’t master the skill, select a more effective learning activity

The learner adapts

The teacher adapts

The system adapts

Personalized instruction

Self-regulation Theory

Classroom orchestration

Metacognition

Adaptive instruction

Personalized instruction

Individualized instruction

Requires knowing the state of the learner
(learner modeling)

Based on effectiveness

Requires a theory
or predictive data

~~Recommender system~~

Based on choices

Learner Modelling

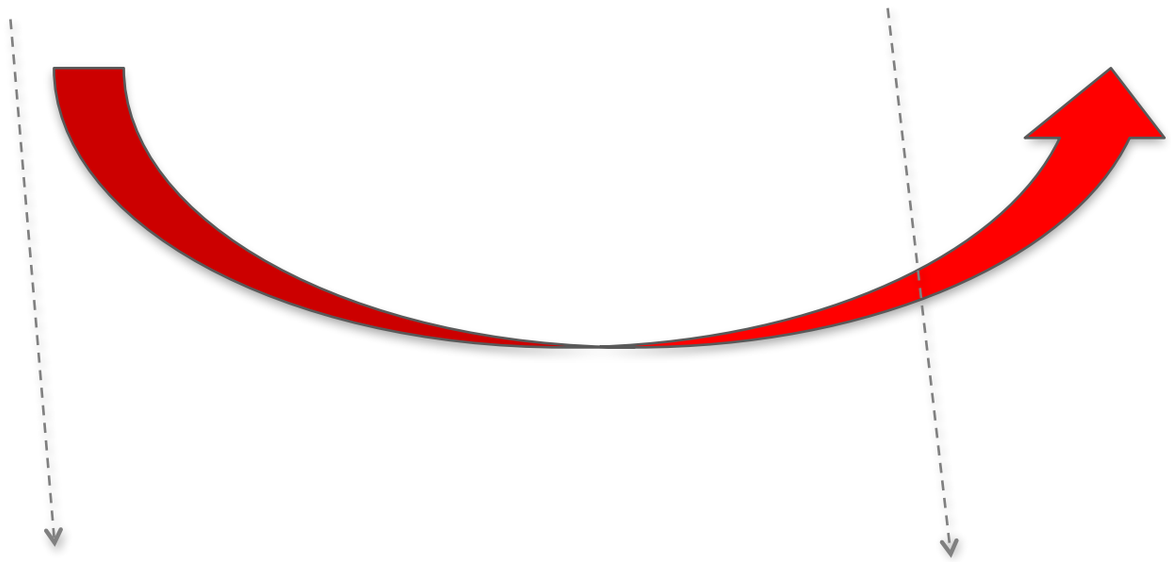
From the learner's behaviour, **infer** his/her knowledge state

$5^2 = 25$ ➔ knows X^2

$5^2 \neq 25$ ➔ doesn't know X^2

Learner Modelling

From the learner's behaviour, infer his/her knowledge state



uses 'while' loop

'often' is not an adverb

confusion (iteration, recursion)

undergeneralisation (adverb end with 'ly')

Learner Modelling

$5^2 =$

- ☐ 52
- ☑ 25
- ☐ 15
- ☐ 10
- ☐ 7

p (knows X^2)= 1 ?

Cognitive Diagnosis

$5^2 = ??$	Knowledge States										
Behavior (Answer)	$5^2 = 25$	$5^n = ...$	$n^2 = n \cdot N$	$x^n = x.x....$	$x^n = x \cdot x$ but bad mult.	$x^n = x.n$	$x^n = x + n$	$x^n = ???$	Sum	Entropy	Normalized entropy
25	**0.10**	**0.20**	**0.30**	**0.40**	0.00	0.00	0.00	0.00	1	1.89	0.63
35	0.00	0.00	0.00	0.00	**0.40**	0.10	0.00	**0.50**	1	1.41	0.47
10	0.00	0.00	0.00	0.00	0.00	**0.79**	0.00	0.20	1	0.79	0.26
27	0.00	0.00	0.00	0.00	0.40	0.00	0.00	**0.59**	1	1.03	0.34
7	0.00	0.00	0.00	0.00	0.00	0.00	**0.59**	0.40	1	1.03	0.34
											0.41

Diagnosis Power

(The lower the better)

Learner Modelling

From the learner's behaviour, infer his/her knowledge state

p (state = knows | correct-answer) = 1 – Guess

p (state = knows | incorrect-answer) = 0 + Slip

Factors that depend upon the response modality

Bayesian Knowledge Tracing, Corbet & Anderson

Learner Modelling

5^2 = ??	Knowledge States										
Behavior (Answer)	5^2 = 25	5^n = ...	n^2 = n . N	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
25	**0.10**	**0.20**	**0.30**	**0.40**	0.00	0.00	0.00	0.00	1	1.89	0.63
35	0.00	0.00	0.00	0.00	**0.40**	0.10	0.00	**0.50**	1	1.41	0.47
10	0.00	0.00	0.00	0.00	0.00	**0.79**	0.00	0.20	1	0.79	0.26
27	0.00	0.00	0.00	0.00	0.40	0.00	0.00	**0.59**	1	1.03	0.34
7	0.00	0.00	0.00	0.00	0.00	0.00	**0.59**	0.40	1	1.03	0.34
											0.41

5^2 = ??	Knowledge States (with SLIP/GUESS factors)										
Behavior (Answer)	5^2 = 25	5^n = ...	n^2 = n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
25	**0.05**	**0.15**	**0.25**	**0.35**	0.05	0.05	0.05	0.05	1	2.53	0.84
35	0.05	0.05	0.05	0.05	**0.34**	0.05	0.00	0.41	1	2.16	0.72
10	0.05	0.05	0.05	0.05	0.00	**0.64**	0.00	0.15	1	1.72	0.57
27	0.05	0.05	0.05	0.05	0.25	0.00	0.00	**0.54**	1	1.87	0.62
7	0.05	0.05	0.05	0.05	0.00	0.00	**0.50**	0.30	1	1.92	0.64
											0.68

In a MOOC ?

From the learner's behaviours, infer his/her knowledge state

b(s) = watch video with many pauses

b(s) = select correct definition of SD in a quiz with 5 possible definitions

b(s) = post a message "There is a mistake on the slide" (and there is one indeed)

X(S)={lost, active, fine, brilliant}

x(s)=[.15 .40 .30 .15]

H_0= 0.94

x(s)= [.05 .15 .25. 55]

H_0 = .80

x(s)= [.01 .02 .02 .95]

H_0 = .18

Normalized entropy of the diagnosis vector

Which question has the highest diagnosis power ?

Question 1

The standard deviation of a distribution is the .....of the sum of ..... from the mean

Question 2

Remove two numbers from this distribution to minimize it’s standard deviation : [1 3 3 5 9 9 9 10 11 18 19 25 29]

x(s)=[.15 .40 .30 .15]

$$H(X) = -\sum_i P(x_i) \log_b P(x_i)$$

H_0= 0.94

The uncertainty of the diagnosis can be estimated by Shannon's entropy applied to the vector fo probabilities for the different states.

Since this value depends upon the number of states, we normalize it on a 0->1 scale by dividing it by the maximal entropy which $\log_2$ of the number of states

The diagnosis power of a question invertedly proportional the normalized entropy of the diagnosis vector

Basic approach to reduce uncertainty

Decrease uncertainty by collecting multiple answers

5^2 = ??	Knowledge States (with SLIP/GUESS factors)										
Behavior (Answer)	5^2 = 25	5^n = ...	n^2 = n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
25	**0.05**	**0.15**	**0.25**	**0.35**	0.05	0.05	0.05	0.05	1	2.53	0.84
35	0.05	0.05	0.05	0.05	**0.34**	0.05	0.00	**0.41**	1	2.16	0.72
10	0.05	0.05	0.05	0.05	0.00	**0.64**	0.00	0.15	1	1.72	0.57
27	0.05	0.05	0.05	0.05	0.25	0.00	0.00	**0.54**	1	1.87	0.62
7	0.05	0.05	0.05	0.05	0.00	0.00	**0.50**	**0.30**	1	1.92	0.64
											0.68
7^2 = ??	Knowledge States (second question)										
Behavior (Answer)	7^2 = 25	7^n = ...	n^2 = n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
49	**0.02**	**0.10**	**0.35**	**0.45**	0.02	0.02	0.02	0.02	1.00	1.95	0.65
56	0.02	0.02	0.02	0.02	**0.61**	0.00	0.00	0.31	1.00	1.43	0.48
14	0.02	0.02	0.02	0.02	0.00	**0.82**	0.00	0.10	1.00	1.04	0.35
72	0.02	0.02	0.02	0.02	0.32	0.00	0.00	**0.60**	1.00	1.44	0.48
9	0.02	0.02	0.02	0.02	0.00	0.00	**0.72**	**0.20**	1.00	1.27	0.42
											0.48
3^3 = ??	Knowledge States (second question)										
Behavior (Answer)	3^3 = 25	3^n = ...	n^3 = n.n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
49	**0.01**	**0.10**	**0.20**	**0.65**	0.01	0.01	0.01	0.01	1.00	1.53	0.51
26	0.01	0.01	0.01	0.01	**0.81**	0.00	0.00	0.15	1.00	0.94	0.31
9	0.01	0.01	0.01	0.01	0.00	**0.82**	0.00	0.14	1.00	0.92	0.31
33	0.01	0.01	0.01	0.01	0.12	0.00	0.00	**0.84**	1.00	0.86	0.29
6	0.01	0.01	0.01	0.01	0.00	0.00	**0.91**	0.05	1.00	0.63	0.21
											0.33

Basic approach to reduce uncertainty

Decrease uncertainty by collecting multiple answers

5^2 = ??	Knowledge States (with SLIP/GUESS factors)										
Behavior (Answer)	5^2 = 25	5^n = ...	n^2 = n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
25	**0.05**	**0.15**	**0.25**	**0.35**	0.05	0.05	0.05	0.05	1	2.53	0.84
35	0.05	0.05	0.05	0.05	**0.34**	0.05	0.00	**0.41**	1	2.16	0.72
10	0.05	0.05	0.05	0.05	0.00	**0.64**	0.00	0.15	1	1.72	0.57
27	0.05	0.05	0.05	0.05	0.25	0.00	0.00	**0.54**	1	1.87	0.62
7	0.05	0.05	0.05	0.05	0.00	0.00	**0.50**	**0.30**	1	1.92	0.64
											0.68
7^2 = ??	Knowledge States (second question)										
Behavior (Answer)	7^2 = 25	7^n = ...	n^2 = n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
49	**0.02**	**0.10**	**0.35**	**0.45**	0.02	0.02	0.02	0.02	1.00	1.95	0.65
56	0.02	0.02	0.02	0.02	**0.61**	0.00	0.00	0.31	1.00	1.43	0.48
14	0.02	0.02	0.02	0.02	0.00	**0.82**	0.00	0.10	1.00	1.04	0.35
72	0.02	0.02	0.02	0.02	0.32	0.00	0.00	**0.60**	1.00	1.44	0.48
9	0.02	0.02	0.02	0.02	0.00	0.00	**0.72**	**0.20**	1.00	1.27	0.42
											0.48
3^3 = ??	Knowledge States (second question)										
Behavior (Answer)	3^3 = 25	3^n = ...	n^3 = n.n.n	x^n = x.x....	x^n = x . x but bad mult.	x^n = x.n	x^n = x + n	x^n = ???	Sum	Entropy	Normalized entropy
49	**0.01**	**0.10**	**0.20**	**0.65**	0.01	0.01	0.01	0.01	1.00	1.53	0.51
26	0.01	0.01	0.01	0.01	**0.81**	0.00	0.00	0.15	1.00	0.94	0.31
9	0.01	0.01	0.01	0.01	0.00	**0.82**	0.00	0.14	1.00	0.92	0.31
33	0.01	0.01	0.01	0.01	0.12	0.00	0.00	**0.84**	1.00	0.86	0.29
6	0.01	0.01	0.01	0.01	0.00	0.00	**0.91**	0.05	1.00	0.63	0.21
											0.33

How does the teacher/system chooses the next question ?

