Creating a collaborative learning atmosphere in the classroom

Refresh teaching event:
Blending elements of distance learning and face-to-face teaching
18.01.2022

Bio-inspired active
and adaptive materials
D-MATL (MSc program)

15-20 students

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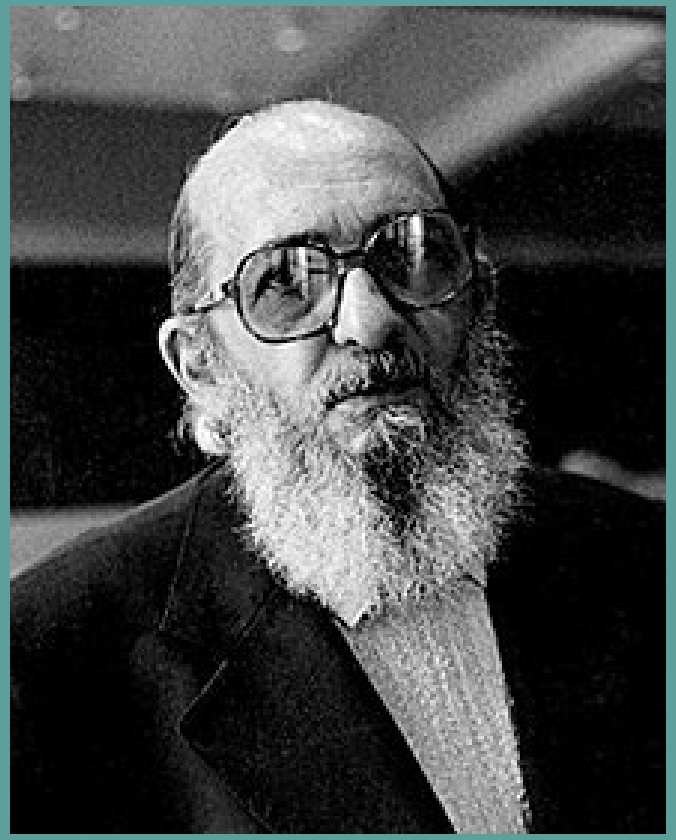
Implementing learning patterns based on critical pedagogy in higher education

The main foundations of critical pedagogy:

1. **Criticism of the "banking model" of education:** scenario in which students are viewed as empty bank accounts that are filled by teachers during the learning process. Freire defended that this approach transforms students into receiving objects that are forced to adjust to the world, which inhibit their creative power.

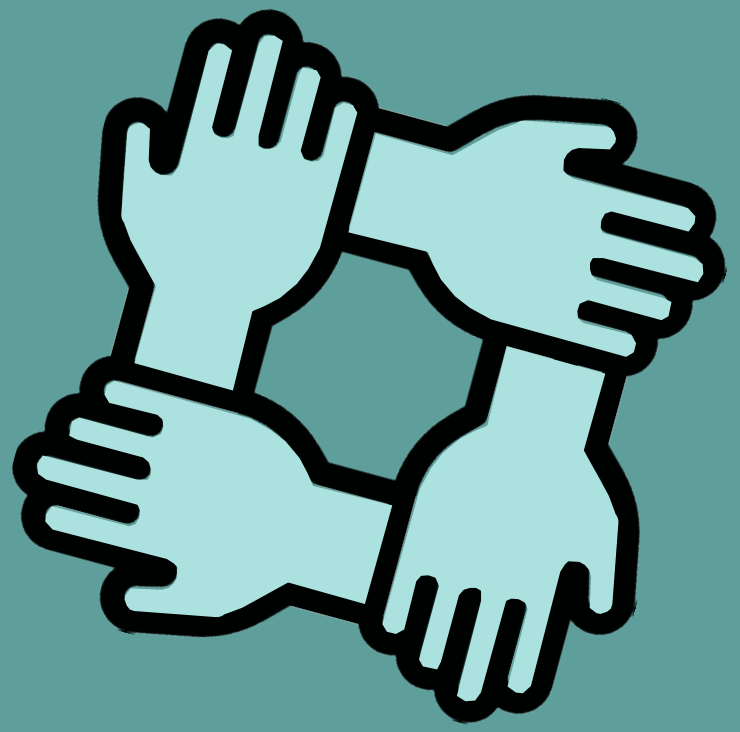
2. **Culture of silence:** according to Freire, unequal social relations create a "culture of silence" that projects a negative, passive and suppressed self-image onto the individuals, causing them to lose the means to critically respond to the knowledge that is offered to them.



