Productive Epistemic Games

in an Investigative Science Learning Environment

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Labs: What are our students supposed to learn?

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Epistemic knowledge

Conceptual knowledge

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Labs: What are our students supposed to learn?

There are too many goals!

(Wilcox & Lewandowski, 2017)

Epistemic knowledge

Conceptual knowledge

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Labs: What are our students supposed to learn?

Lab education should **focus on experimentation** rather than theory (Smith & Holmes, 2021) and this may improve students' critical thinking skills and views on experimentation (Walsh et al., 2022)

Experimentation as in **"the approach, techniques, skills and ways of thinking when conducting authentic physics experiments"** (Smith & Holmes, 2021, p. 662)

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Epistemic knowledge

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Labs: How are our students supposed to learn?

Active learning is more effective than traditional lectures (Wieman, 2014; Deslauriers et al., 2011, Deslauriers et al., 2019) and improves epistemological skills in laboratory education (Holmes et al., 2015)

Learning environments that use active learning require students **”processing and applying information”** (Wieman, 2014, p. 8319) **through for example discussions and problem solving together with other students**

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Labs: What and how are our students supposed to learn?

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What makes students productive within a learning environment that involves these aspects?

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Successful in regards to the goals of the learning environment

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What makes students productive within a learning environment that involves these aspects?

We need:

1) Learning environment that involves a focus on experimentation and active learning

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The learning environment

Investigative Science Learning Environment (ISLE) (e.g. Etkina et al., 2013)

Two goals (Etkina et al., 2021):

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Two goals (Etkina et al., 2021):

1) To engage students in processes that mirror the scientific processes used by physicists

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2) To enhance social aspects related to laboratory work

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The learning environment

Elements of ISLE

(Etkina et al. 2021)

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The learning environment

Elements of ISLE

Observational experiments

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Explanations

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Observational experiments

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Testing experiments (with predictions based on explanations)

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Elements of ISLE

Observational experiments

Explanations

Testing experiments (with predictions based on explanations)

Reflection and revision (if outcome doesn't agree with predictions)

(Etkina et al. 2021)

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The learning environment

Elements of ISLE

Observational experiments

Explanations

Testing experiments (with predictions based on explanations)

Reflection and revision (if outcome doesn't agree with predictions)

More testing experiments (if outcomes does agree with predictions)

(Etkina et al. 2021)

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Active learning more effective than traditional lectures (Wieman, 2014; Deslauriers et al., 2019) and improves epistemological skills in laboratory education (Holmes et al., 2015)

What makes students productive within a learning environment that involves these aspects?

We need:

2) Framework to study epistemological aspects

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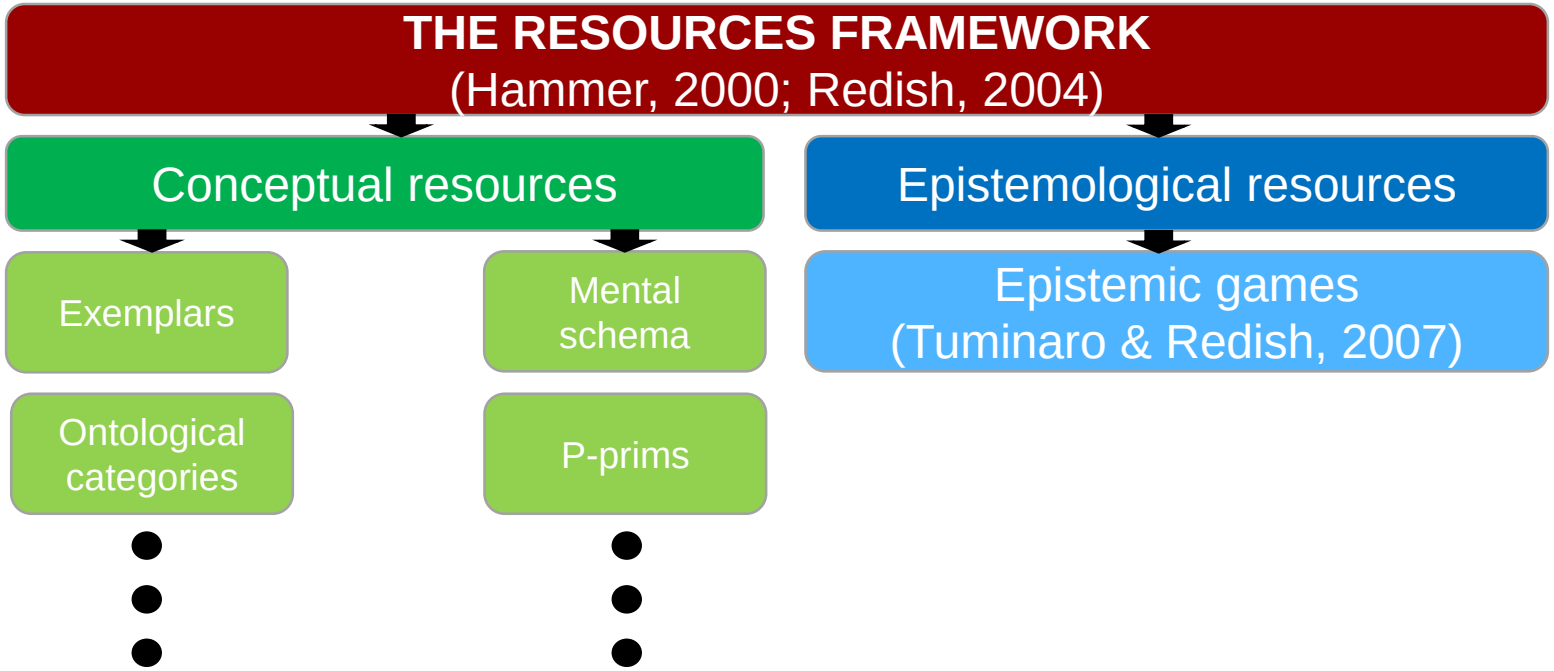
The framework



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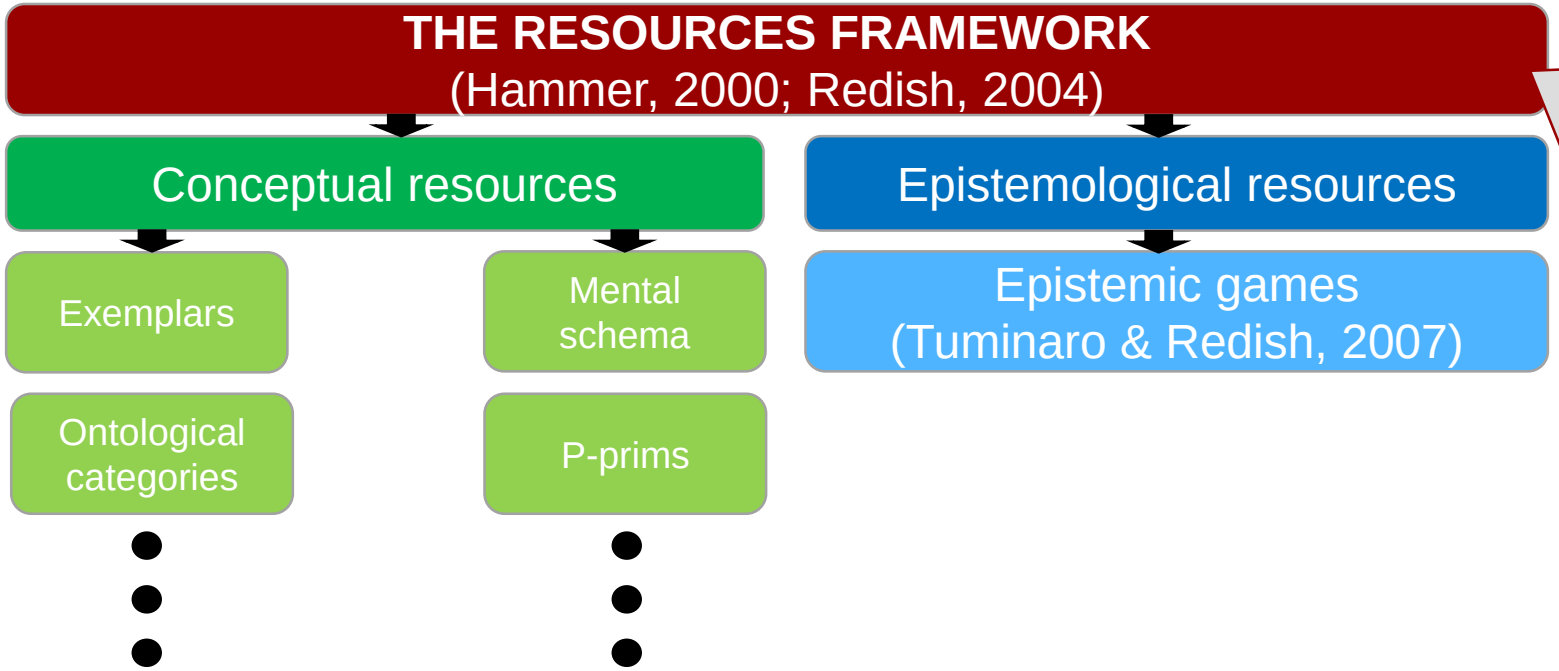
The framework