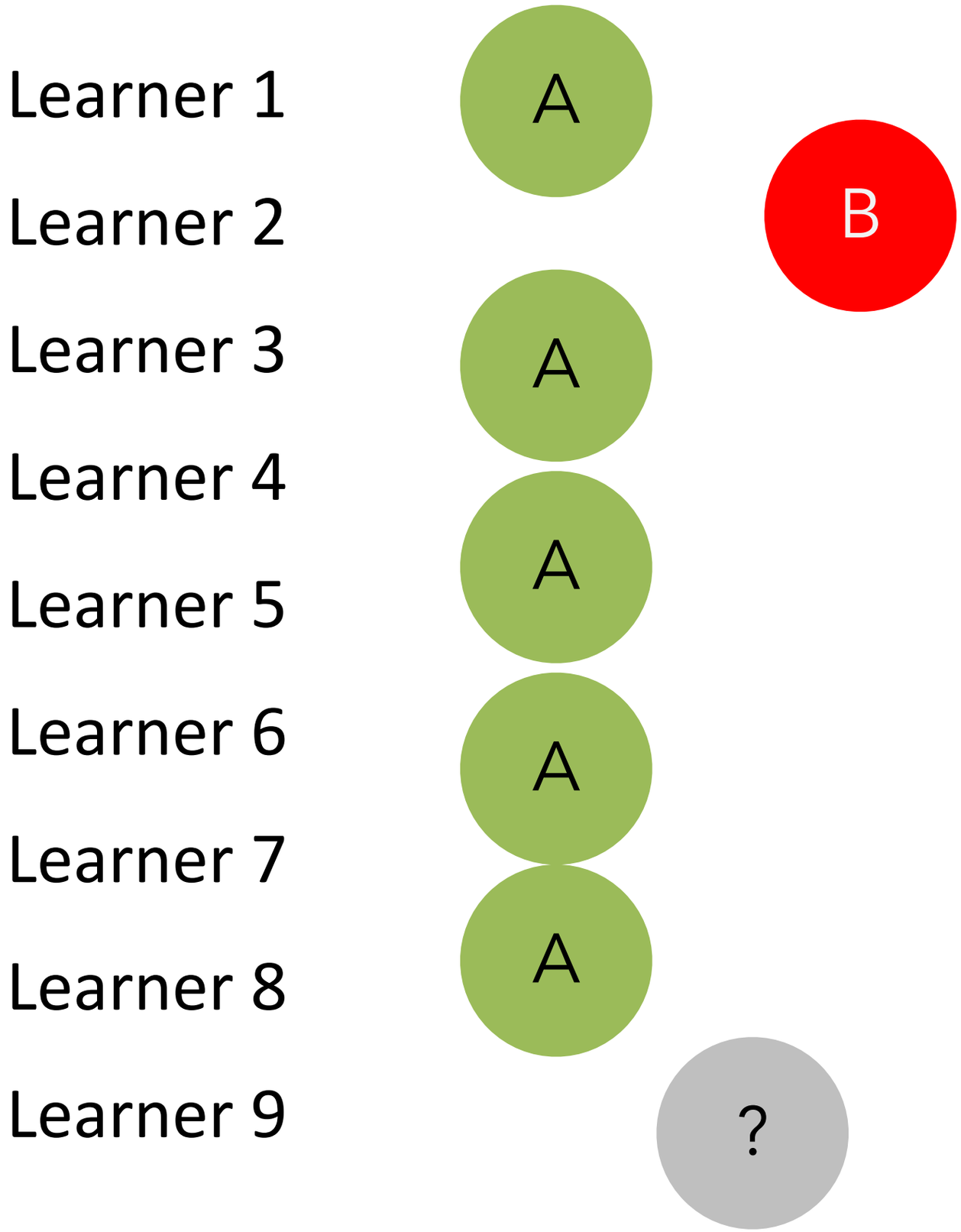
- Because it will maximize the learning gain of the learner ?

Exploitation

- Because it will maximize the system knowledge about the learner ?

Exploration

Exploration Exploitation Tradeoff



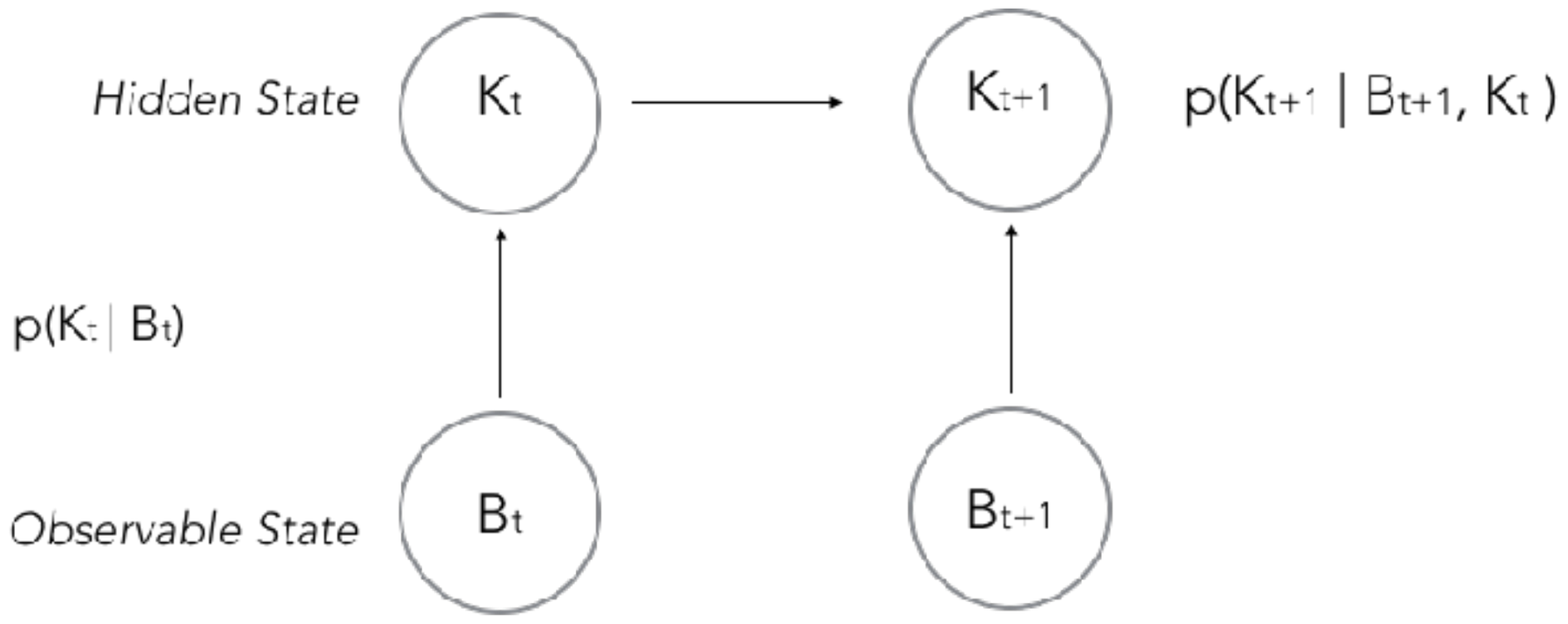
Learner Modelling

From the learner's behaviour, **infer** his/her knowledge state

+

From the learner's previous state, **predict** his/her knowledge state

From the learner's behaviour and **his previous state,** infer his/her knowledge state



Bayesian Knowledge Tracing

EPFL

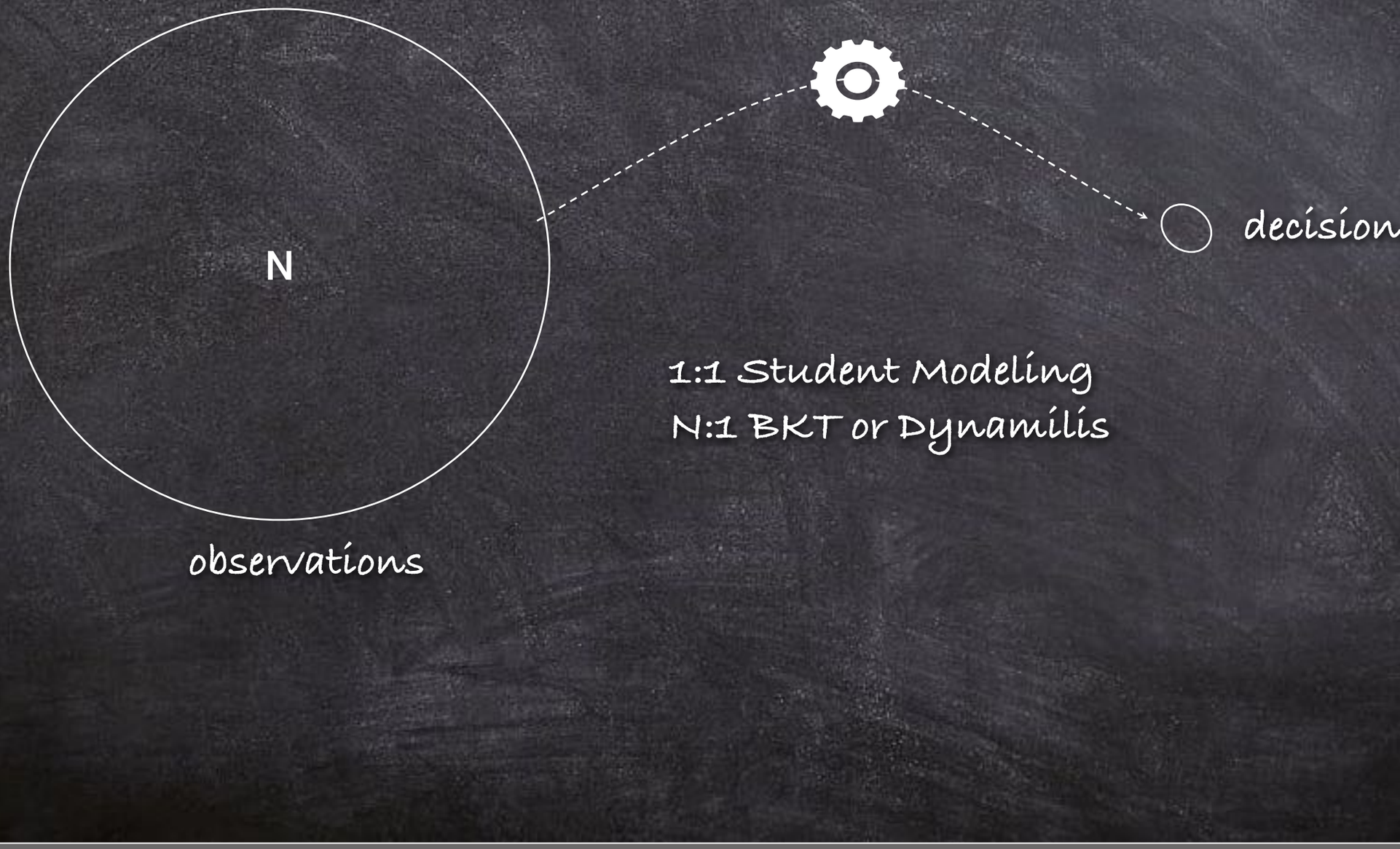
CS-421 **Machine learning for behavioral data**

Käser Tanja

Cursus	Sem.	Type
Cybersecurity	MA2, MA4	Opt.
Data Science	MA2, MA4	Opt.
Informatique	MA2, MA4	Opt.
SC master EPFL	MA2, MA4	Opt.

Language	English
Credits	4
Session	Summer
Semester	Spring
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Project	2 weekly
Number of positions	

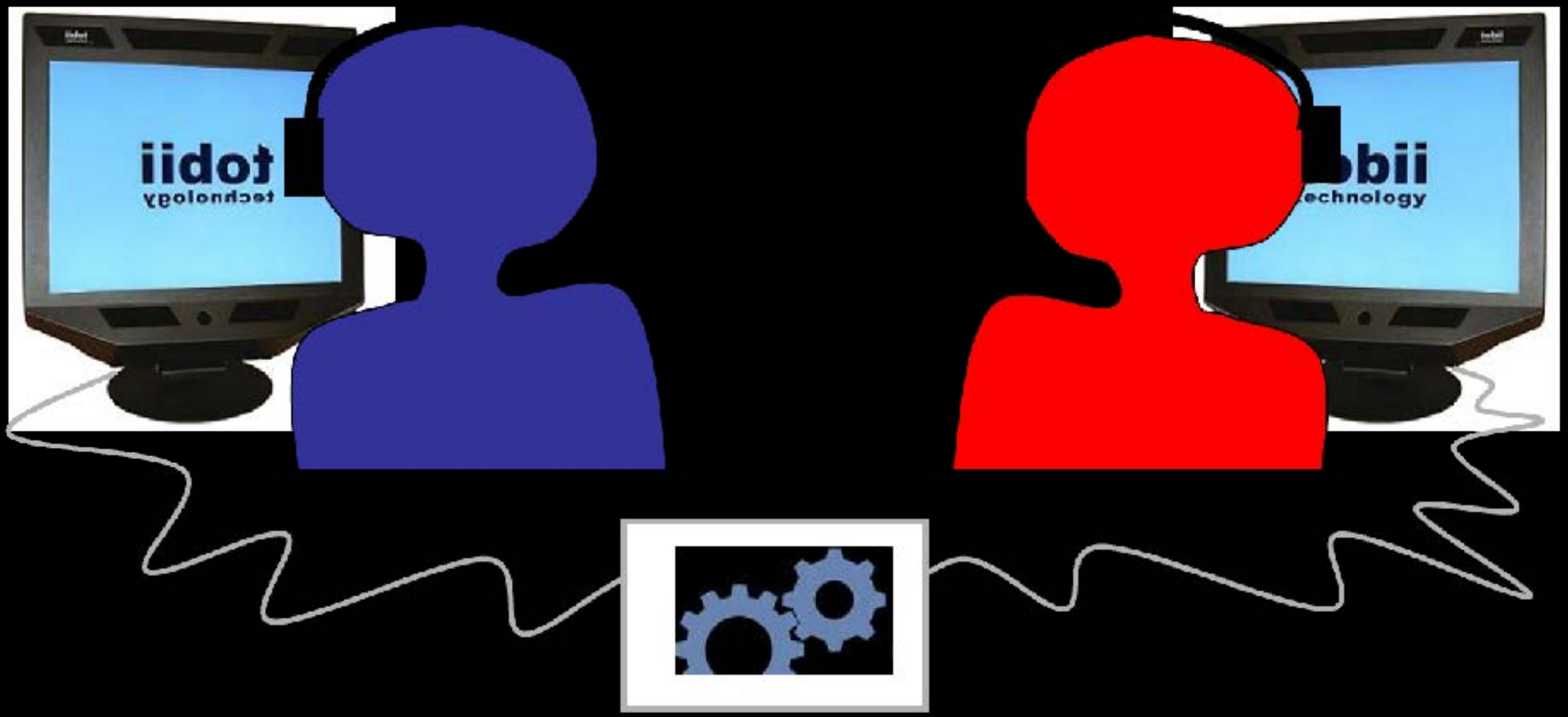
Learning Analytics Ratios



P.Dillenbourg

EPFL

Dual Eye Tracking



Learning Analytics Ratios

observations

decision

1:1 Student Modeling

N:1 BKT or Dynamilis

2:2 Dual Eye tracking

P.Dillenbourg

Associate Vice-president for Education

EPFL

DUET - Dual Eye-Tracking
Pair programming experiment

Low gaze recurrence

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

P. Jermann, M. A. Nussli & P. Dillenbourg
© CRAFT – http://craft.epfl.ch/

Supported by the Swiss National Science Foundation (grants #K-12K1-117909 and #PZ00P_126611)