Prof. Paulo Freire (1921-1997)
Educator

Central pedagogical elements employed in this course

Active Learning



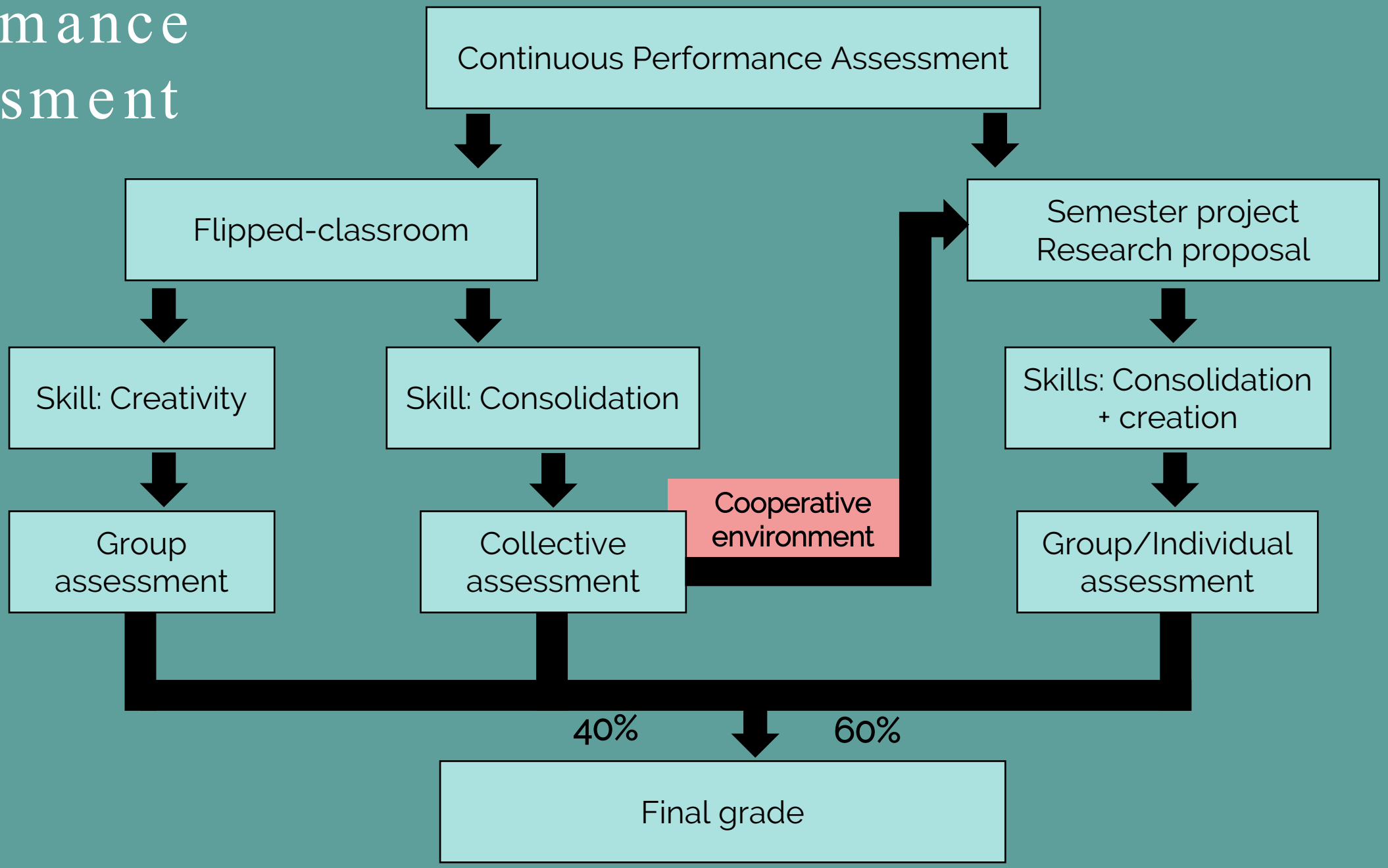
Collective construction of knowledge

From responsive to adaptive learning behavior

Responsive learning behavior → Active & Adaptive learning behavior

- **Introduction of multiple elements of performance assessment;**
- **Focus on active assignments and group work;**
- **Individual assignments are coupled to group work.**

Performance assessment



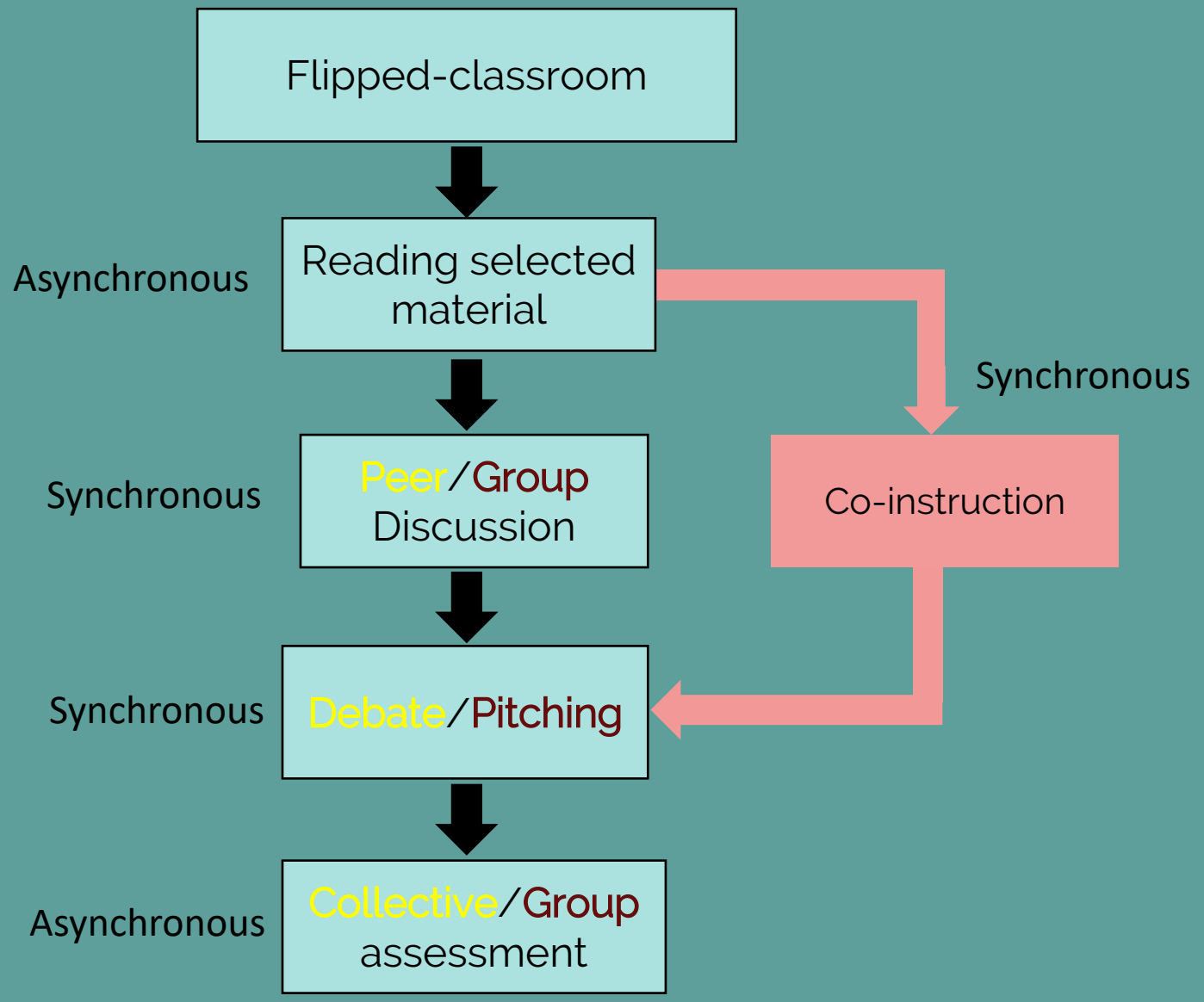
General structure flipped-classroom (before pandemic)