”*Resource* – a compiled knowledge element, [...], different levels of structure may be used as resources by different individuals.”
(Redish, 2004, p. 58)

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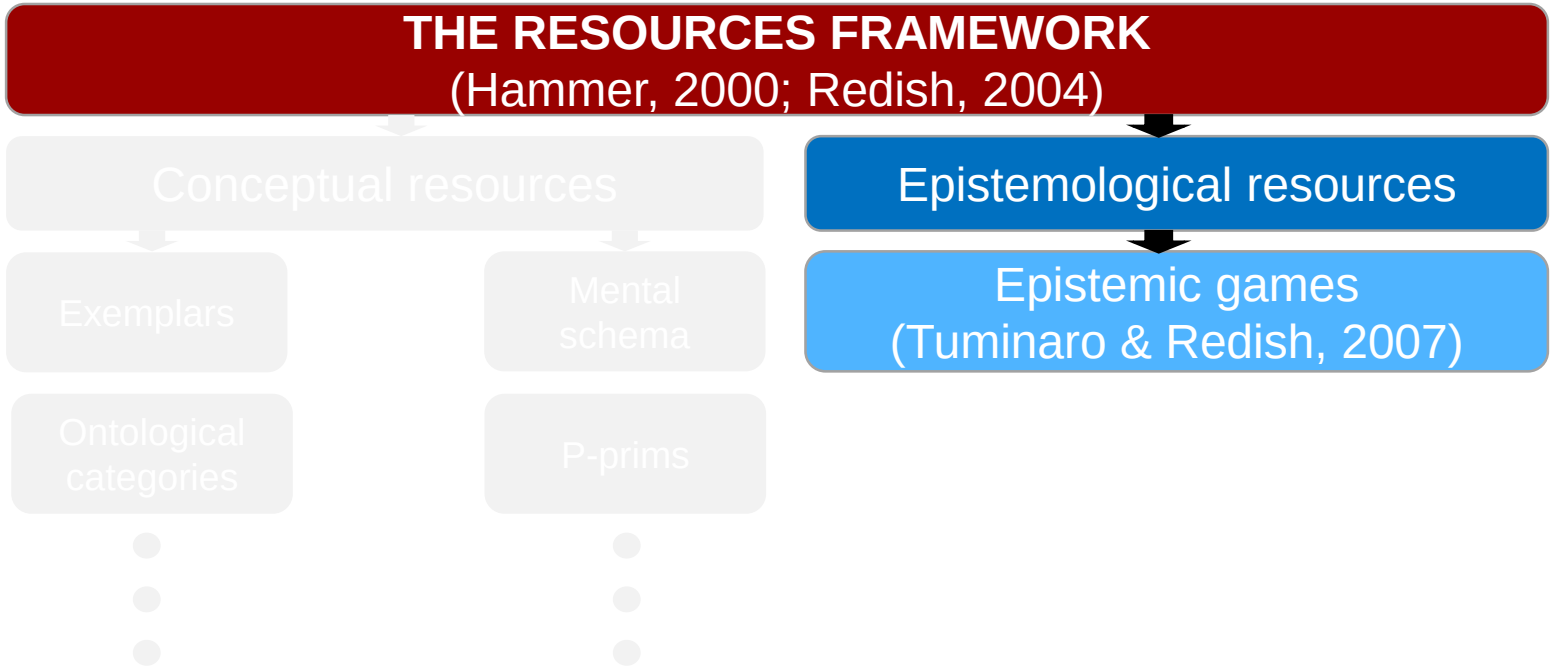
The framework



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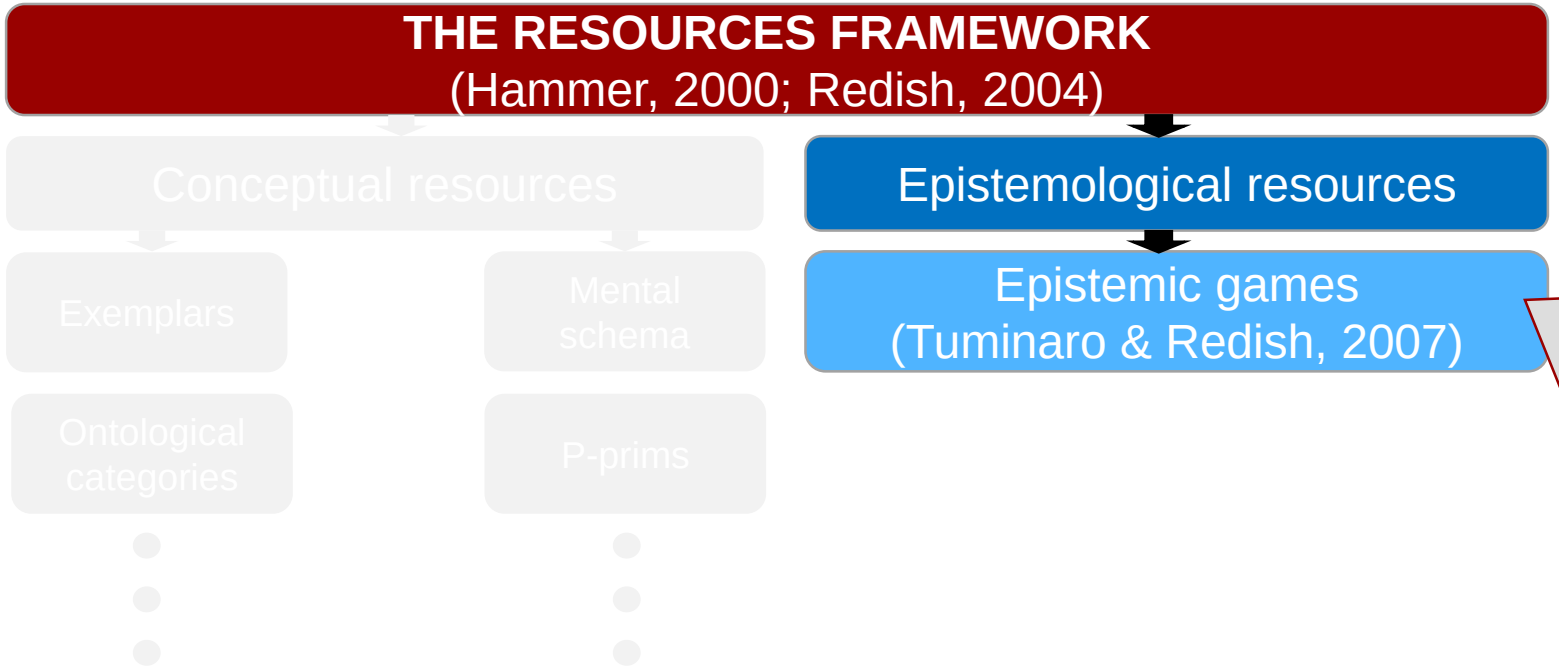

”a coherent activity that uses particular kinds of knowledge and processes associated with that knowledge to create knowledge or solve a problem.” (Redish, 2004, p. 30)

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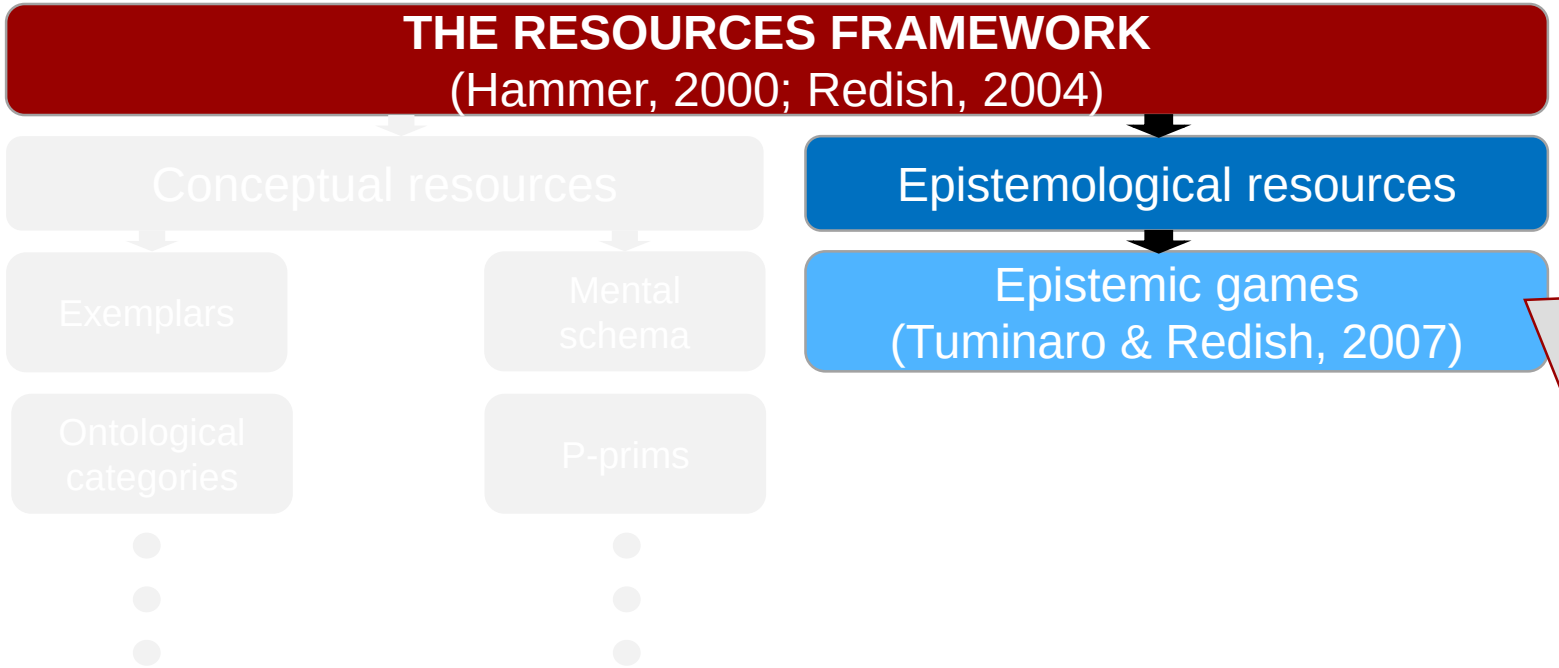