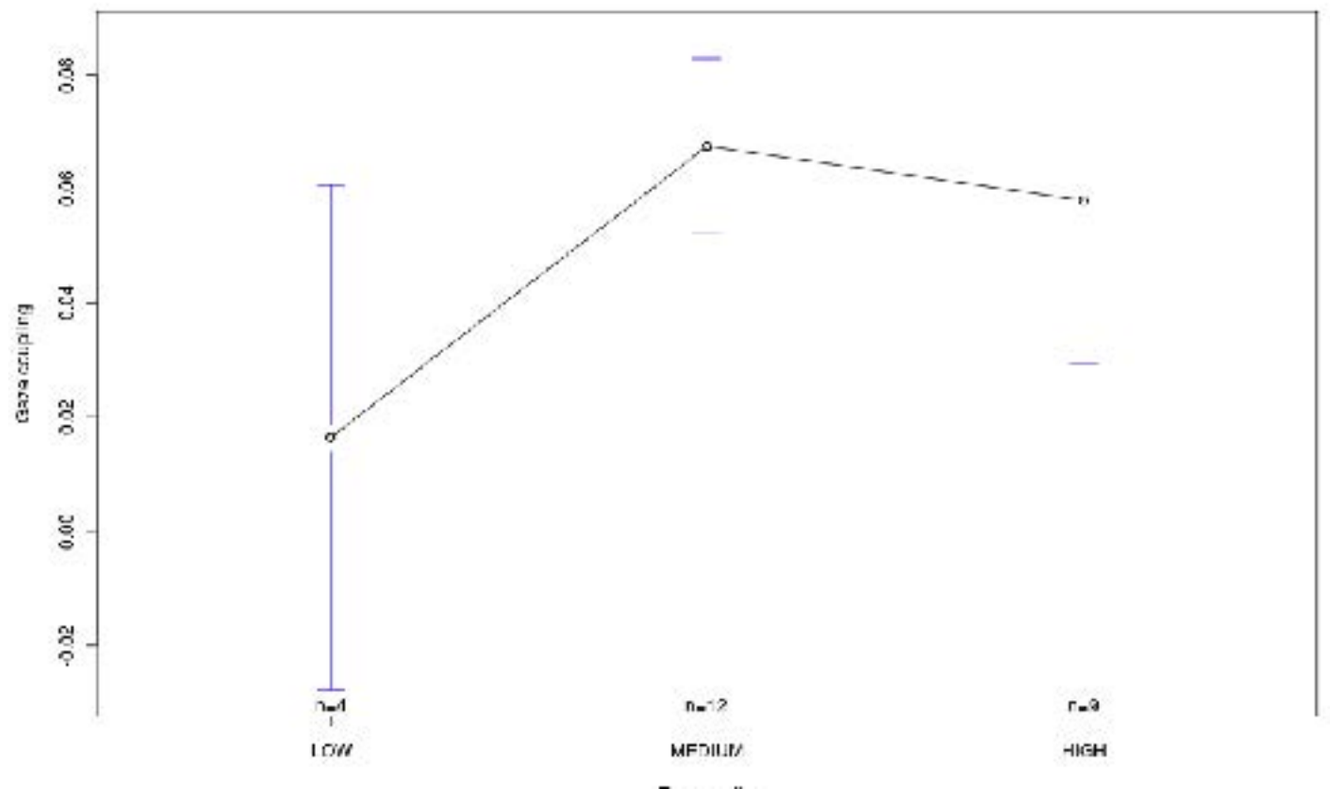
DUET - Dual Eye-Tracking
Pair programming experiment

High gaze recurrence

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

P. Jermann, M.-A. Nüssli & P. Dillenbourg
© CRAFT – http://craft.epfl.ch/

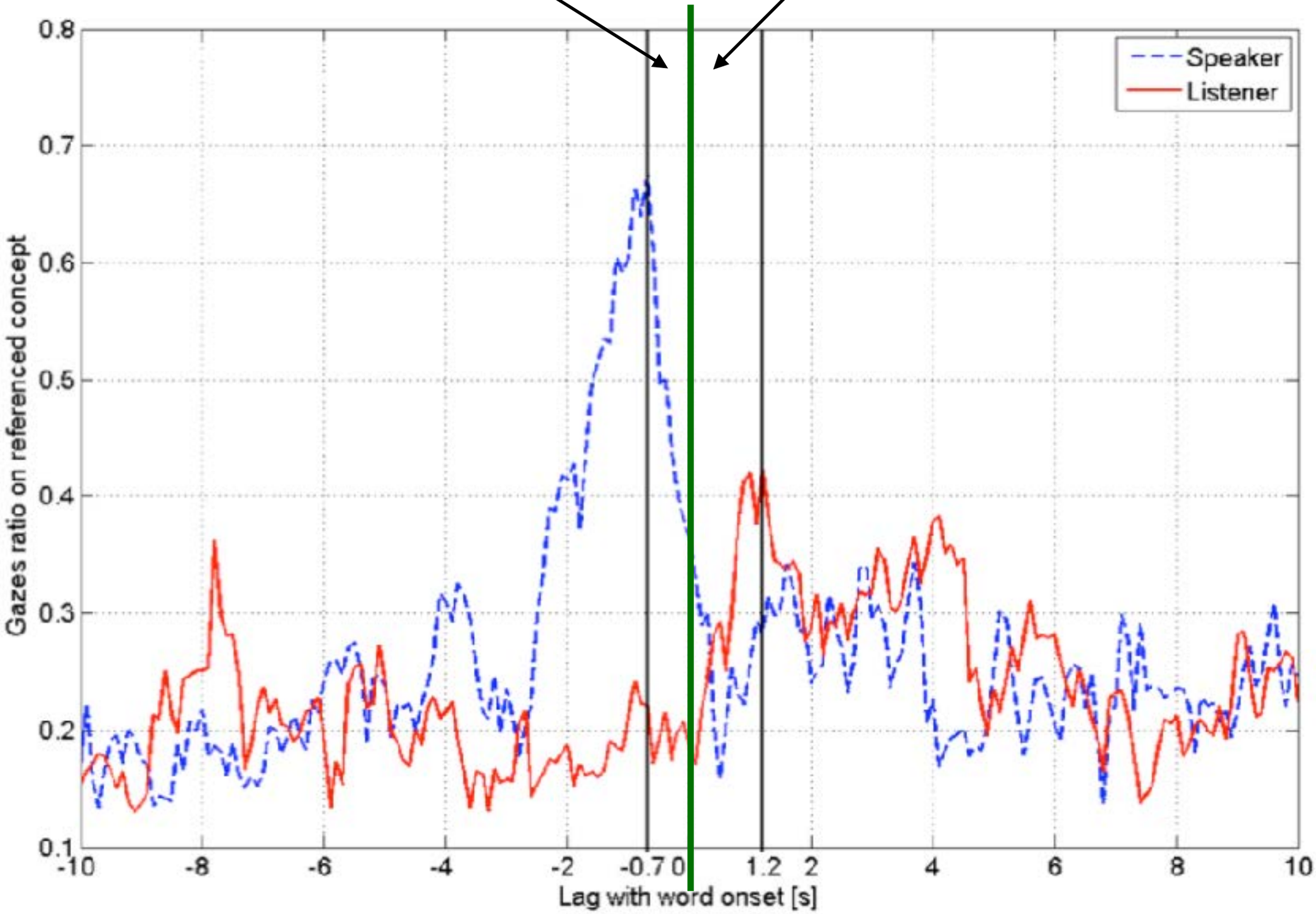
Supported by the Swiss National Science Foundation (grants #K-12K1-117909 and #PZ00P_126611)



Nüssli, Jermann & Mullins

gaze(Sara)-voice(Sara) lag
± 700 ms

voice(Sara)-gaze(Mike) lag
±1200 ms



gaze(Sara)-gaze(Mike) lag
± 2 secondes

Mirweis Sangin, Marc-Antoine Nüssli, Patrick Jermann

Learning Analytics Ratios

observations

decision

1:1 Student Modeling

N:1 BKT or Dynamilis

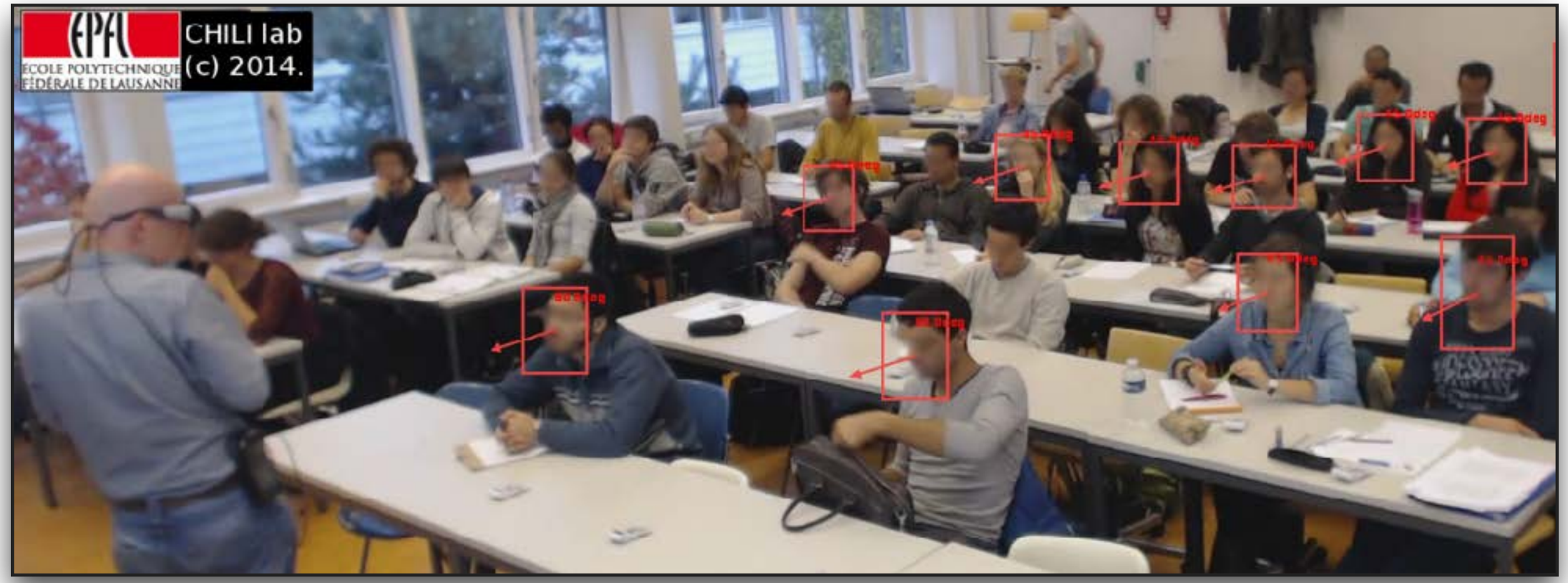
2:2 Dual Eye tracking

N:N Classroom analytics

P.Dillenbourg

You passed below 5% attention

Classroom Analytics



Raca, M., & Dillenbourg, P. (2013). System for assessing classroom attention. In *Proceedings of 3rd International Learning Analytics & Knowledge Conference*

Do you really want to put cameras in classes ?