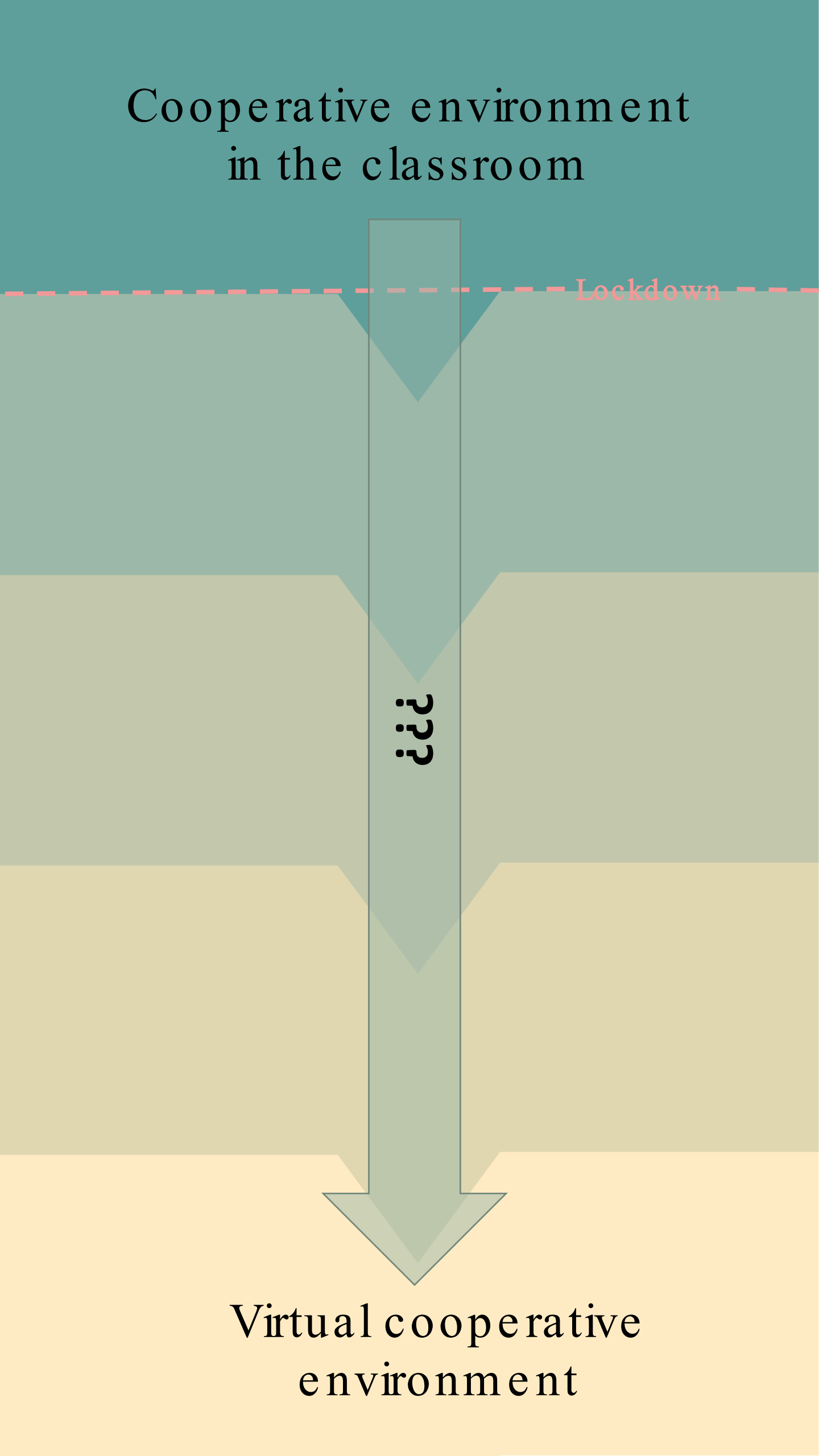
Format 1: Biological design principles

Goal: Consolidation of knowledge
Specific tasks: Peer-discussion (2 students) + Classroom debate

Format 2: Materials science perspective

Goal: Stimulation of creativity
Specific tasks: Group discussion (3-5 students) + pitching



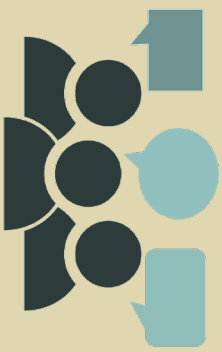

Cooperative environment
in the classroom
Lockdown
???
Virtual cooperative
environment