Basically: Strategies to create, gather, share and process knowledge.

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The framework

THE RESOURCES FRAMEWORK
(Hammer, 2000; Redish, 2004)

Conceptual resources

Exemplars

Ontological categories

Mental schema

P-prims

Epistemological resources

Epistemic games
(Tuminaro & Redish, 2007)

Examples:

- List making
- Pictorial Analysis Game *(e.g. free-body diagram)*
- Recursive Plug-and-Chug

Basically: Strategies to create, gather, share and process knowledge.

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Research question

What makes students productive within a learning environment that involves these aspects?

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Research question

What makes students productive within a learning environment that involves these [experimentation and active learning] aspects?

What epistemic games do students employ when formulating observations, hypotheses and designing possible experiments about a phase transition within an investigative science learning environment?

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Activity: Frame

General: Think aloud! Tell each other how you reason, what you associate to and think about. For example "but we know from "X" that…", "When I cook food…", "I remember a lab from high school in which…"

Go through the following steps:

1. **Observe** the ice in front of you when salt is added to the ice. What happens? Try to be as complete in your descriptions as possible.

2. Formulate some possible **explanations** to your observations. It is encouraged to formulate multiple such explanations (at least 2). The explanations do not have to be correct, but they should be experimentally testable. Write down your explanations.

3. **How would you test** your explanations? Propose different testing experiments.

4. The researcher shows what equipment that is available. **Modify** or add to your testing experiments if necessary after seeing the equipment.

5. Give a **prediction**, based on your explanations, for the experiments before you carry them out. Predictions for the experiments should be based on the different explanations (what happens in the experiment if the explanation holds?).

6. **Carry out** the testing experiment, note the result and compare with your predictions. Discuss what the result tells you about your explanations. Is it possible to **reject** any of them?

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Activity: Participants

Physics teacher students (TS)

Electrical engineering students (ES)

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Activity: Participants

Physics teacher students (TS)

Electrical engineering students (ES)

- The teacher students have some experience with ISLE.
- The teacher students have additional training in thinking about learning and knowledge.
- About the same amount of training in physics.
- No background in chemistry
- Phenomenon novel for both pairs.

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Activity: Phenomenon

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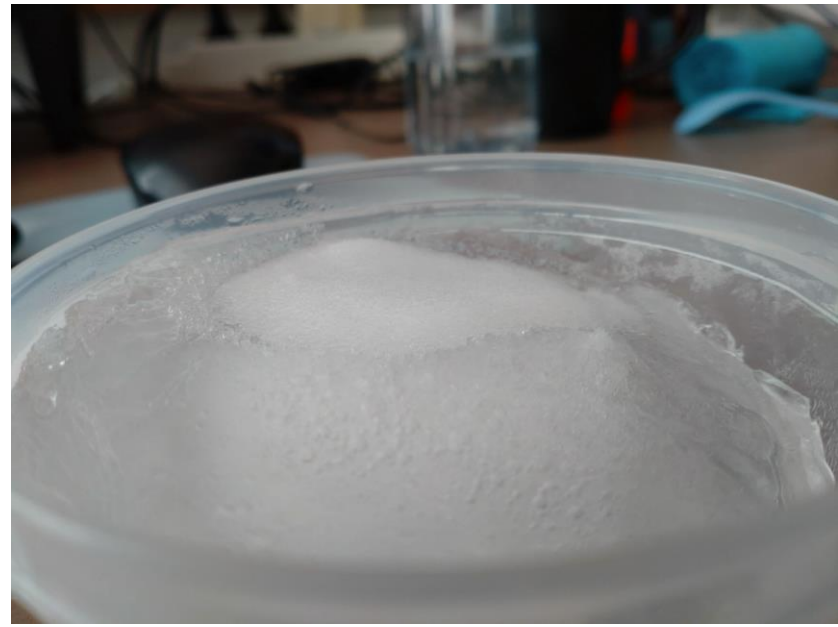
The ice melts



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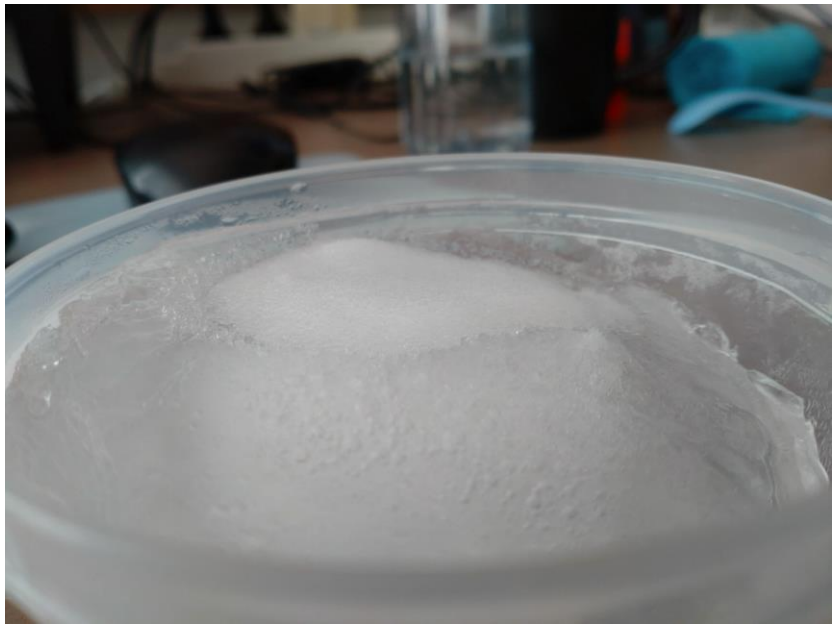
Activity: Phenomenon

The ice melts

Some potential explanations:

- The temperature for the phase transition is lowered when salt is added to the ice
- The salt has a higher temperature than the surroundings
- The salt has a higher thermal conductivity than the surroundings
- There is an exothermic reaction when salt dissolves in water



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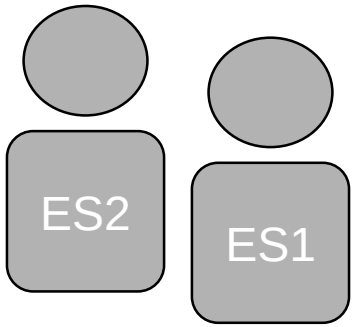
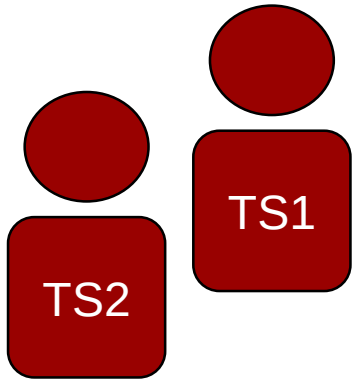
Activity:
Sharing knowledge
– ”interthinking”

Engineering students (ES) &
Teacher students (TS)





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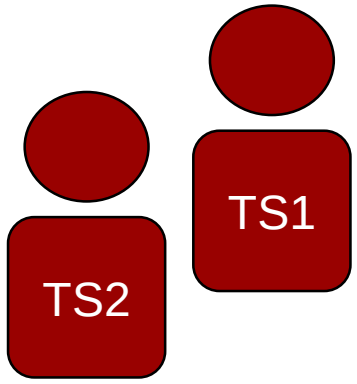
Activity: Sharing knowledge – ”interthinking”

I'm thinking that it also melts because of heat transfer.