NO

EPFL Exercises Session

assistant

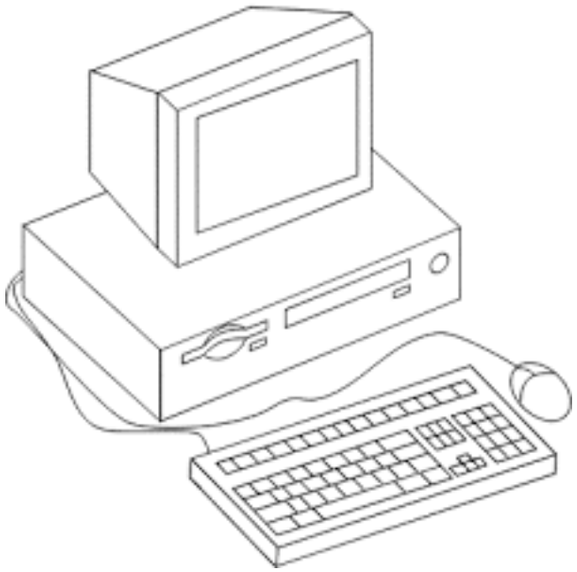
works

waits

"While Waiting Productivity" LOSS : 62% ➔ 6%

H. Alavi, O. Guédat

Classware: the classroom is a digital system



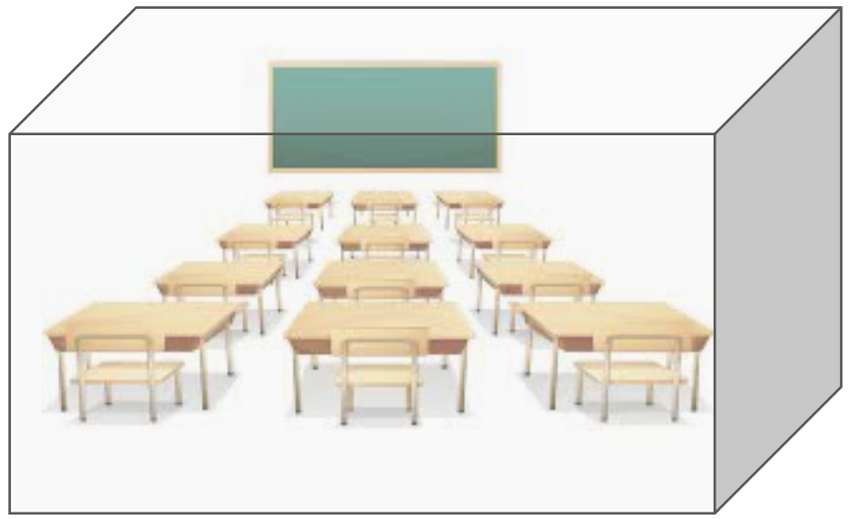
learning analytics

individual student

knowledge state

system decision

open student model



classroom analytics

n students

activity state

teacher decision

dashboards

Learning Analytics Ratios

observations

decision

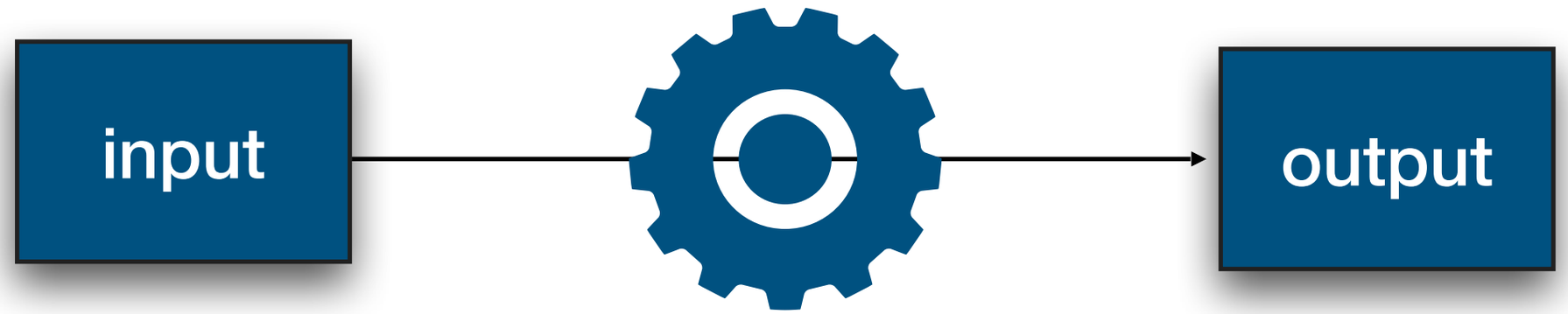
1:1 Student Modeling
N:1 BKT or Dynamilis
2:2 Dual Eye tracking
N:N Classroom analytics

P.Dillenbourg

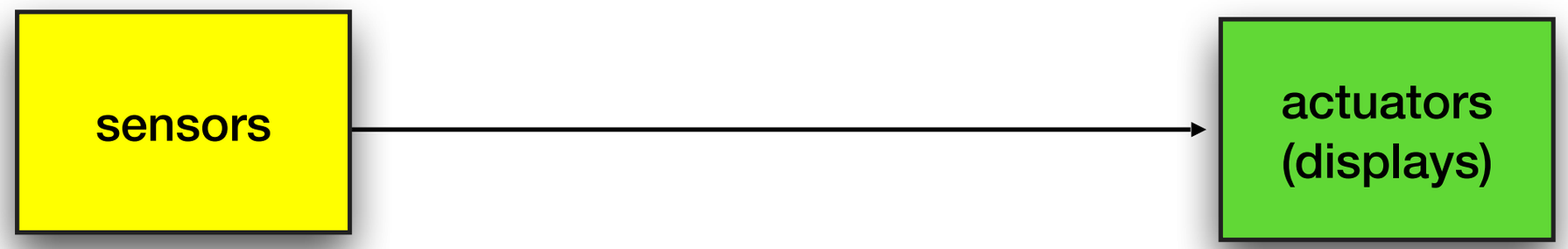
EPFL

Associate Vice-president for Education

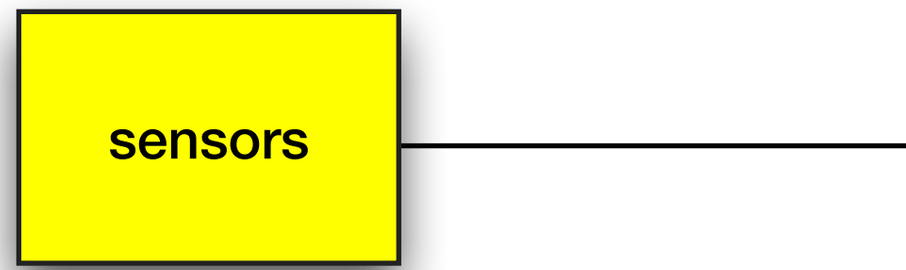
My (physical) classroom is a digital environment



My (physical) classroom is a digital environment



- **Accelerometer** that measures acceleration forces
- **Magnetometer** that measures magnetization/magnetic fields
- **Light sensor** that measures the strength of light
- **Gyroscope** that measures orientation
- **Hygrometer** that measures moisture in the atmosphere
- **Thermometer** that measures ambient temperature
- **Barometer** that measures atmospheric pressure
- **Proximeter** that detects when something is close



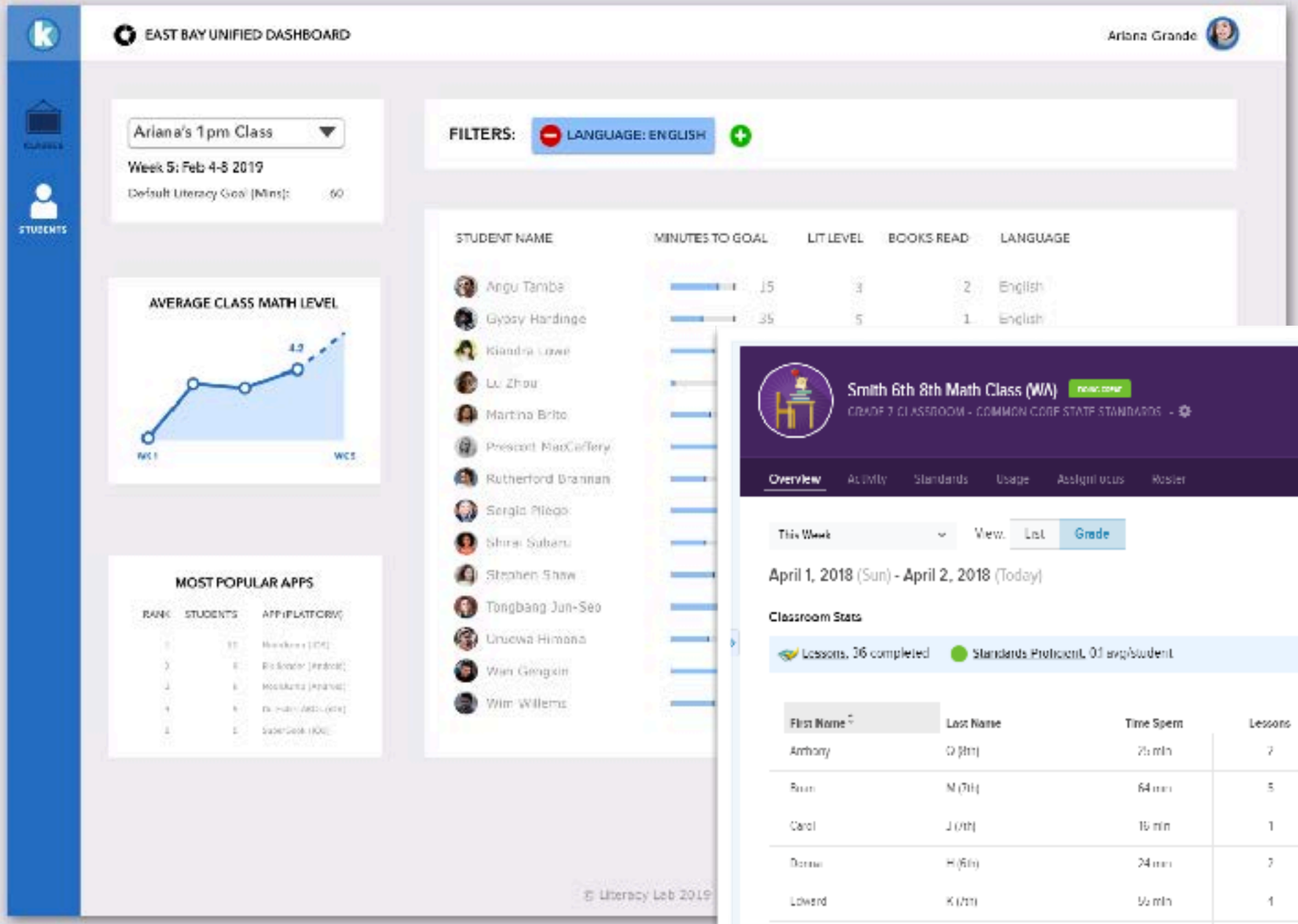
- **Precision Gas Sensor** - Test air quality, carbon monoxide levels
- **Reducing Gas Sensor** - Sense methane, propane, and natural gas leaks
- **Oxidizing Gas Sensor** - Ozone sensing and chlorine leaks
- **Non-Contact Thermometer** - Check food temperature, engine diagnostics, …
- **Humidity Sensor** - Check heat index, food storage conditions
- **Temperature Sensor** - Measure ambient temperature
- **Light Sensor** - For checking light intensity, sunlight monitoring,….
- **Color Sensors** - Use as a color meter, color matcher/analyzer, even pattern recognition
- **Pressure Sensor** - Blood pressure monitor
- **Proximity Sensor** - Use it as a stud finder or liquid level monitor
- **Expansion Connector** - Connecting other sensors like EKGs, Thermal Printers, and more

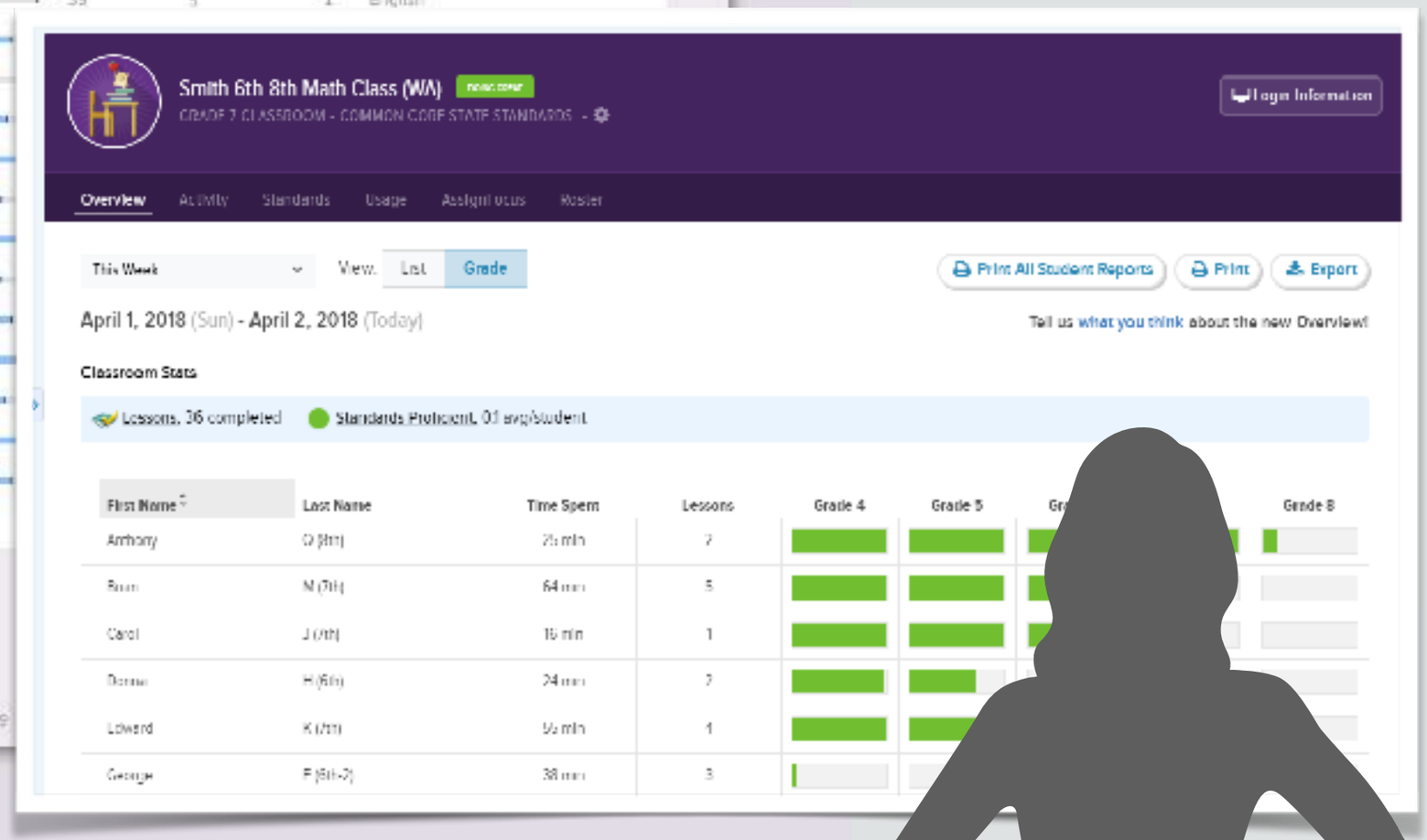
Kidapolis

Dreambox

Dashboard

actuators (displays)