Cooperative environment in the classroom

Lockdown

Format adjustment

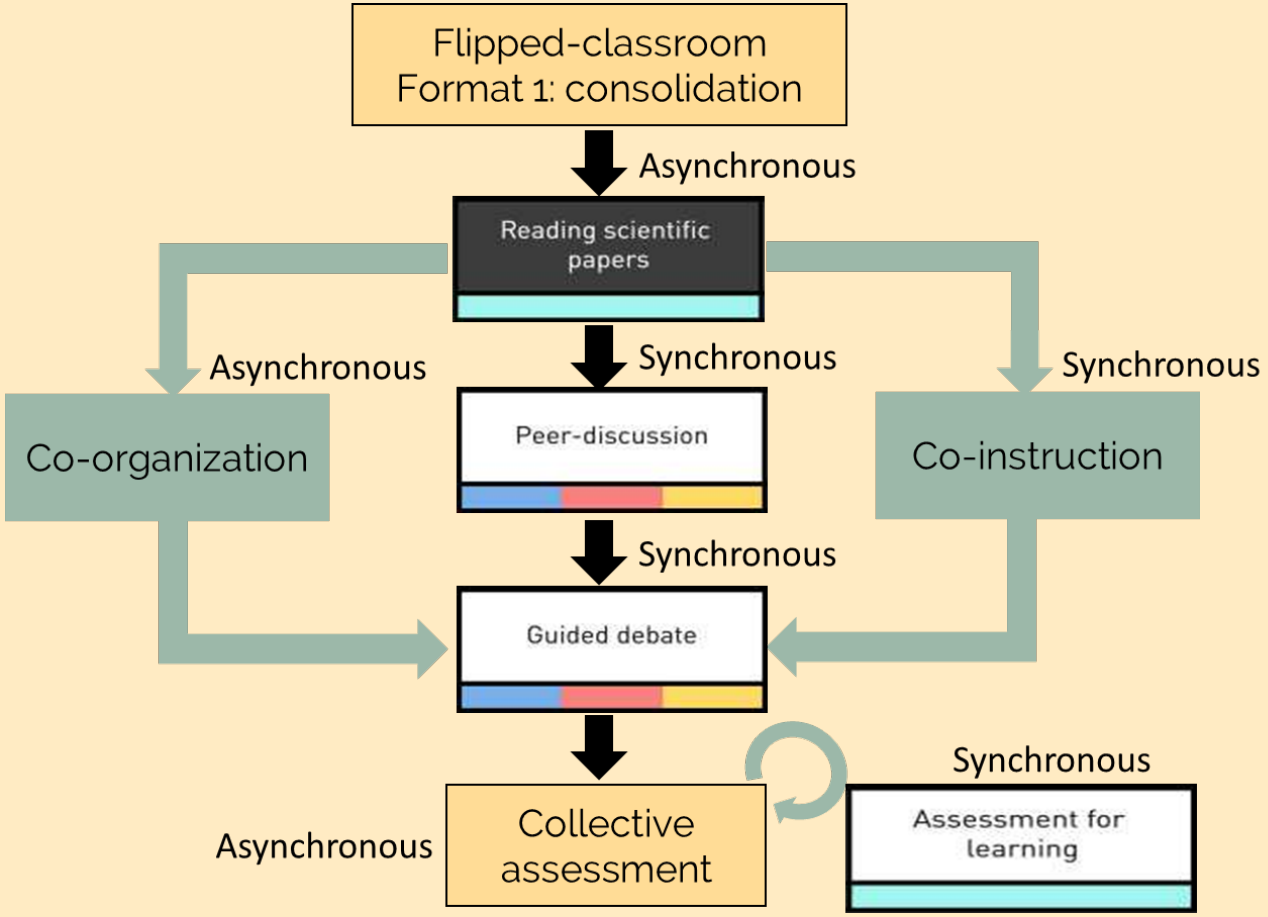
Assessment for learning

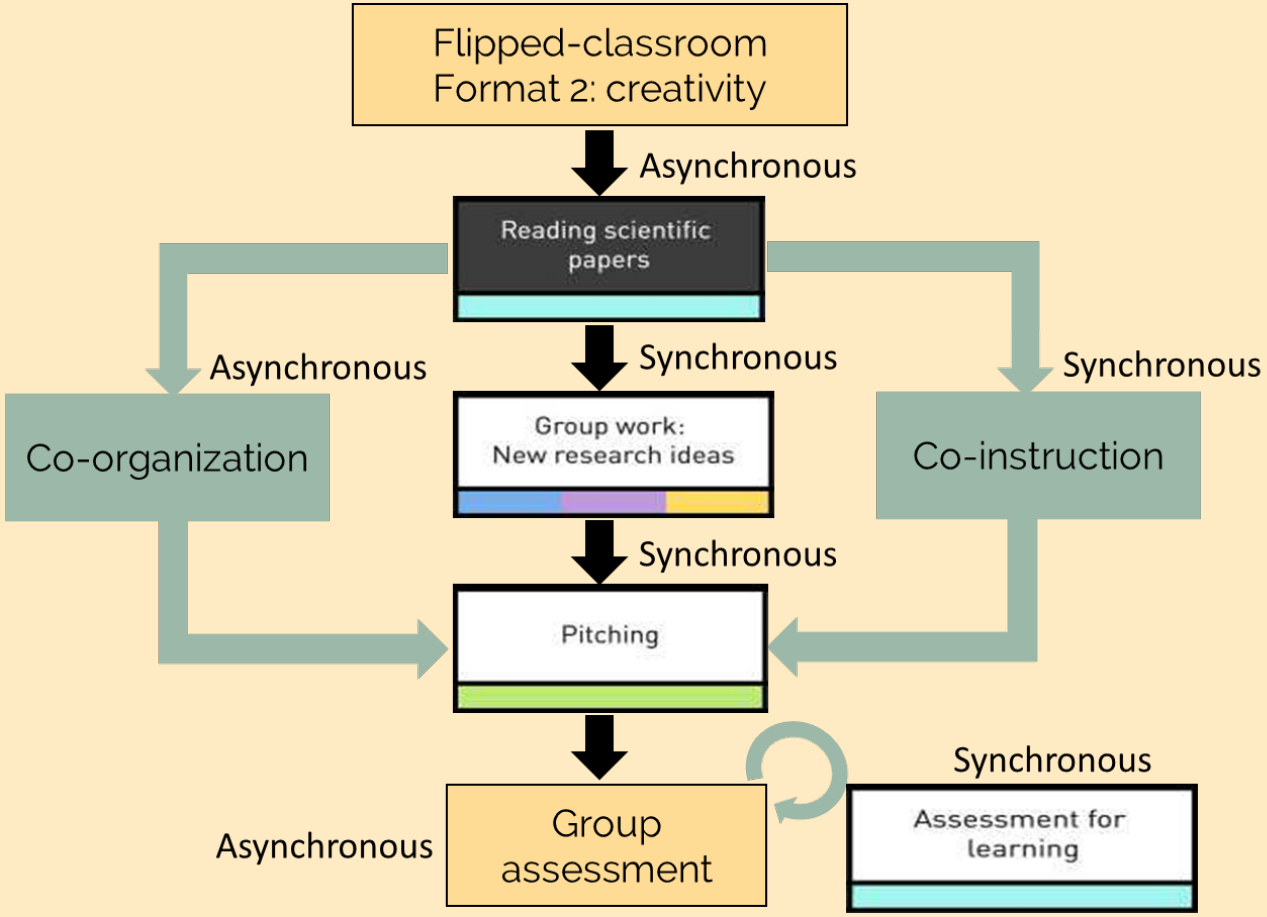


Guided discussion

Virtual cooperative environment

Co-teaching flipped-classrooms

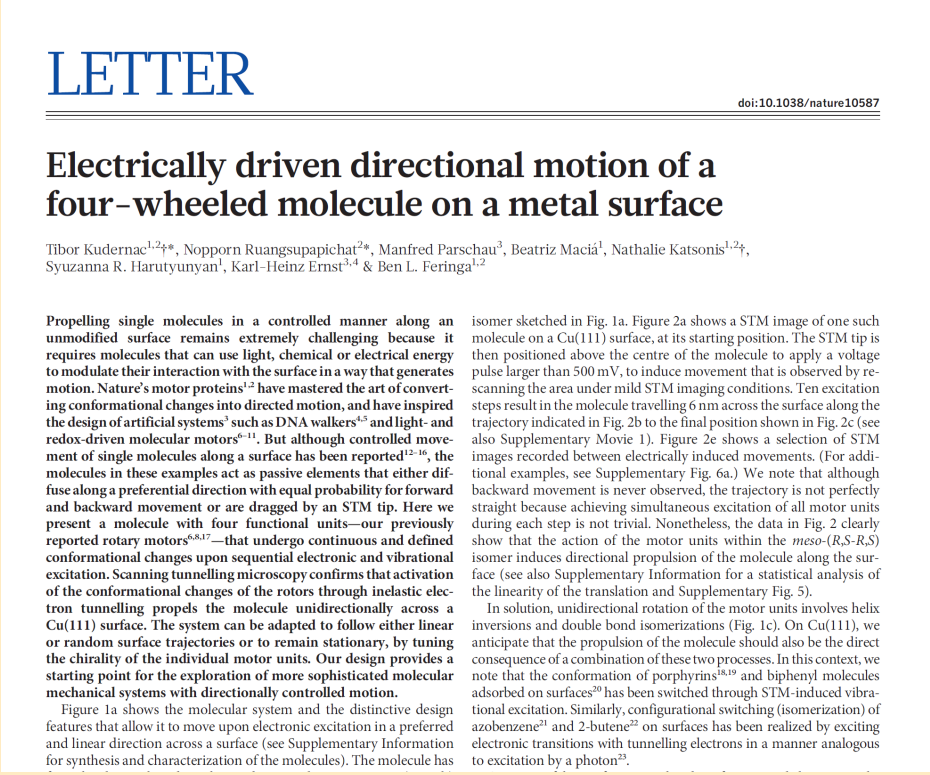




Acquisition | Discussion | Practice | Investigation | Collaboration | Production

Asynchronous step: Reading selected material

Scientific article on the topic of the lecture



LETTER

doi:10.1038/nature10587

Electrically driven directional motion of a four-wheeled molecule on a metal surface

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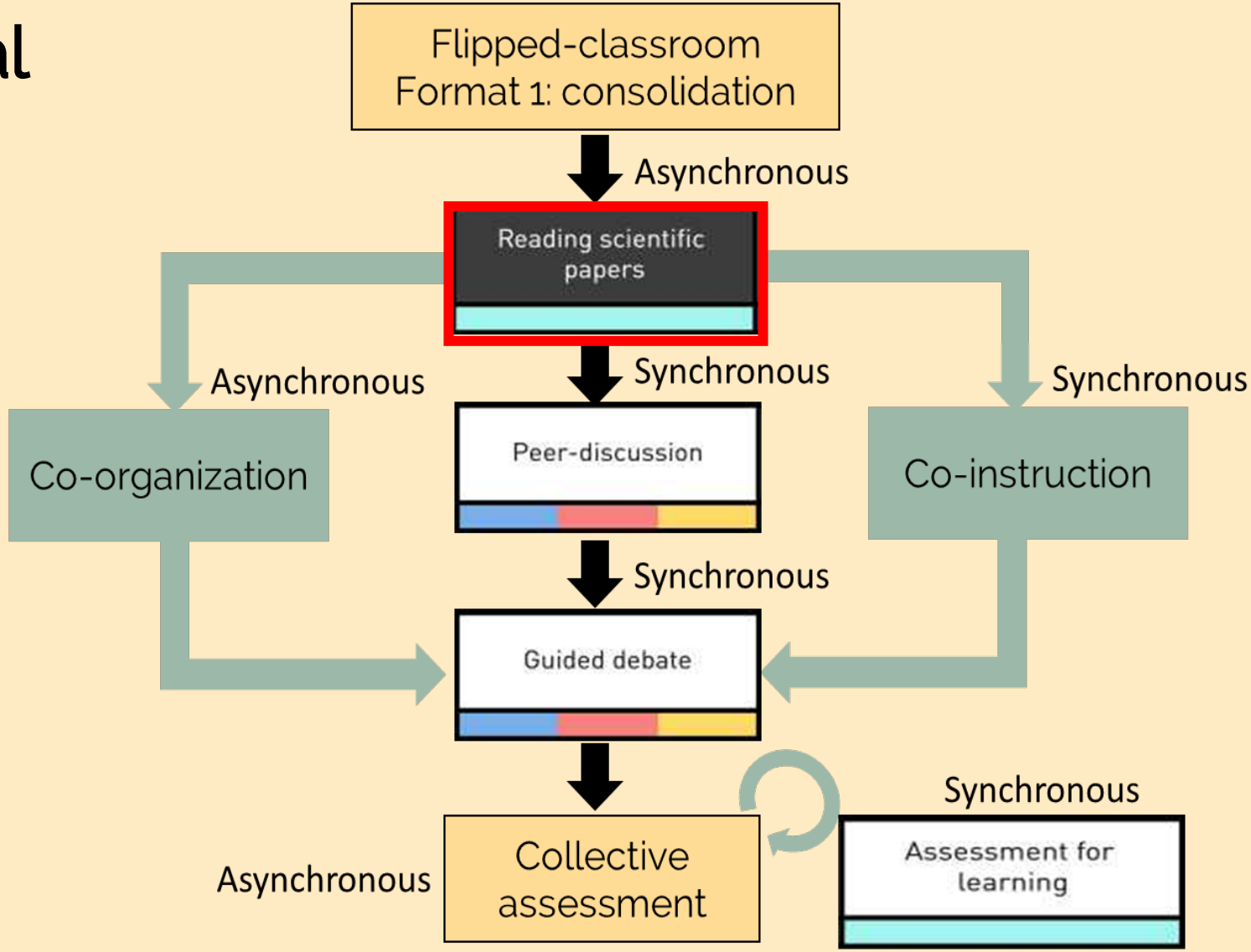
Propelling single molecules in a controlled manner along an unmodified surface remains extremely challenging because it requires molecules that can use light, chemical or electrical energy to modulate their interaction with the surface in a way that generates motion. Nature's motor proteins[1,2] have mastered the art of converting conformational changes into directed motion, and have inspired the design of artificial systems[3] such as DNA walkers[4,5] and light- and redox-driven molecular motors[6–11]. But although controlled movement of single molecules along a surface has been reported[12–16], the molecules in these examples act as passive elements that either diffuse along a preferential direction with equal probability for forward and backward movement or are dragged by an STM tip. Here we present a molecule with four functional units—our previously reported rotary motors[6,8,17]—that undergo continuous and defined conformational changes upon sequential electronic and vibrational excitation. Scanning tunnelling microscopy confirms that activation of the conformational changes of the rotors through inelastic electron tunnelling propels the molecule unidirectionally across a Cu(111) surface. The system can be adapted to follow either linear or random surface trajectories or to remain stationary, by tuning the chirality of the individual motor units. Our design provides a starting point for the exploration of more sophisticated molecular mechanical systems with directionally controlled motion.