Exploratory talk
Explaining ideas to each other and building a shared knowledge base- ”knowledge is made more publicly accountable and reasoning is more visible in the talk” (Mercer, 1995, p. 104)



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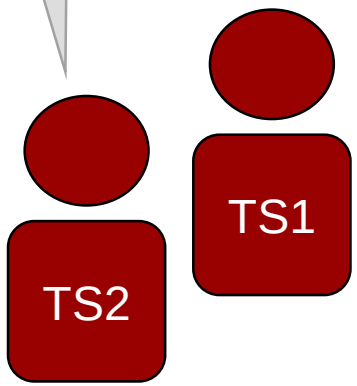

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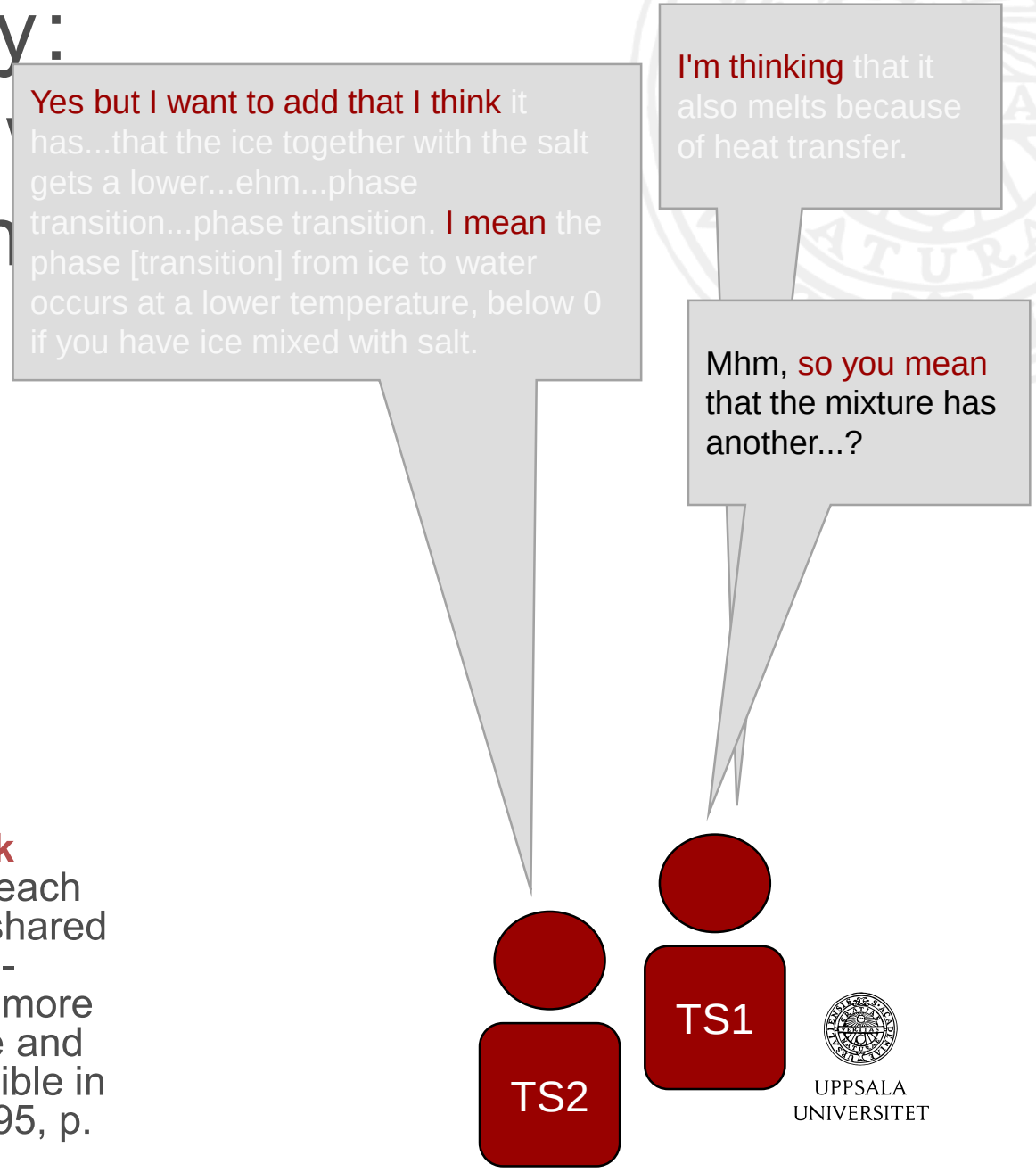

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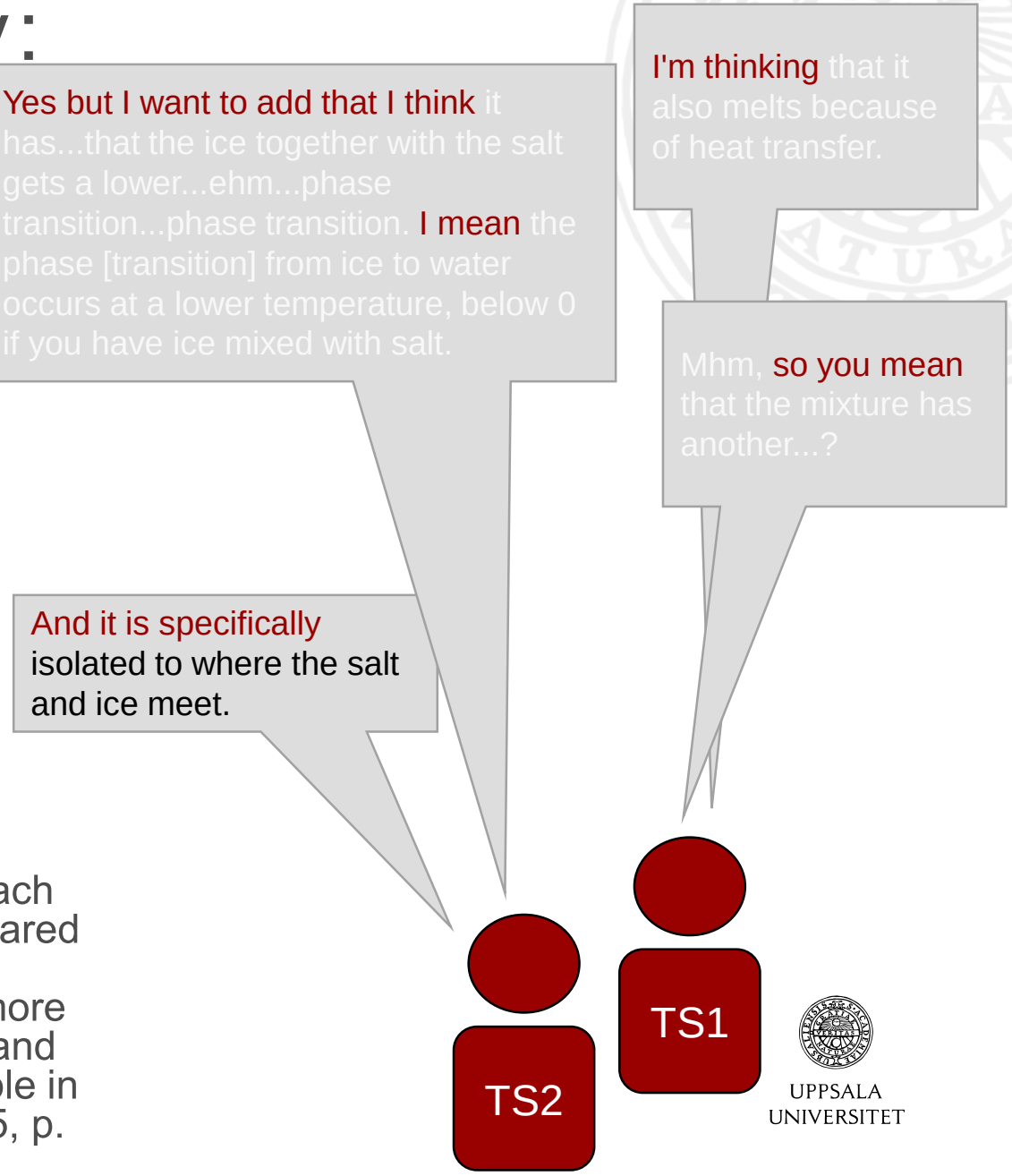

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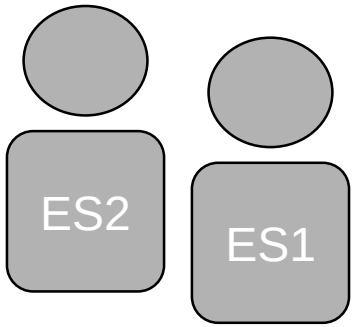