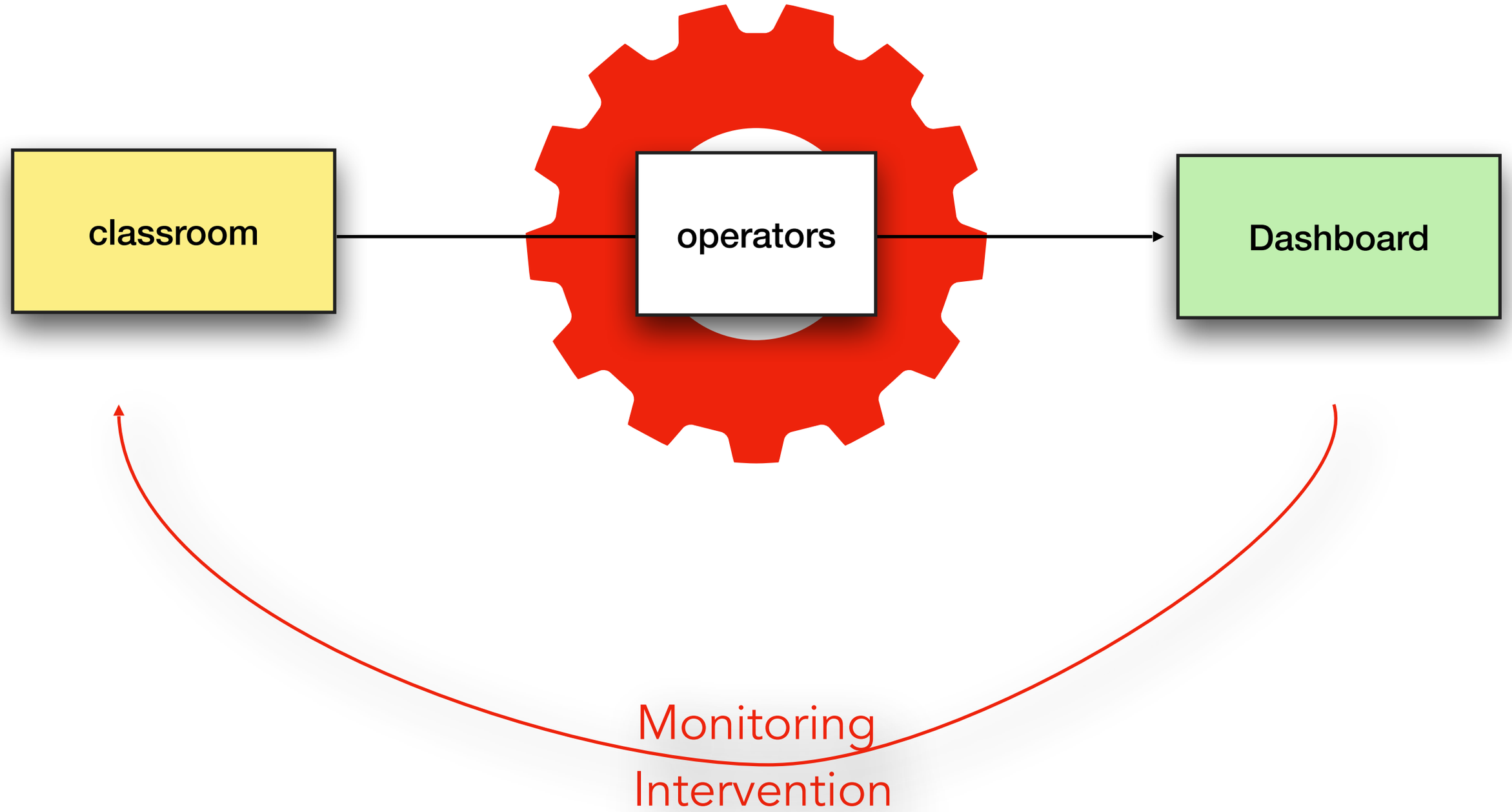
Kidapolis

Dreambox

Dashboard

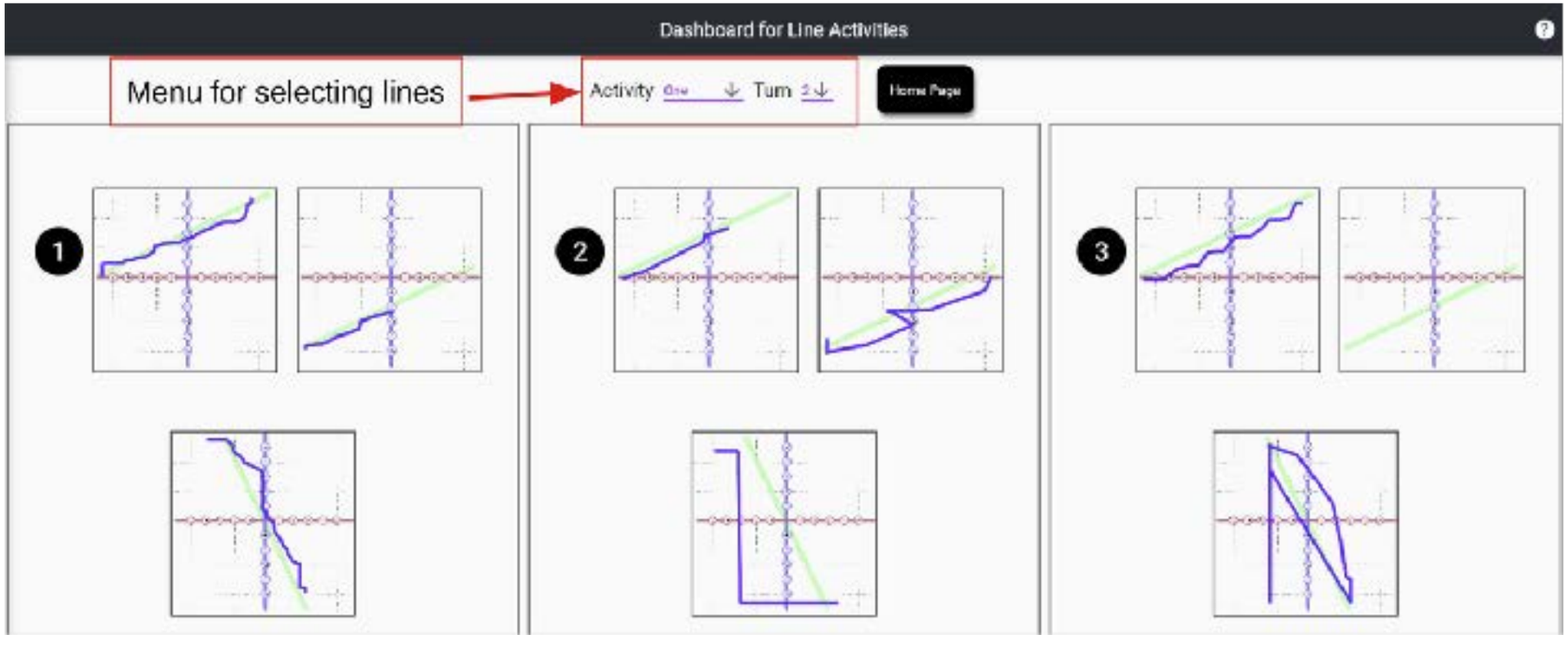
Classroom Data → **Visualisation**

Aggregation, comparison, visualisation,….