Figure 1a shows the molecular system and the distinctive design features that allow it to move upon electronic excitation in a preferred and linear direction across a surface (see Supplementary Information for synthesis and characterization of the molecules). The molecule has isomer sketched in Fig. 1a. Figure 2a shows a STM image of one such molecule on a Cu(111) surface, at its starting position. The STM tip is then positioned above the centre of the molecule to apply a voltage pulse larger than 500 mV, to induce movement that is observed by re-scanning the area under mild STM imaging conditions. Ten excitation steps result in the molecule travelling 6 nm across the surface along the trajectory indicated in Fig. 2b to the final position shown in Fig. 2c (see also Supplementary Movie 1). Figure 2e shows a selection of STM images recorded between electrically induced movements. (For additional examples, see Supplementary Fig. 6a.) We note that although backward movement is never observed, the trajectory is not perfectly straight because achieving simultaneous excitation of all motor units during each step is not trivial. Nonetheless, the data in Fig. 2 clearly show that the action of the motor units within the *meso*-(*R*,*S*-*R*,*S*) isomer induces directional propulsion of the molecule along the surface (see also Supplementary Information for a statistical analysis of the linearity of the translation and Supplementary Fig. 5).

In solution, unidirectional rotation of the motor units involves helix inversions and double bond isomerizations (Fig. 1c). On Cu(111), we anticipate that the propulsion of the molecule should also be the direct consequence of a combination of these two processes. In this context, we note that the conformation of porphyrins[18,19] and biphenyl molecules adsorbed on surfaces[20] has been switched through STM-induced vibrational excitation. Similarly, configurational switching (isomerization) of azobenzene[21] and 2-butene[22] on surfaces has been realized by exciting electronic transitions with tunnelling electrons in a manner analogous to excitation by a photon[23].



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Asynchronous step: Co-organization (teachers)

Underlying concepts are extracted from reading material to guide the in-class debate

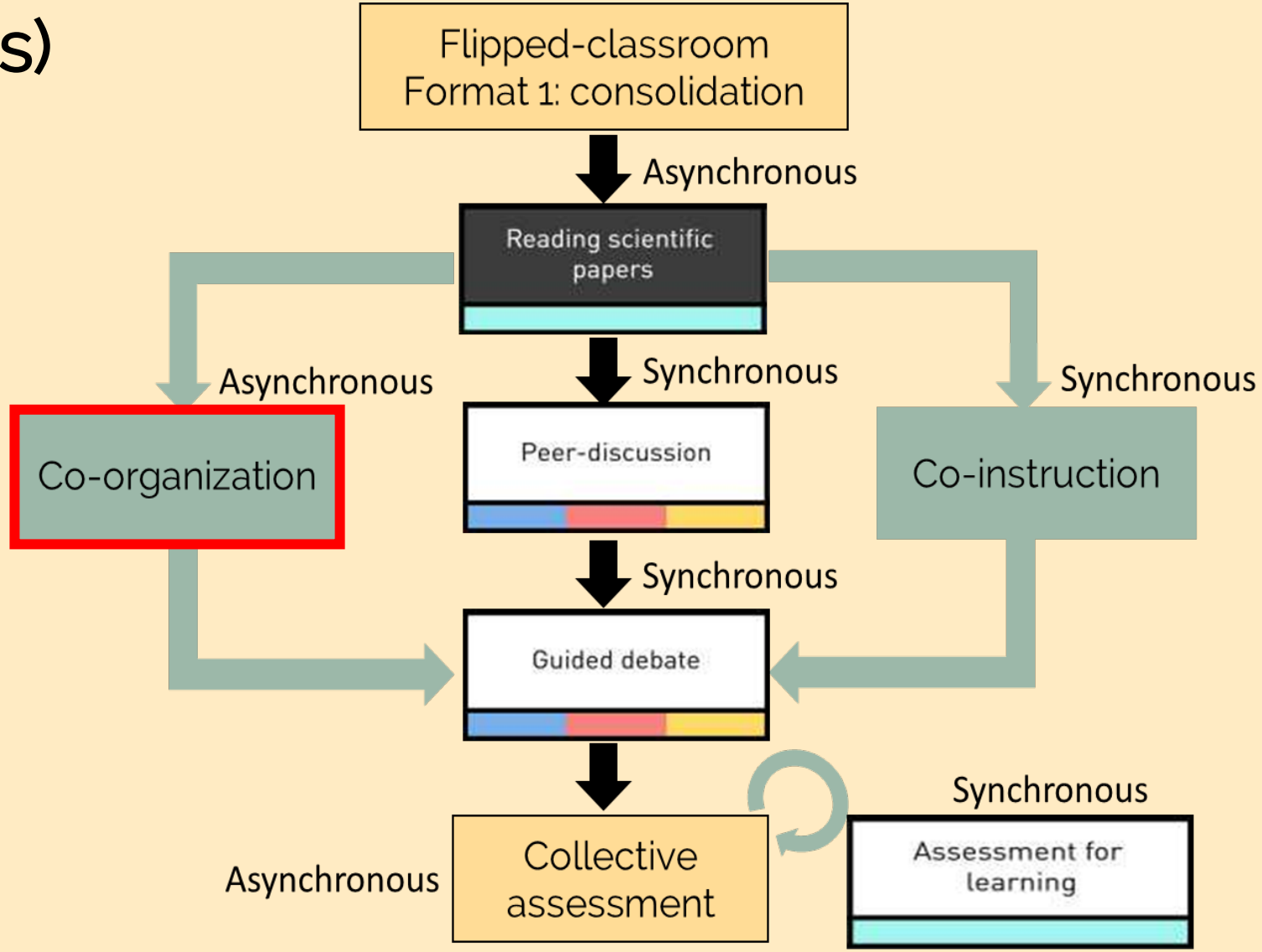
Atomically precise motors and walkers in synthetic systems

Paper: Electrically driven directional motion of a four-wheeled molecule on a metal surface

1. Inspiration - cars + molecular motors driven by isomerization
   - What other nanomotors have we seen during the class? What is the bioinspiration? What is the role of kinesins?

2. Mechanism - electron pulses by STM induce isomerization around a double bond and promote also vibrational excitation.
   - How do the authors avoid that the molecule sticks for good to the substrate?
   - How does a change in conformation convert into a movement?
   - How come the STM does not just drag the molecule along?
   - Is the system reversible? What is the role of impulse polarity over motion?
   - How is the control over motion achieved?
   - Can it be run without using an STM?

3. Limitations - heavily relying on how the "car" lands on the Cu (111) surface: different initial states and different enantiomers cause weird motions. Only R,S-R,S moves forward with a 0.7 nm theoretical step (experimentally, more like 0.6 nm). Requires UHV and an STM to work.
   - What are the main limitations of the systems?
   - How can we tell what is the maximum work this machine can perform?
   - Could it carry any payload?