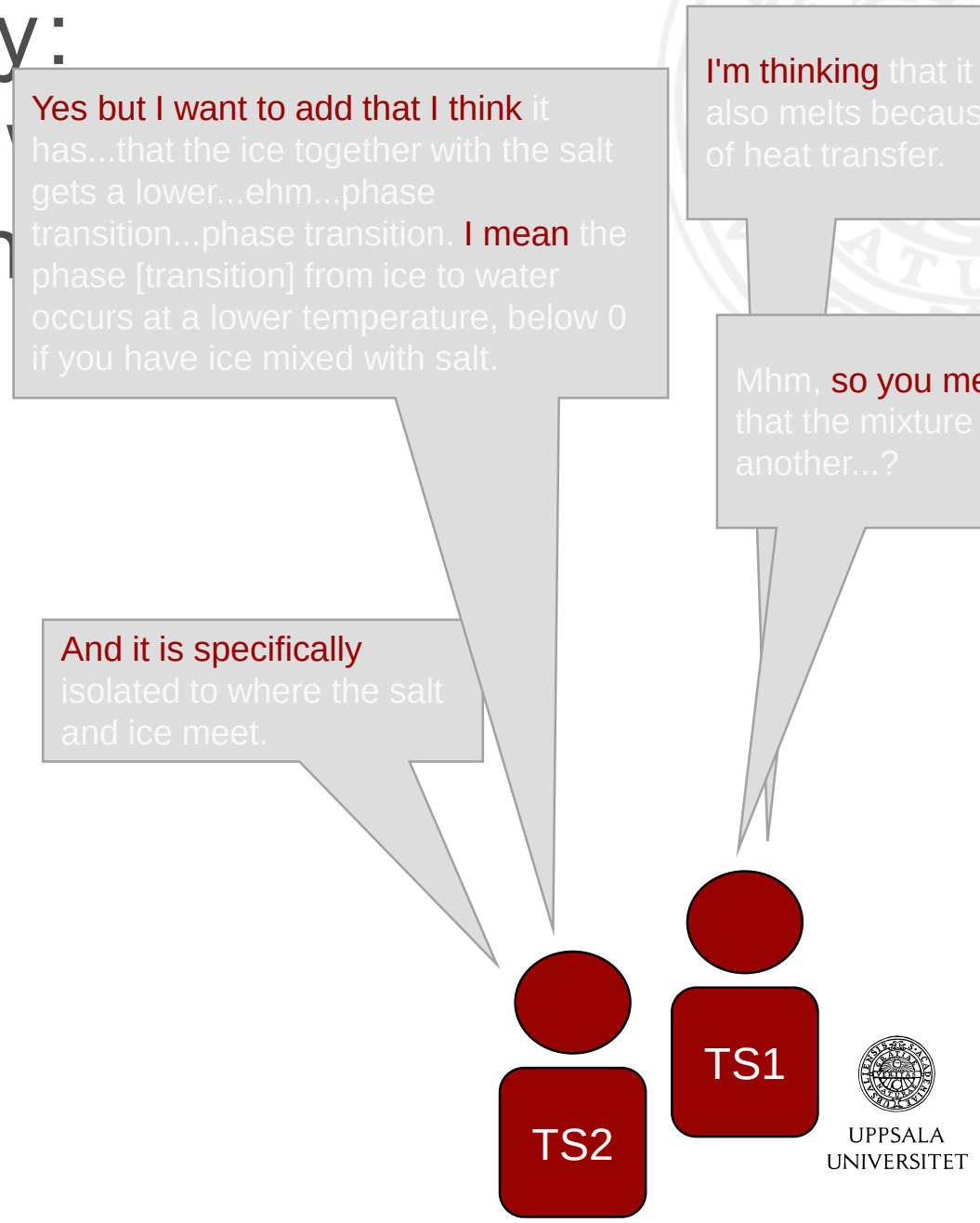

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Activity:
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– ”interthin

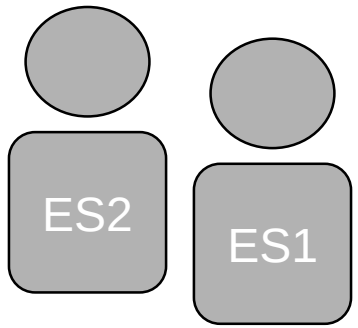
I cant remember any explanation for it. I can't really remember.

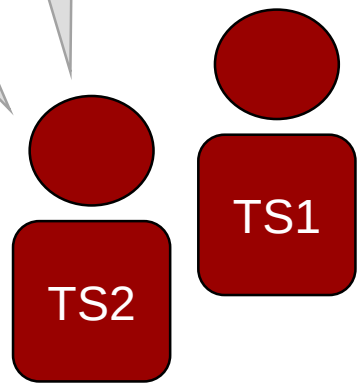
Yes but I want to add that I think it has...that the ice together with the salt gets a lower...ehm...phase transition...phase transition. I mean the phase [transition] from ice to water occurs at a lower temperature, below 0 if you have ice mixed with salt.

I'm thinking that it also melts because of heat transfer.

Mhm, so you mean that the mixture has another...?

And it is specifically isolated to where the salt and ice meet.





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ES2

ES1

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But should we say that it takes a free electron but...it feels like...it is really difficult to think creatively. You don't want to break...This with equilibrium, it feels like there should be energy added for it to be...some potential maybe. It always wants to go there where it fits the best, where it is the highest...I don't remember what it is called but I mean it is really potential between molecules in this way. [inaudible] and the location where it fits the best kind of.

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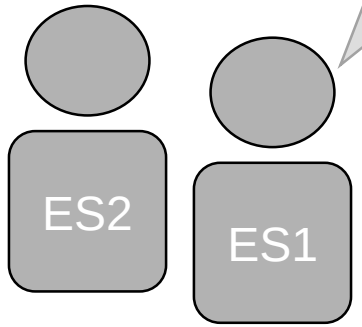

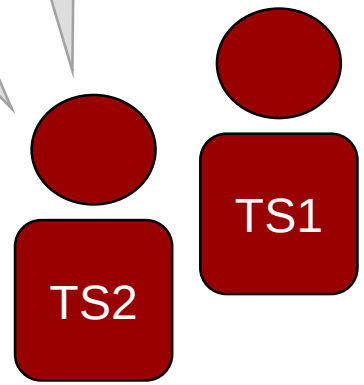

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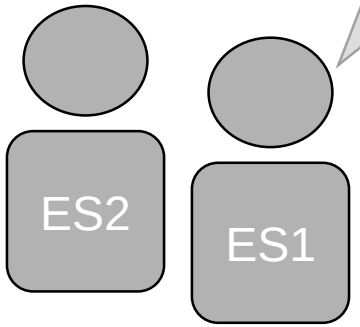

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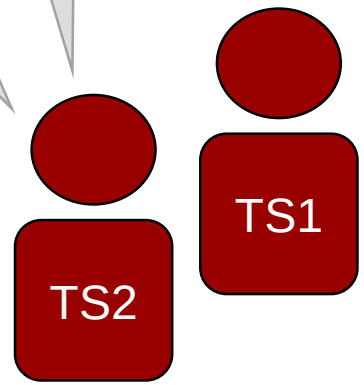

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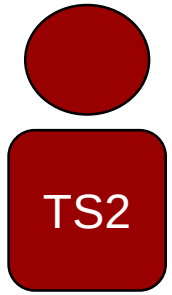
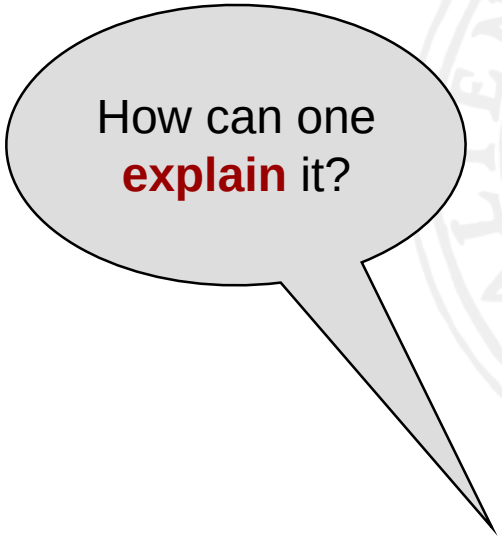
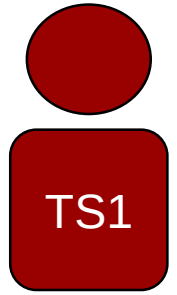
Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against







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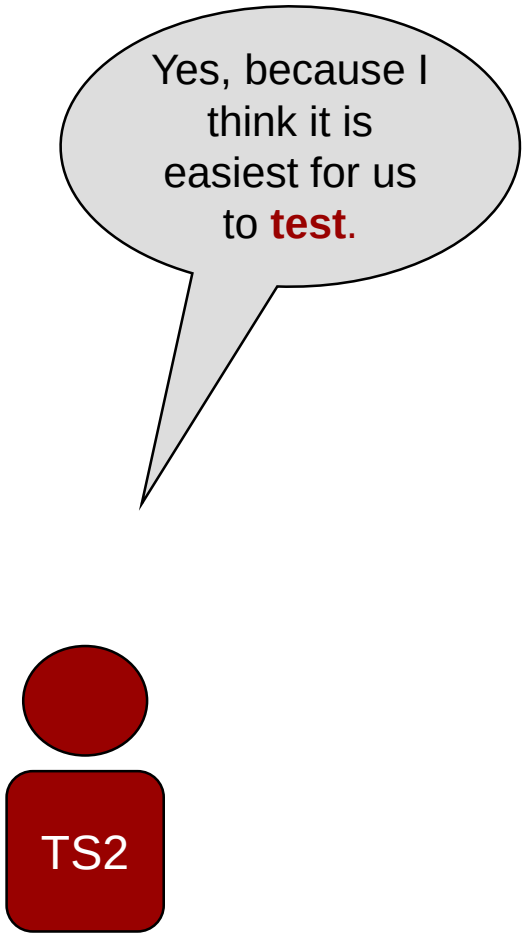
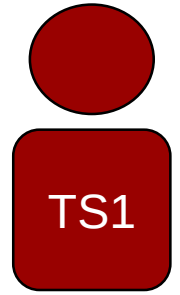
ISLE as a framework for the students to regulate against



How can one **explain** it?