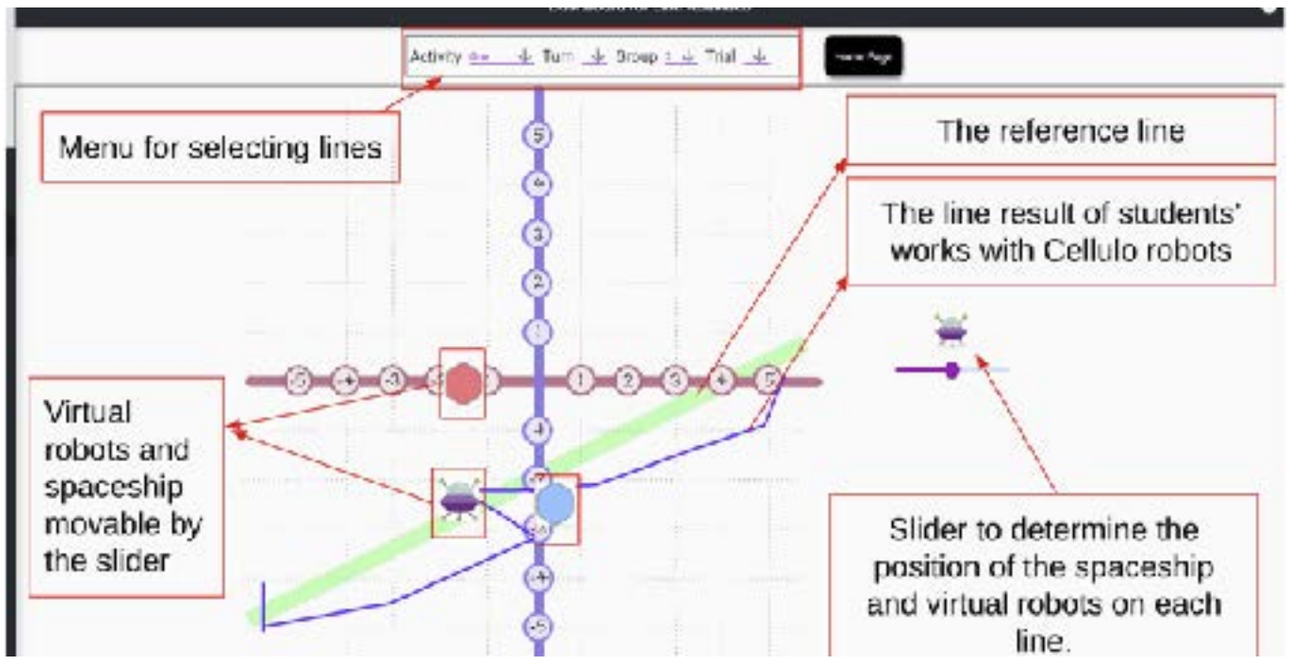


Sina Shahmoradi, EPFL

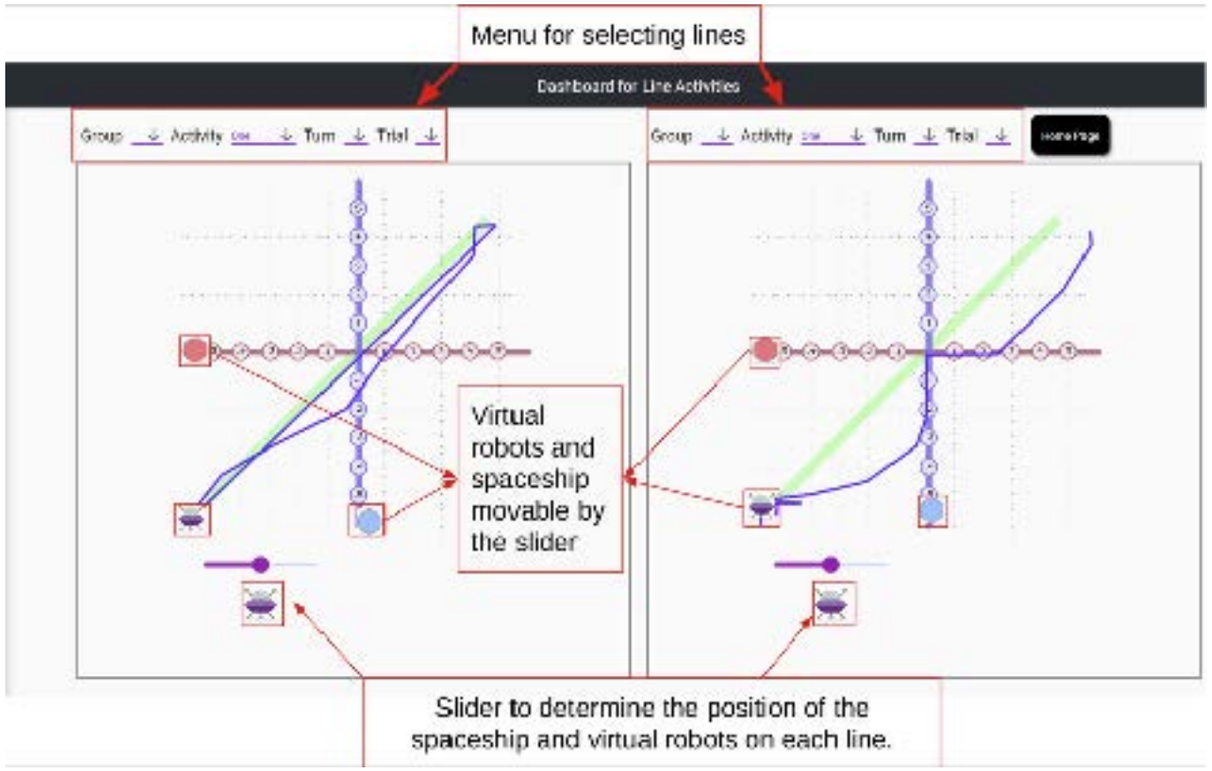
Teacher's Dashboard



Aggregated mode



Zoom mode



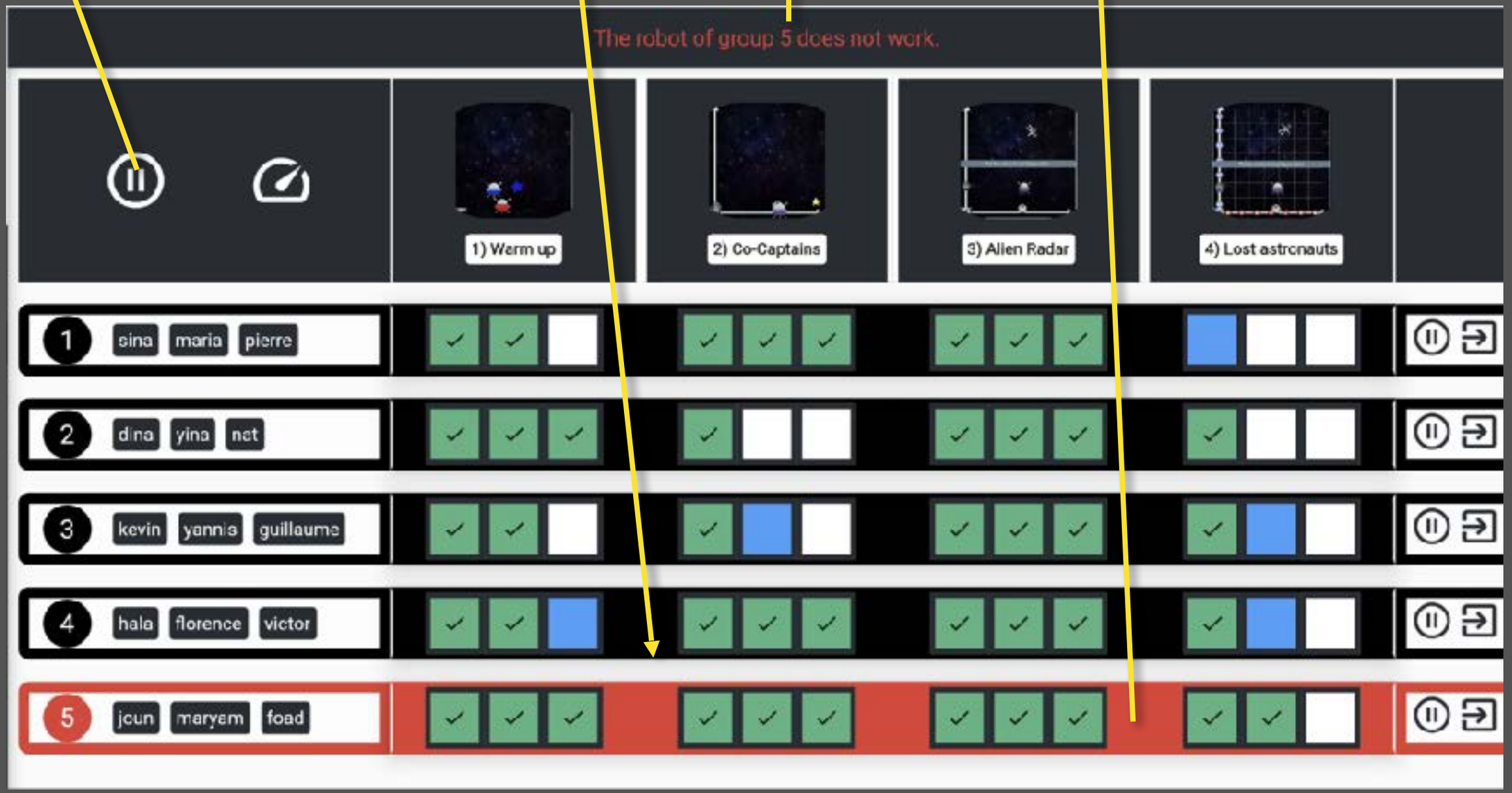
Comparison mode

Pause/Resume
the class activity

Progress-bar

Robot Failure Alert

Pause/Resume a
group activity




respect listen try
I like ...
I wish ...
We are here to learn.
Autonomous

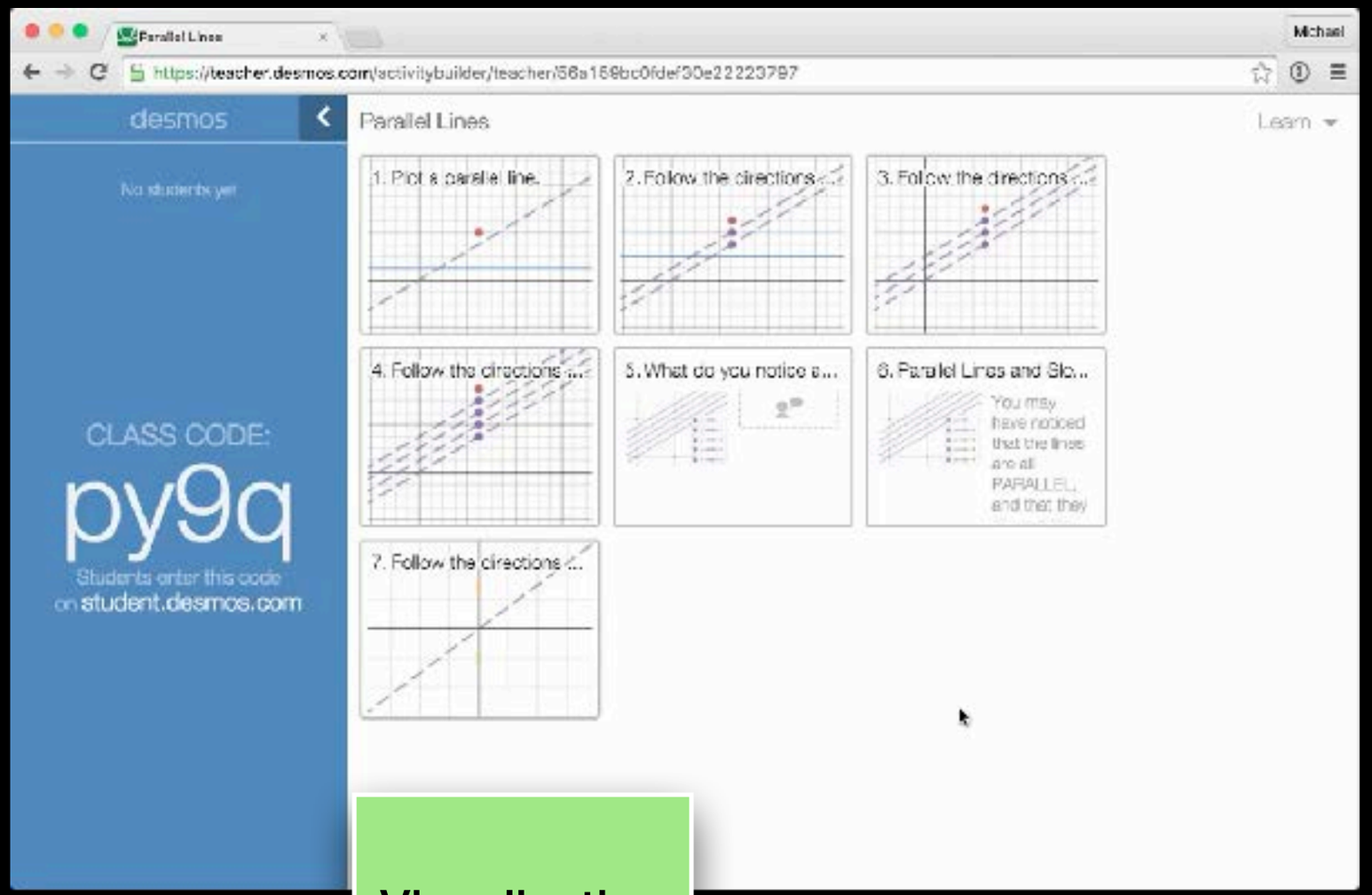
Distributed

Data

Visualisation

Centralized

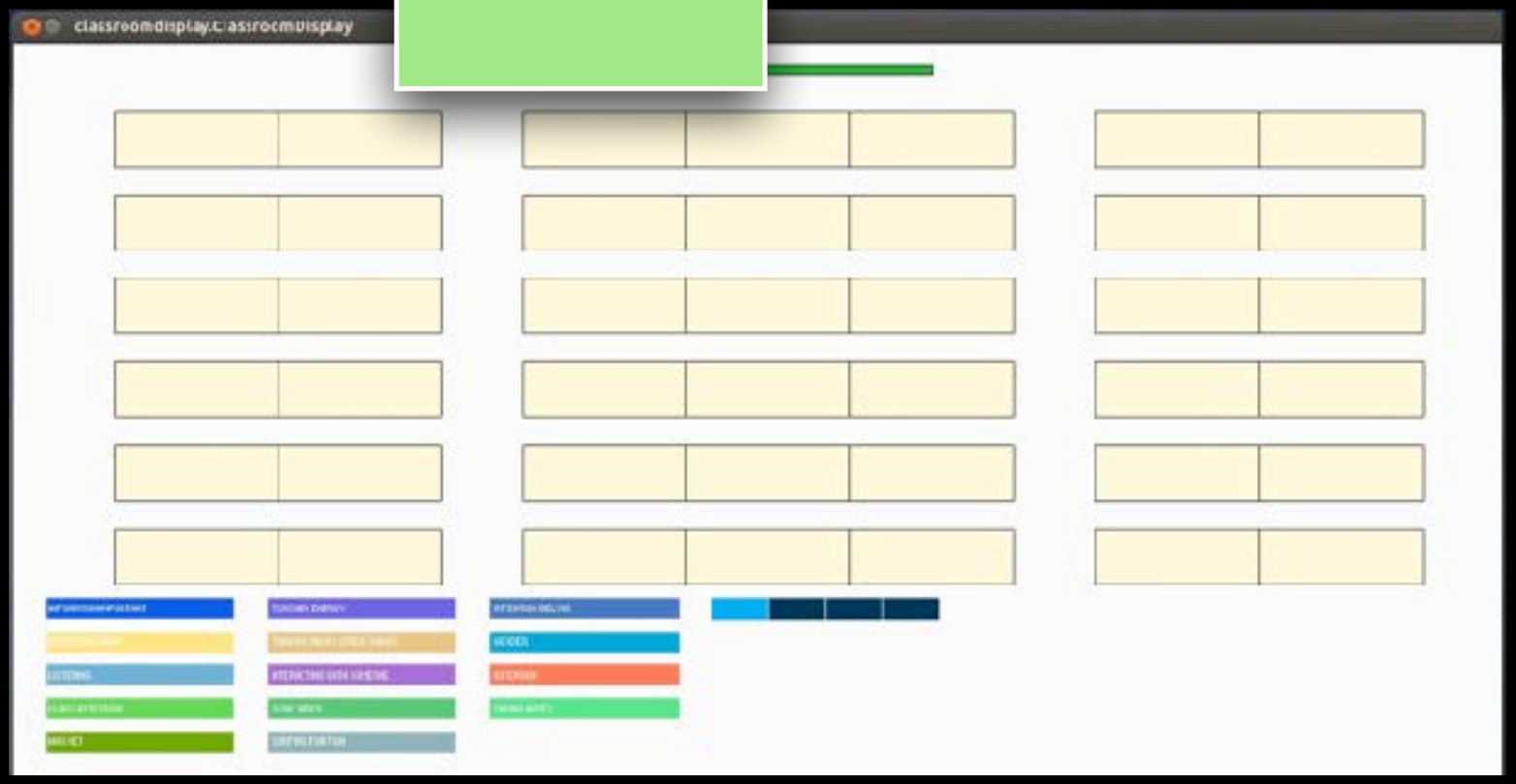
Realtime