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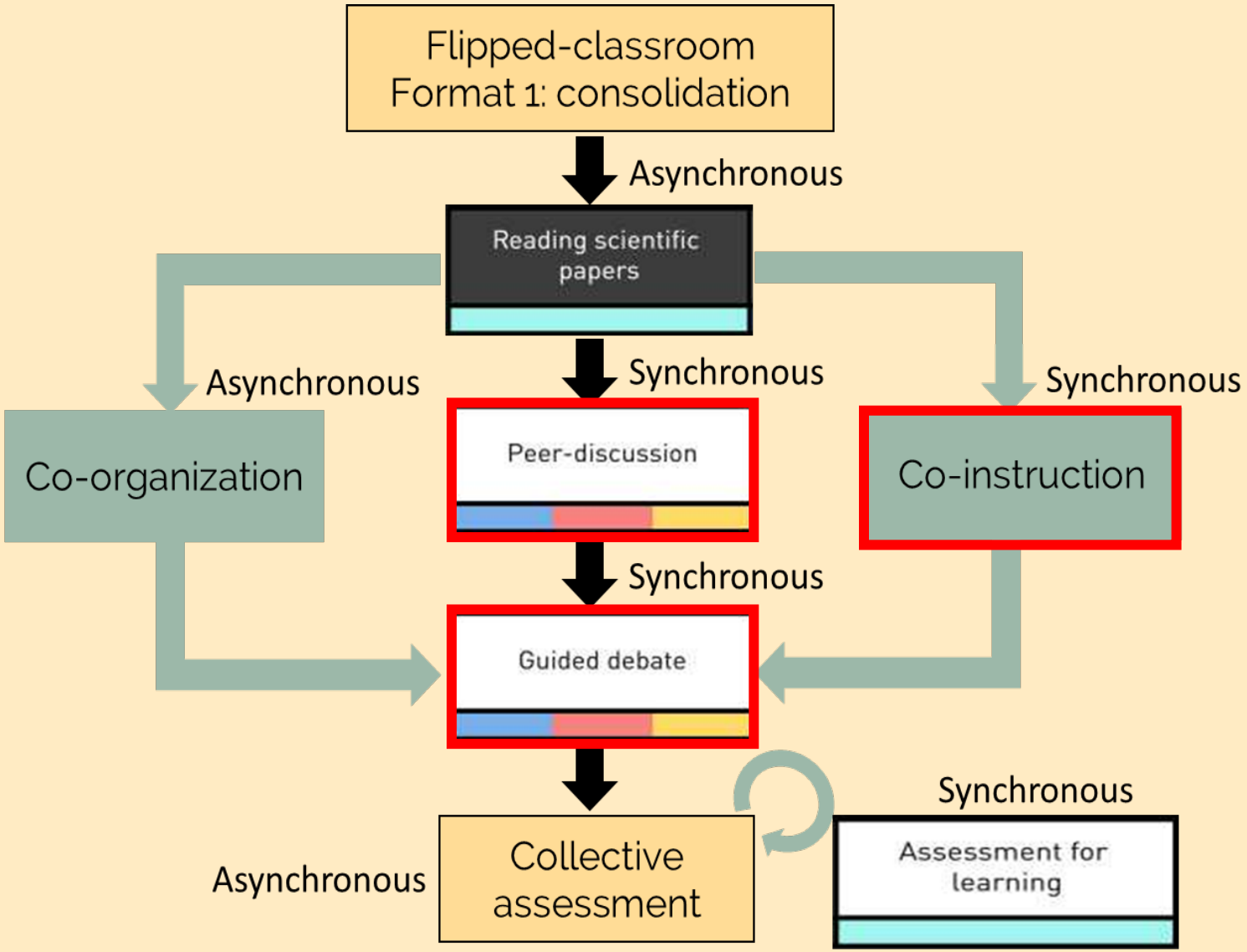
Synchronous assignment

Peer-discussion (students): students discuss with their peers in breakout rooms about the material assigned;

Debate (students): after the peer-discussion, a debate is open to the entire classroom;

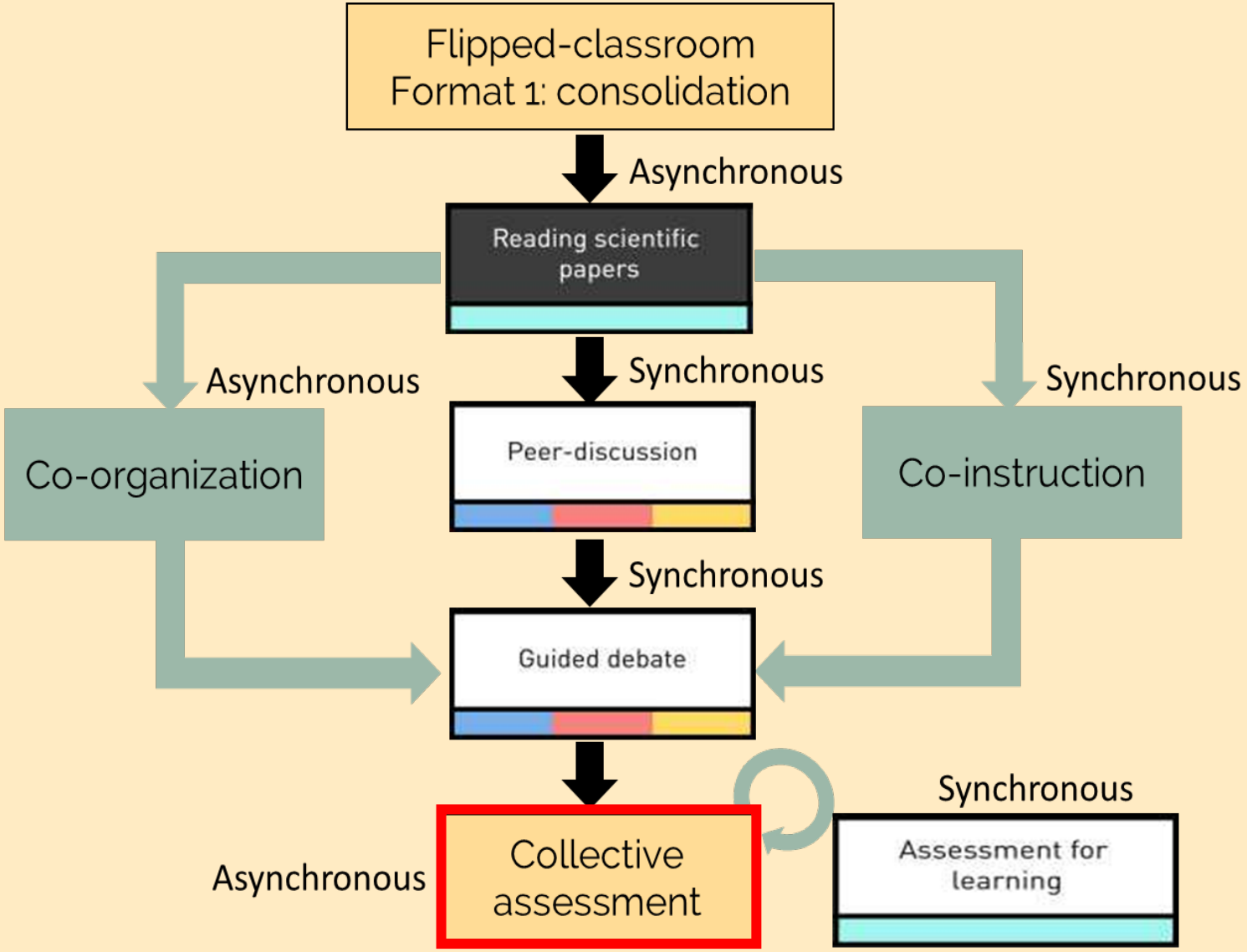
Co-instruction (teachers) : teaching instructors use the *"List of Key Concepts"* to guide the discussion in the classroom.