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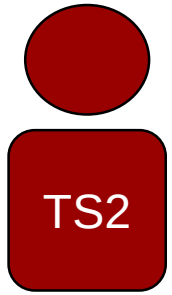
Activity: Sharing practice

Self-regulation

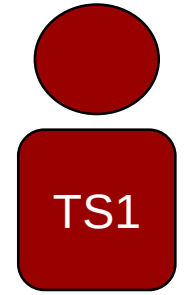
ISLE as a framework for the students to regulate against

Yes, because I think it is easiest for us to **test**



How can one explain it?

Ok, but in any case, we **saw** that it quickly became wet.



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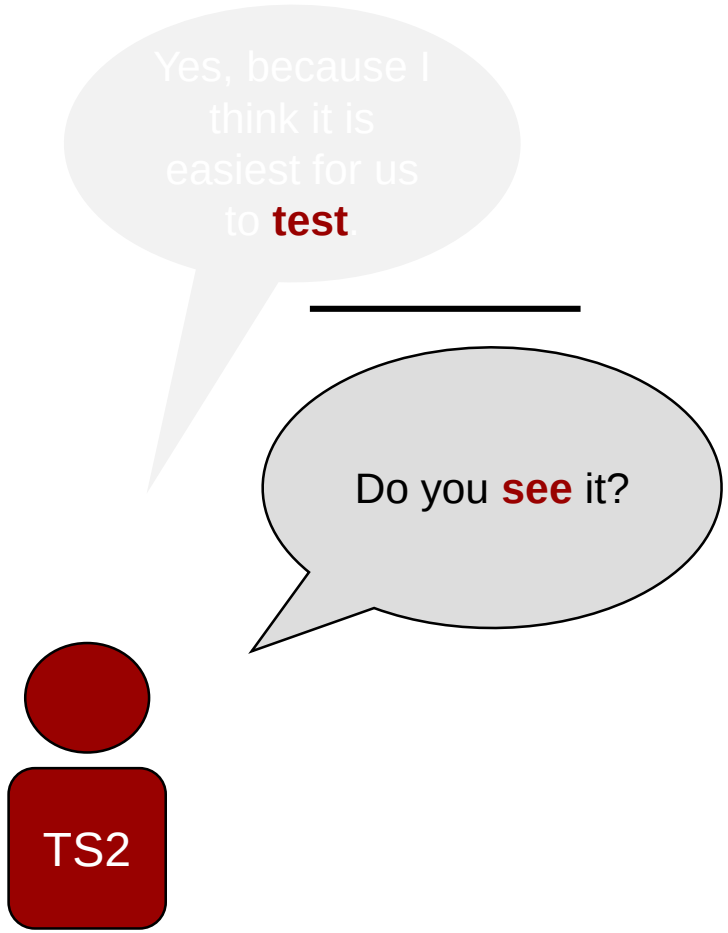
Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against



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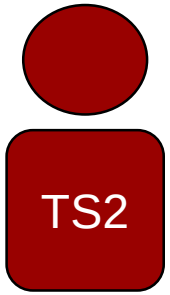
Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against

Yes, because I think it is easiest for us to **test**

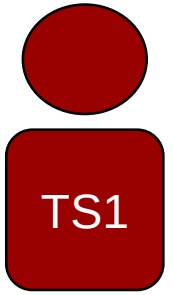
Do you **see** it?



How can one **explain** it?

Ok, but in any case, we **saw** that it quickly became wet.

But do you **see** that it is getting wet? Do you **see** that it is beginning to melt?



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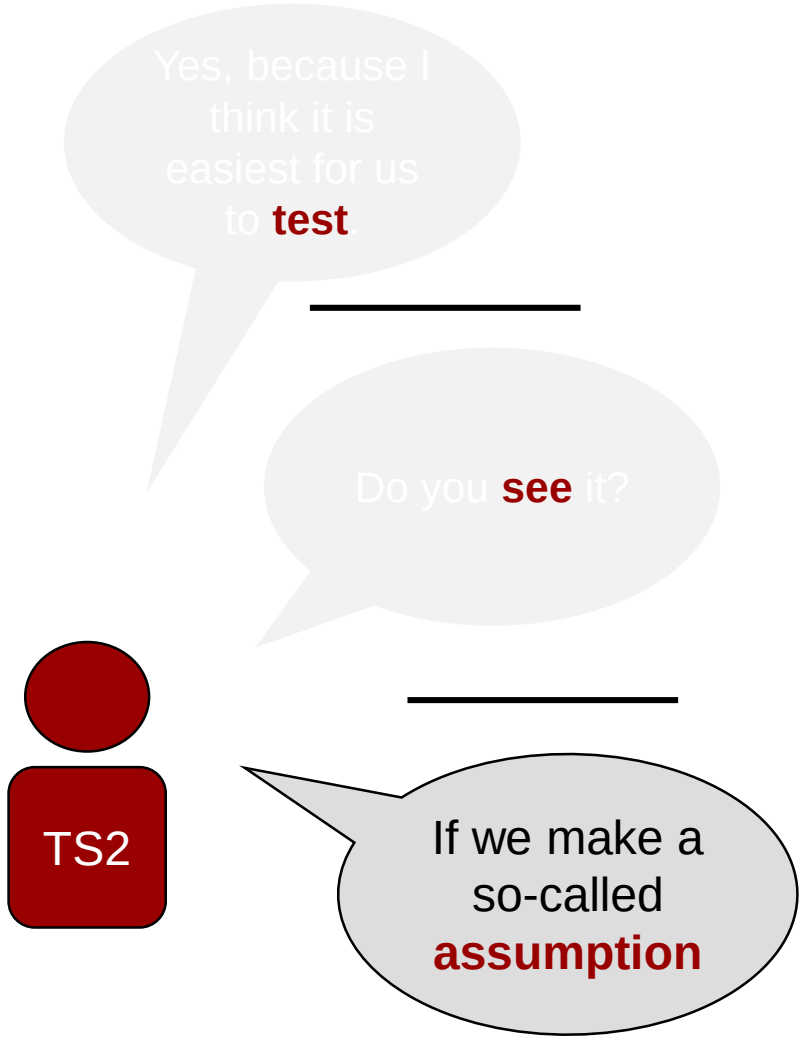
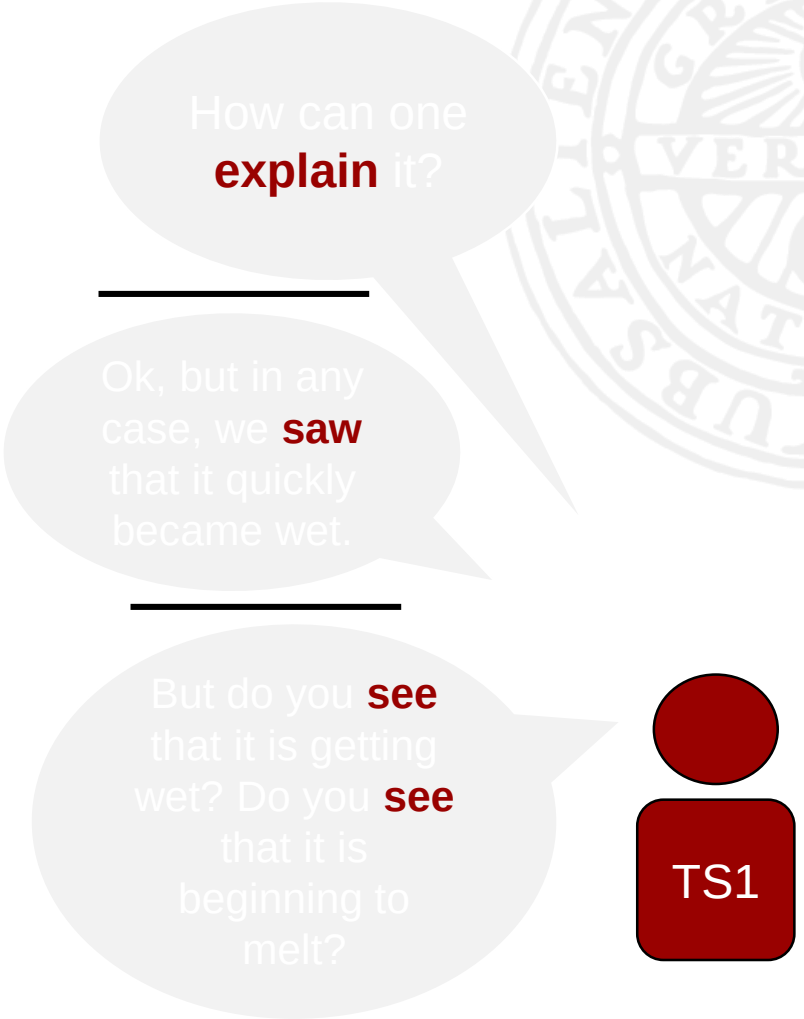
Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against





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Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against

Yes, because I think it is easiest for us to **test**

Do you **see** it?