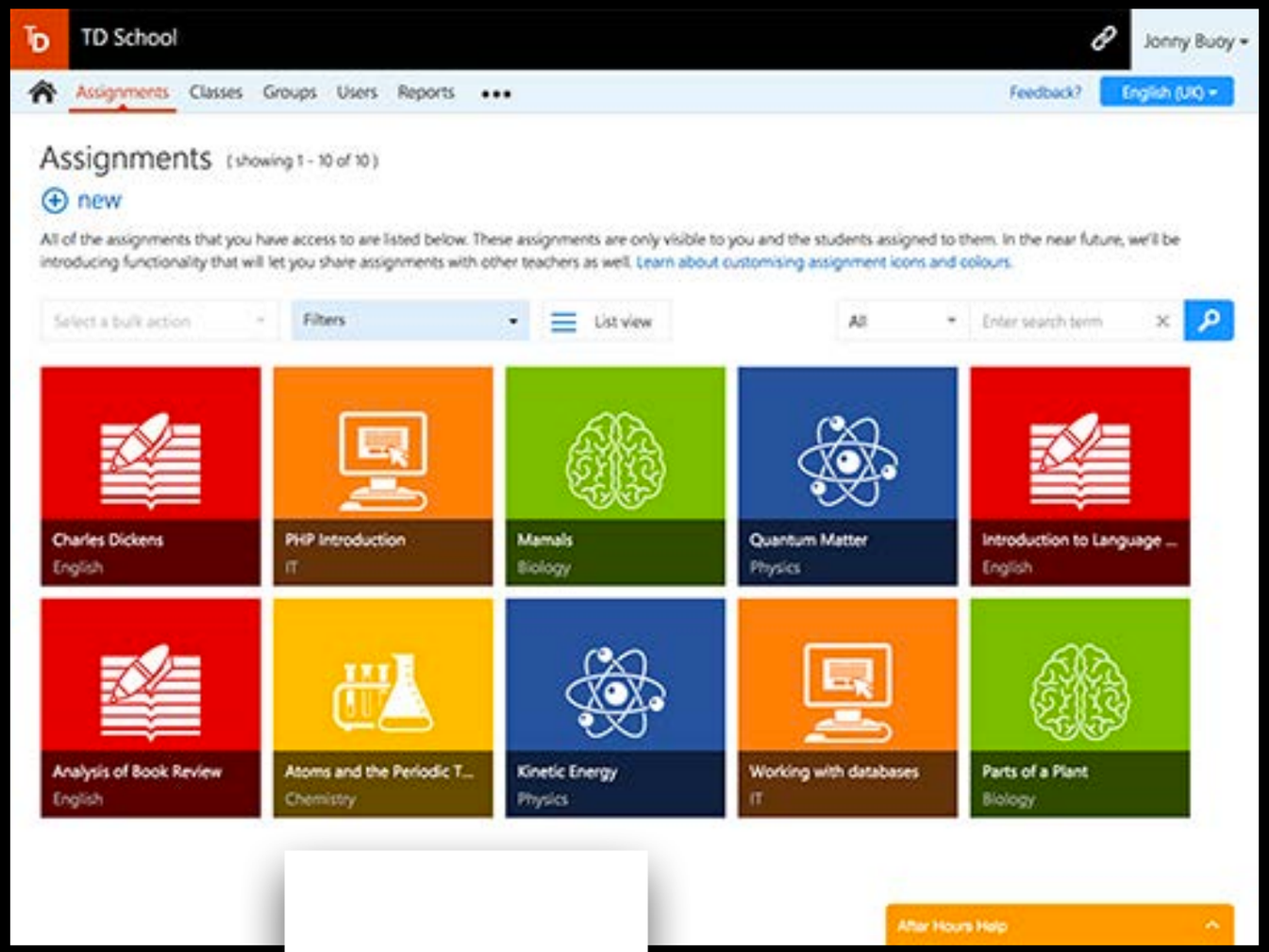
Data

Visualisation

Replay



Focal



Data

Visualisation

Peripheral
(ambient)

Public Dashboard

Data

Visualisation

Private Dashboard

https://www.brightfishlearning.com/reports/

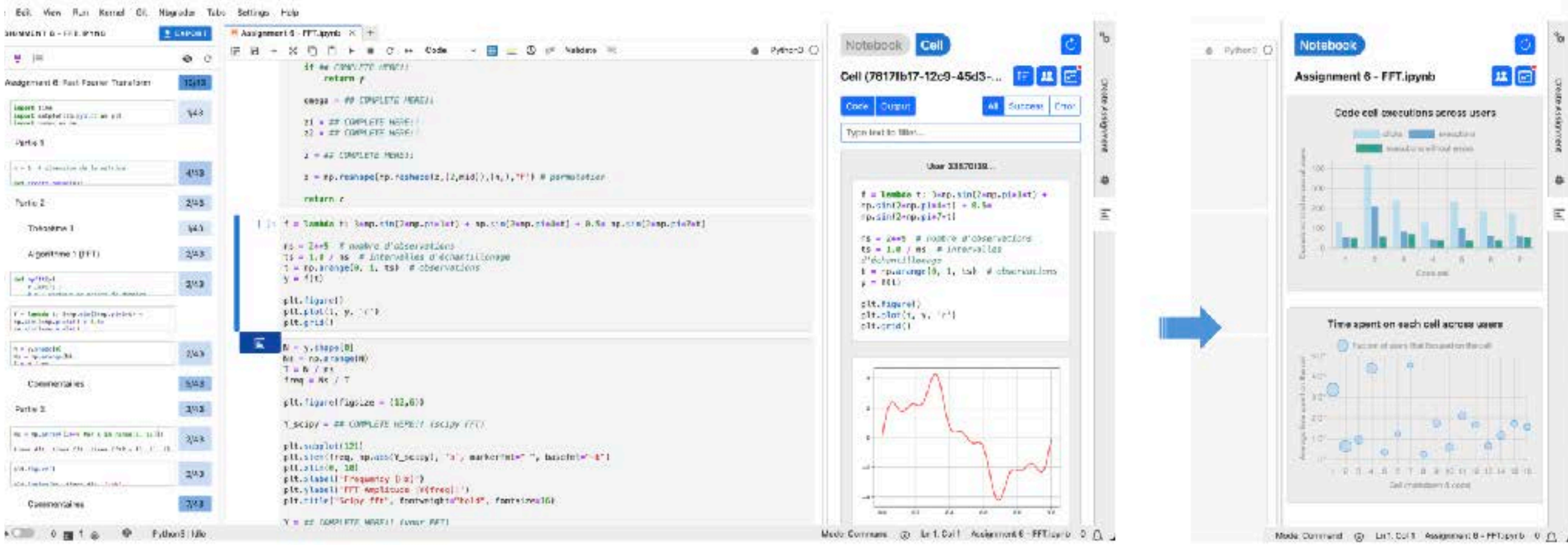
Dashboard for Jupyter Notebooks

Student Location

Reflection

Cell View

Aggregate View



Zhenyu Cai, Richard Lee Davis, Raphaël Mariétan, Roland Tormey, & Pierre Dillenbourg

LUMILO

real-time, continuous assessment for K-12 teachers

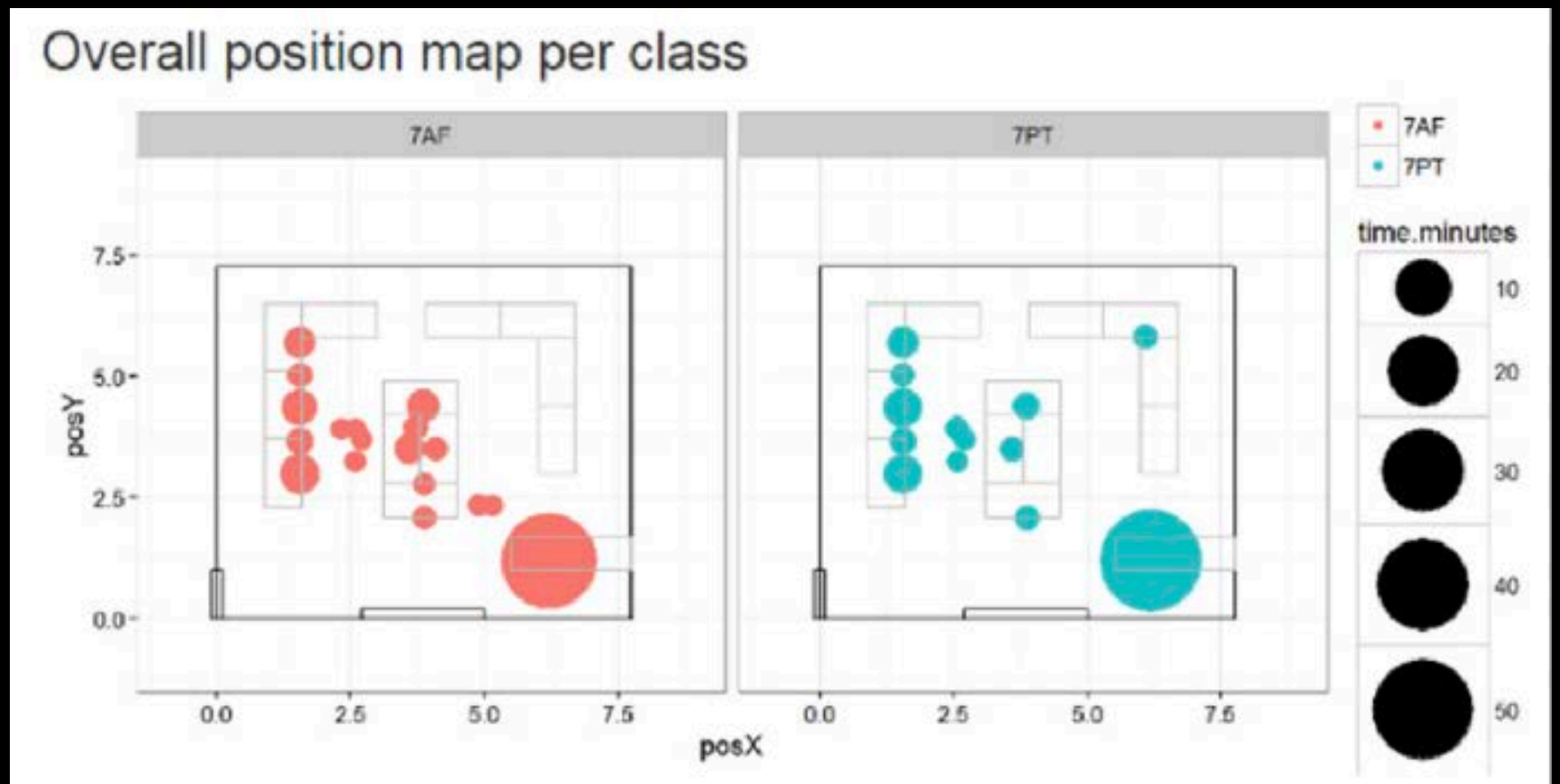
47% « out of the loop »