Collective assessment

Teaching instructors assess the collective performance of the classroom using a scoring rubrics with criteria that are linked to the learning goals of the course.

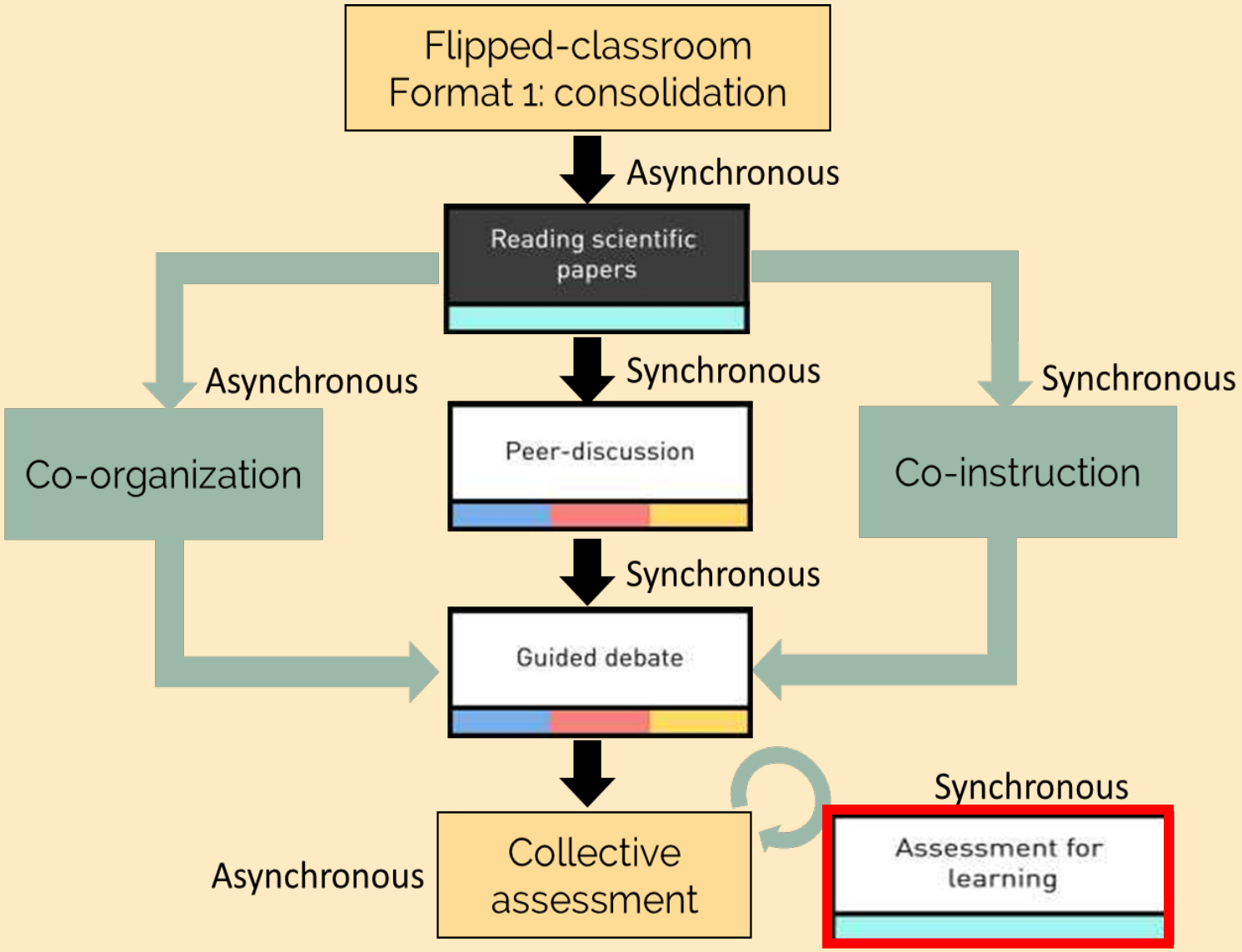
Criteria	Points			
	N/A	Insufficient	Sufficient	Excellent
Engagement in discussions (weight: 2)	0	2	4	6
Identification of the dynamic design principles present in the biological system	0	1	2	3
Explanation of working principles of out-of-equilibrium components in the biological system	0	1	2	3
Identification of possible applications in materials science	0	1	2	3



Acquisition Discussion Practice Investigation Collaboration Production

Co-assessment for learning

Assessment for learning (AFL) is a pedagogical tool that creates feedback on learning tasks that can be used to improve student's performance. *AFL* allows teaching instructors and students to align expectations and construct together new pathways towards the learning goals of the course.



Important elements to stimulate a collective mindset in the classroom

- Deconstruction of the hierarchy in the classroom;
- Openness to the *unknown;*
- Provision of regular feedback on performance (assessment for learning);
- Team effort (teaching instructors + students).

Acknowledgements

- Teaching assistants: Tommaso Magrini, Alessandro Dutto and Marco Binelli
- LET team: Philip Barth, Julia Kehl and Pia Scherrer
- D-MATL: Lorenzo de Pietro and Sara Morgenthaler

"Tell me and I forget, teach me and I may remember, involve me and I learn."

Benjamin Franklin