If we make a so-called **assumption**

TS2

How can one **explain** it?

Ok, but in any case, we **saw** that it quickly became wet.

But do you **see** that it is getting wet? Do you **see** that it is beginning to melt?

TS1

But it was an **observation**.

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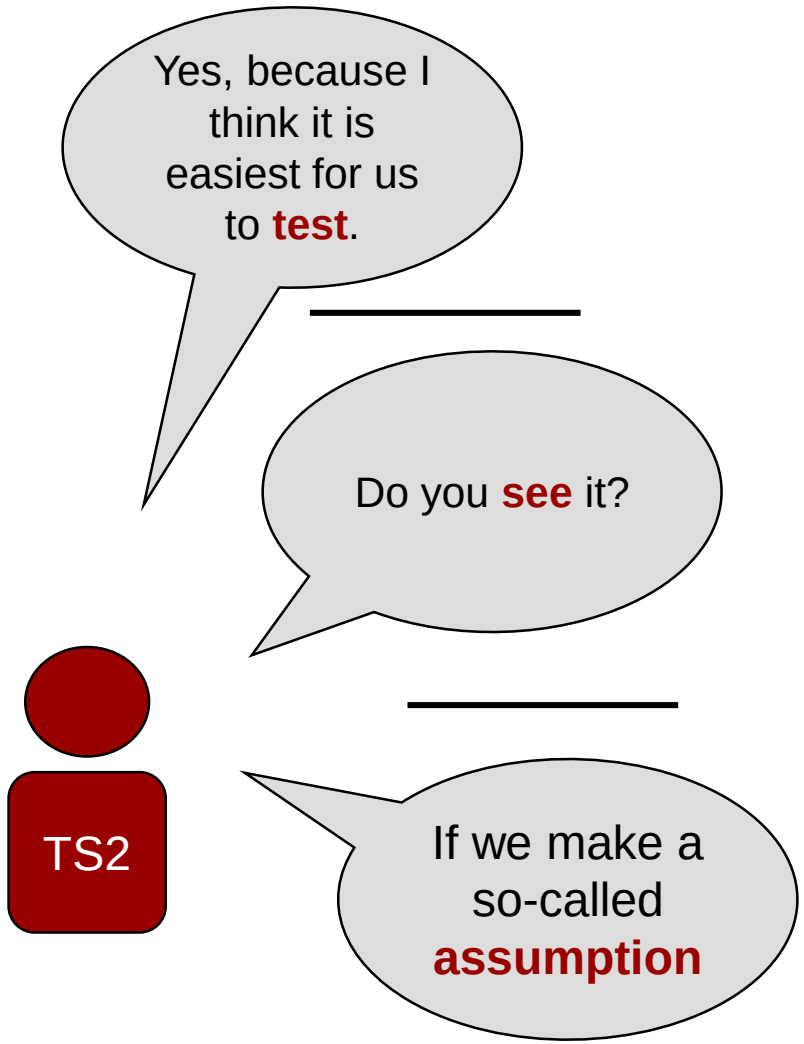
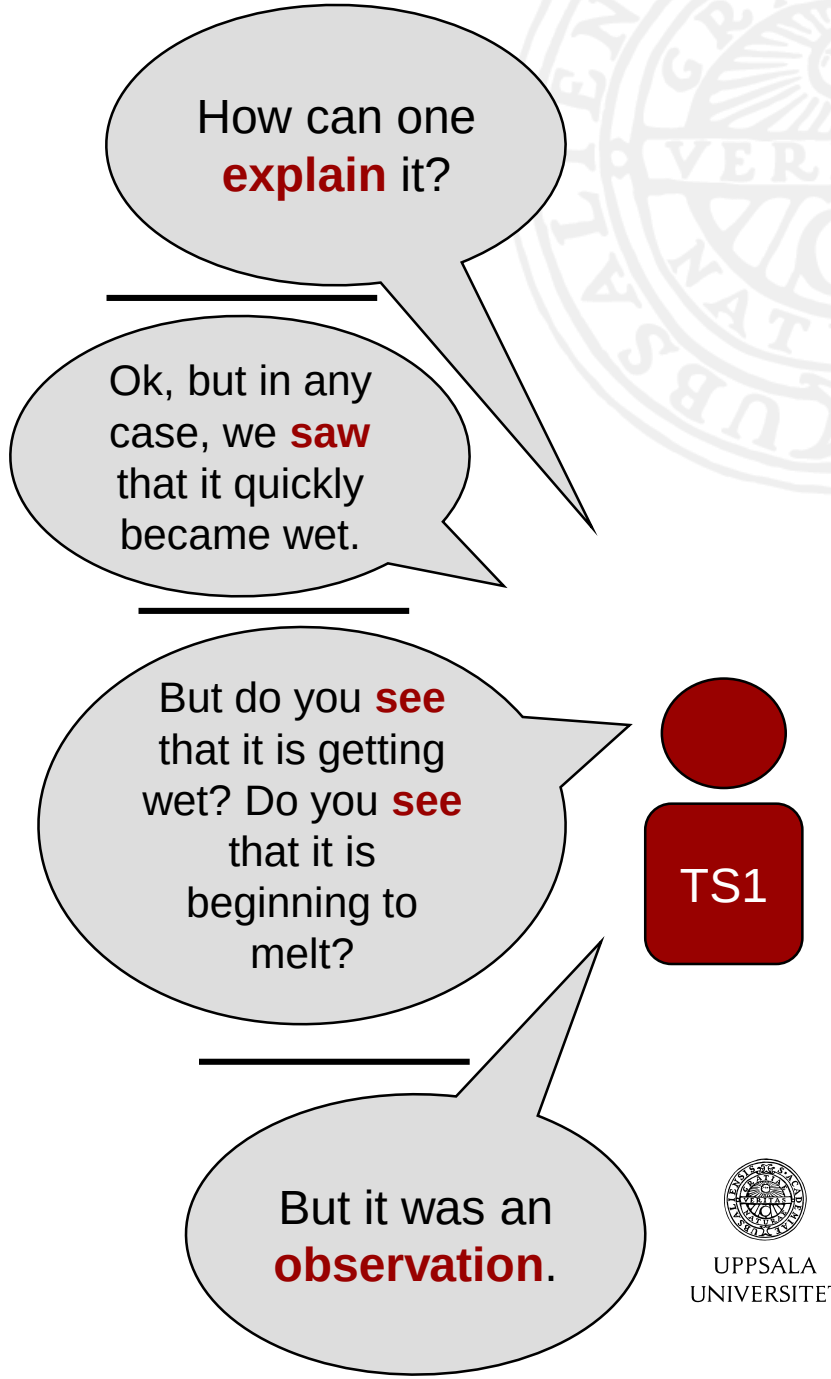
Activity: Sharing practice

Self-regulation

ISLE as a framework for the students to regulate against





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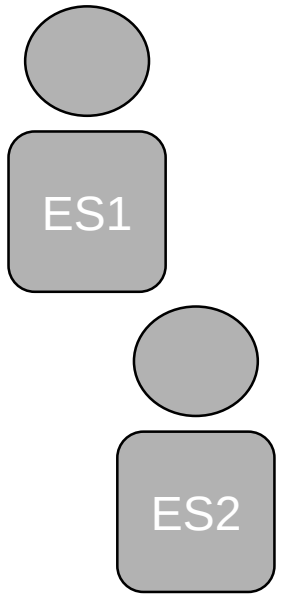
Activity: Sharing practice

So what can you give as **explanations** now? […]