K. Hostein, V. Aleven & N. Rummel

Teachers'
Data

Visualisation

Sarrade Isabelle, EPFL



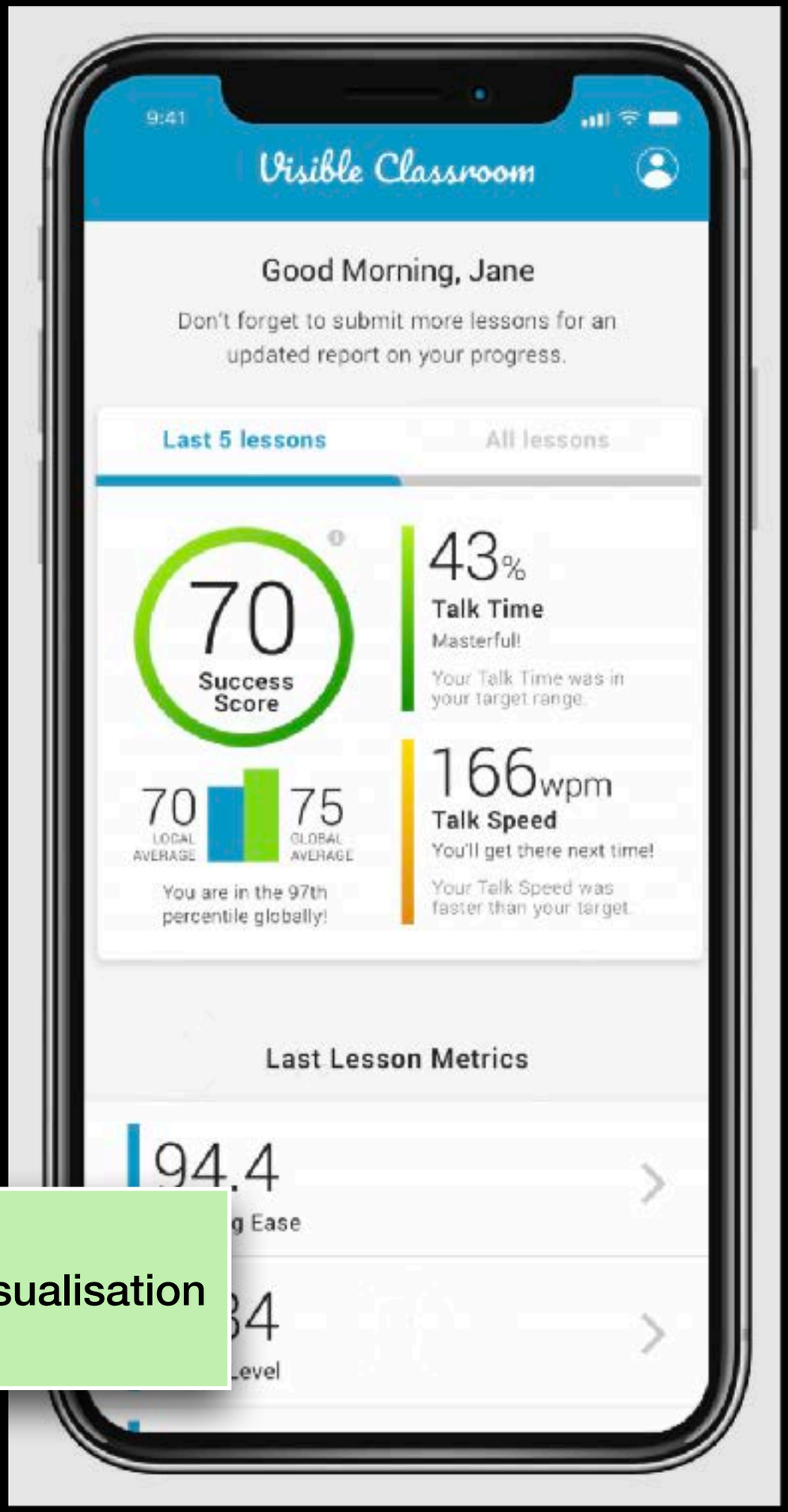
Prieto et al

Teachers' Data

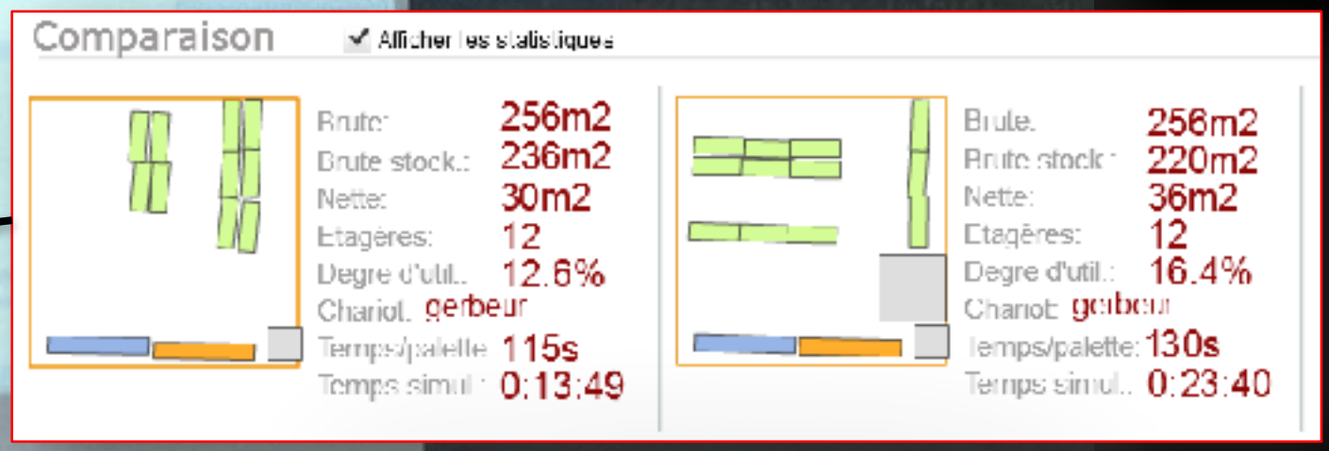
Visualisation

Teachers'
Data

Visualisation



(1) monitoring



(2) debriefing

Problem Solving

Lecture

Question

Please order a standard return 2nd clas

Enter command

from Lausanne to Davos standard C2|re

Question

Please order a young return 2nd class ticket from Basel to Geneve without bike.

Your Ticket

From	To
Basel	Geneve

Travel	Fare
Return	

Class	Bike

City

Basel	Davos	Fribourg
Geneve	Lausanne	Neuchatel
	Zurich	

Travel

One-way	Return

Fare

Standard	Young	Half-fare

Class

Bike

Question

Please order a standard return 2nd class ti

From:
Fribourg

To:
Zurich

Travel:
Return

Fare:
Standard

Class:
2nd

Bike:
No

:24

Question

Please order a standard return 2nd class ticket from Basel to Zurich with a bike.

From
Basel

To
Zurich

Travel

- One-way
- Return

Fare

- Standard
- Young
- Half-fare

Class

- 1st
- 2nd

Bike

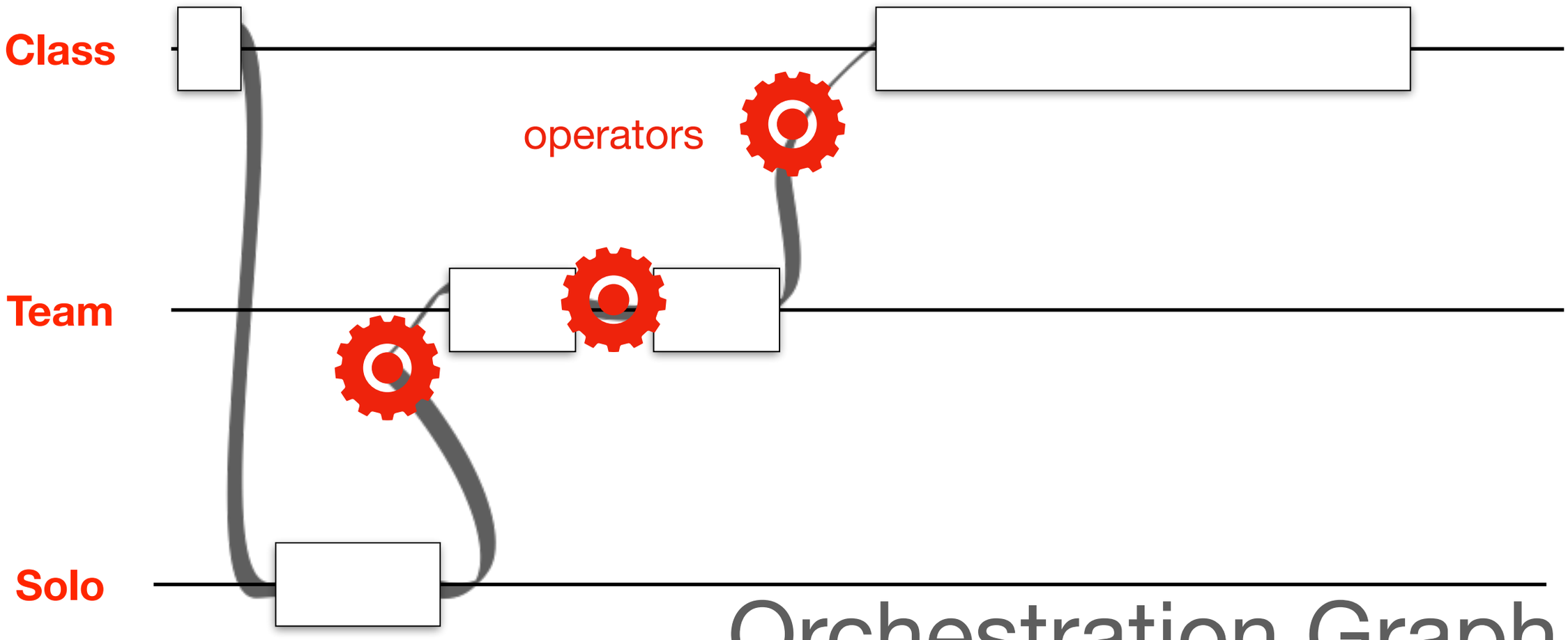
- Yes
- No

:36

HELP

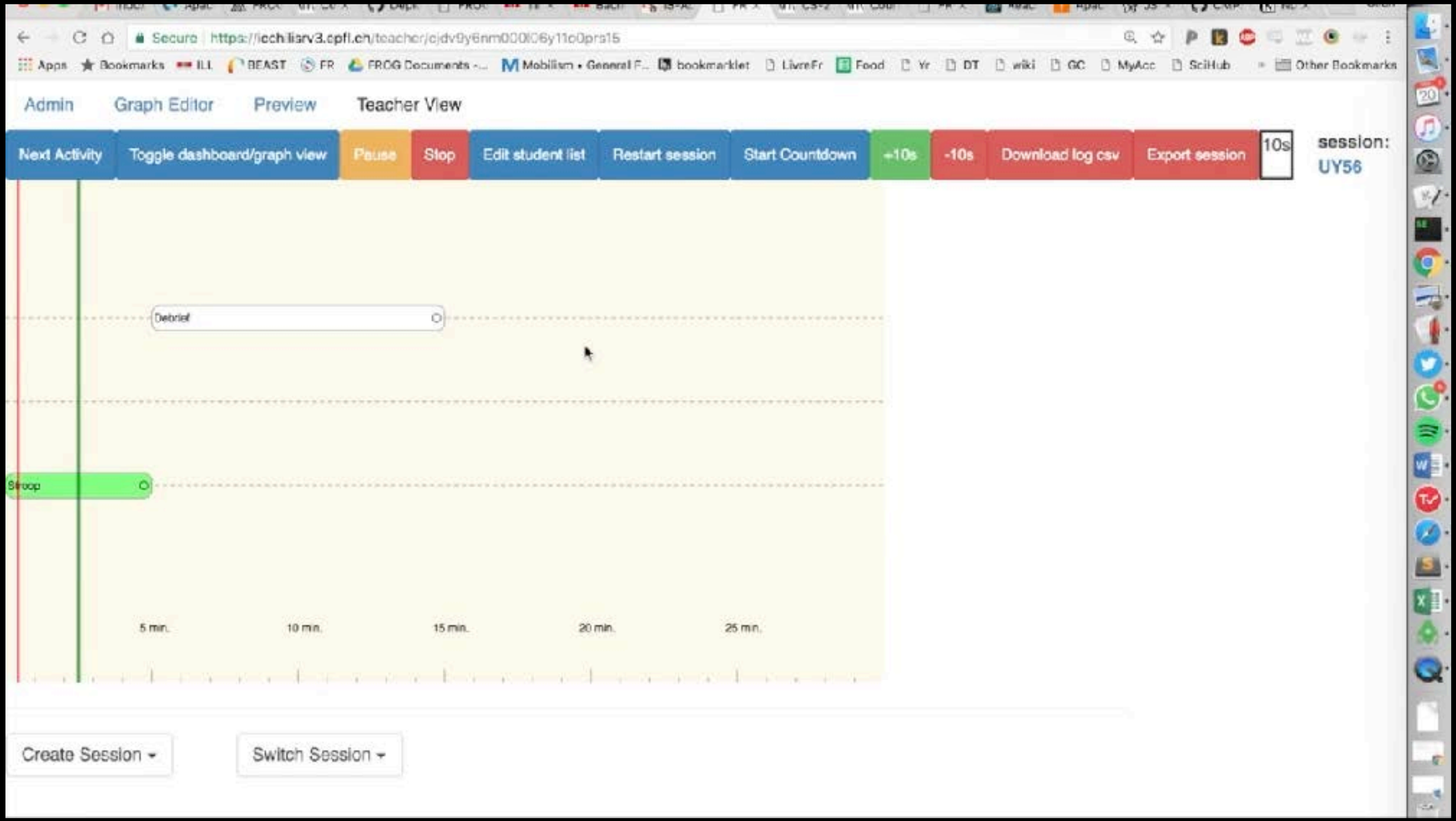
BUY

Debriefing



Orchestration Graph

Timing


Secure https://icchiiarv3.epfl.ch/teacher/cjdv9y6nm000l06y11o0prs15
Apps Bookmarks ILL BEAST FR FROG Documents -... Mobilism • General F... bookmarklet LivreFr Food Yr DT wiki GC MyAcc SciHub Other Bookmarks
Admin
Graph Editor
Preview
Teacher View
Next Activity
Toggle dashboard/graph view
Pause
Stop
Edit student list
Restart session
Start Countdown
+10s
-10s
Download log csv
Export session
10s
session:
UY56
Debrief
Stroop
5 min.
10 min.
15 min.
20 min.
25 min.
Create Session
Switch Session

Learning Analytics Ratios

observations

decision

1:1 Student Modeling
N:1 BKT or Dynamilis
N:2 Dual Eye Tracking
C:C Dashboards
N:C Classroom analytics
N:N Social Network Analysis
N:S Training needs Analysis

$2<C<N<P$

P.Dillenbourg