External regulation –

ISLE as a framework for the students to regulate against



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Activity: Sharing practice

External regulation –

ISLE as a framework for the students to regulate against

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Activity: Sharing practice

External regulation –

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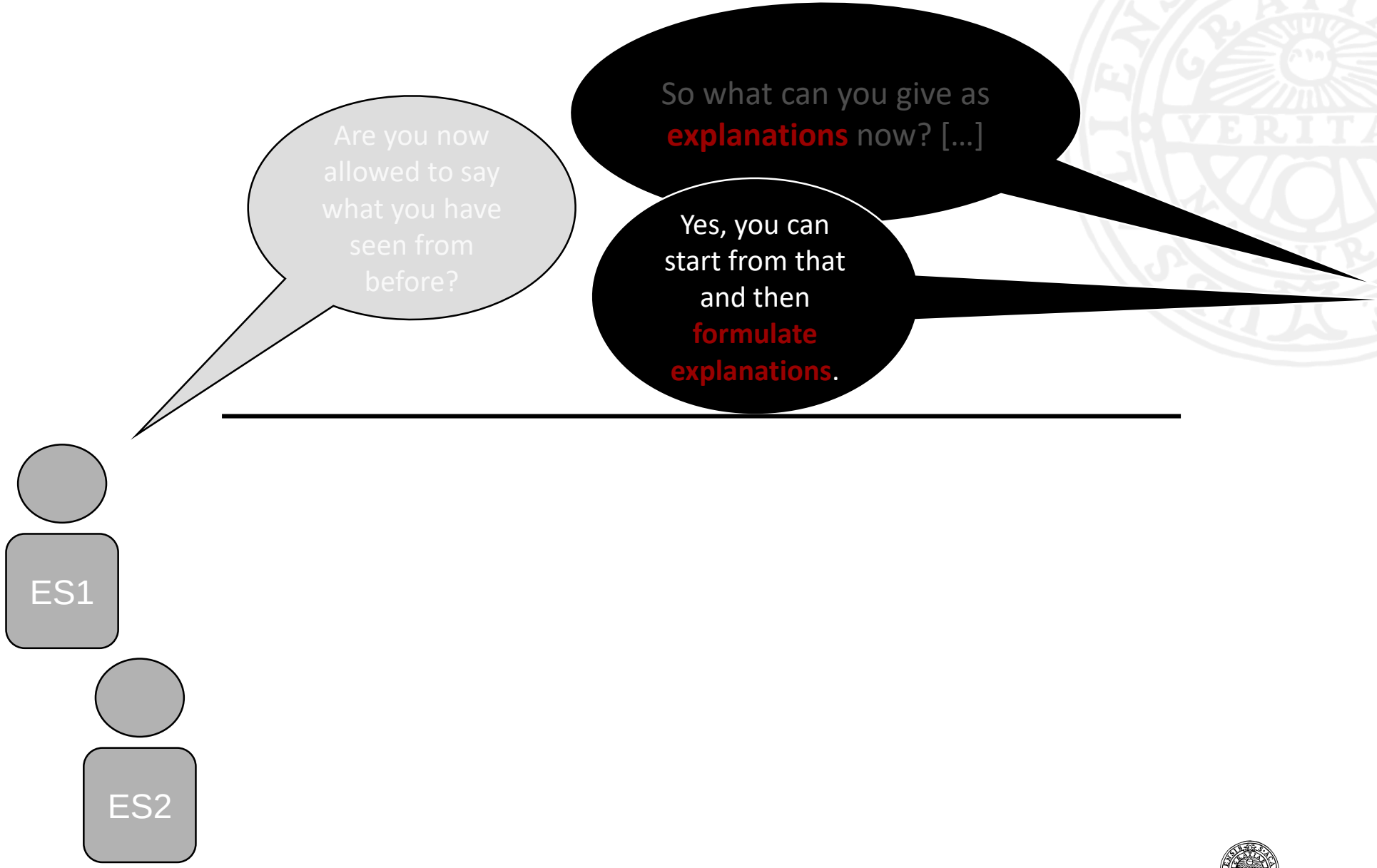

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Activity: Sharing practice

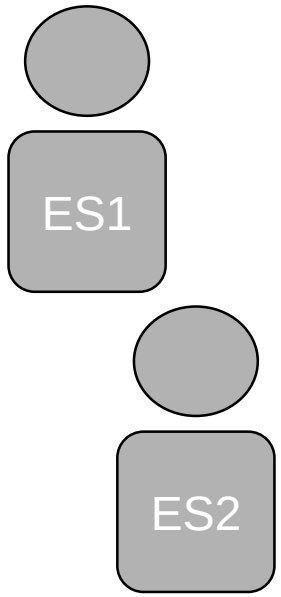
Are you now allowed to say what you have seen from before?

So what can you give as **explanations** now? […]

Yes, you can start from that and then **formulate explanations**.

External regulation –

ISLE as a framework for the students to regulate against



But you can also come up with an **explanation** that is easy to **test** and **reject**

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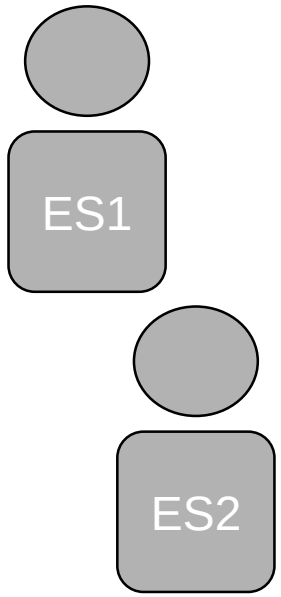
Activity: Sharing practice

External regulation –

ISLE as a framework for the students to regulate against



Are you now allowed to say what you have seen from before?

So what can you give as **explanations** now? […]

Yes, you can start from that and then **formulate explanations**.

Should we not write down the zeroth law or whatever it was called?

But you can also come up with an **explanation** that is easy to **test** and **reject**

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Activity: Sharing practice

External regulation –

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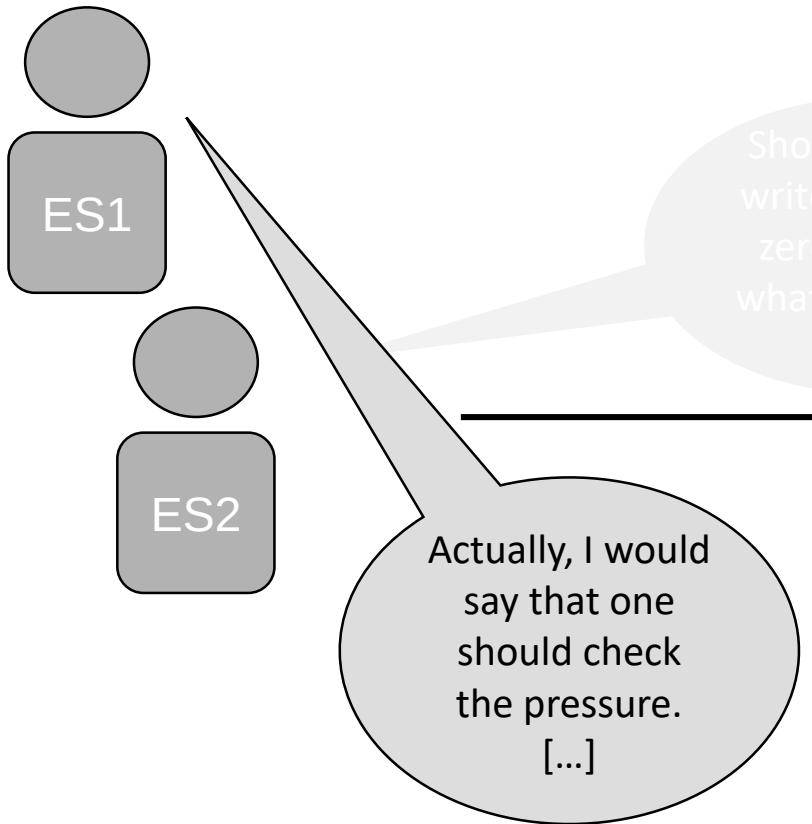

Are you now allowed to say what you have seen from before?

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Yes, you can start from that and then **formulate explanations**.

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Activity: Sharing practice

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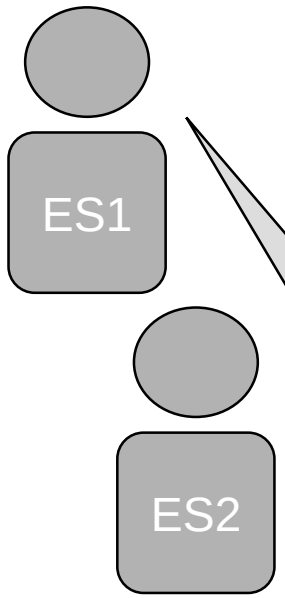

Are you now allowed to say what you have seen from before?

So what can you give as **explanations** now? […]

Yes, you can start from that and then **formulate explanations**.

Should we not write down the zeroth law or whatever it was called?

But you can also come up with an **explanation** that is easy to **test** and **reject**

Actually, I would say that one should check the pressure. […]

You can first think: what is the **observation** you have?

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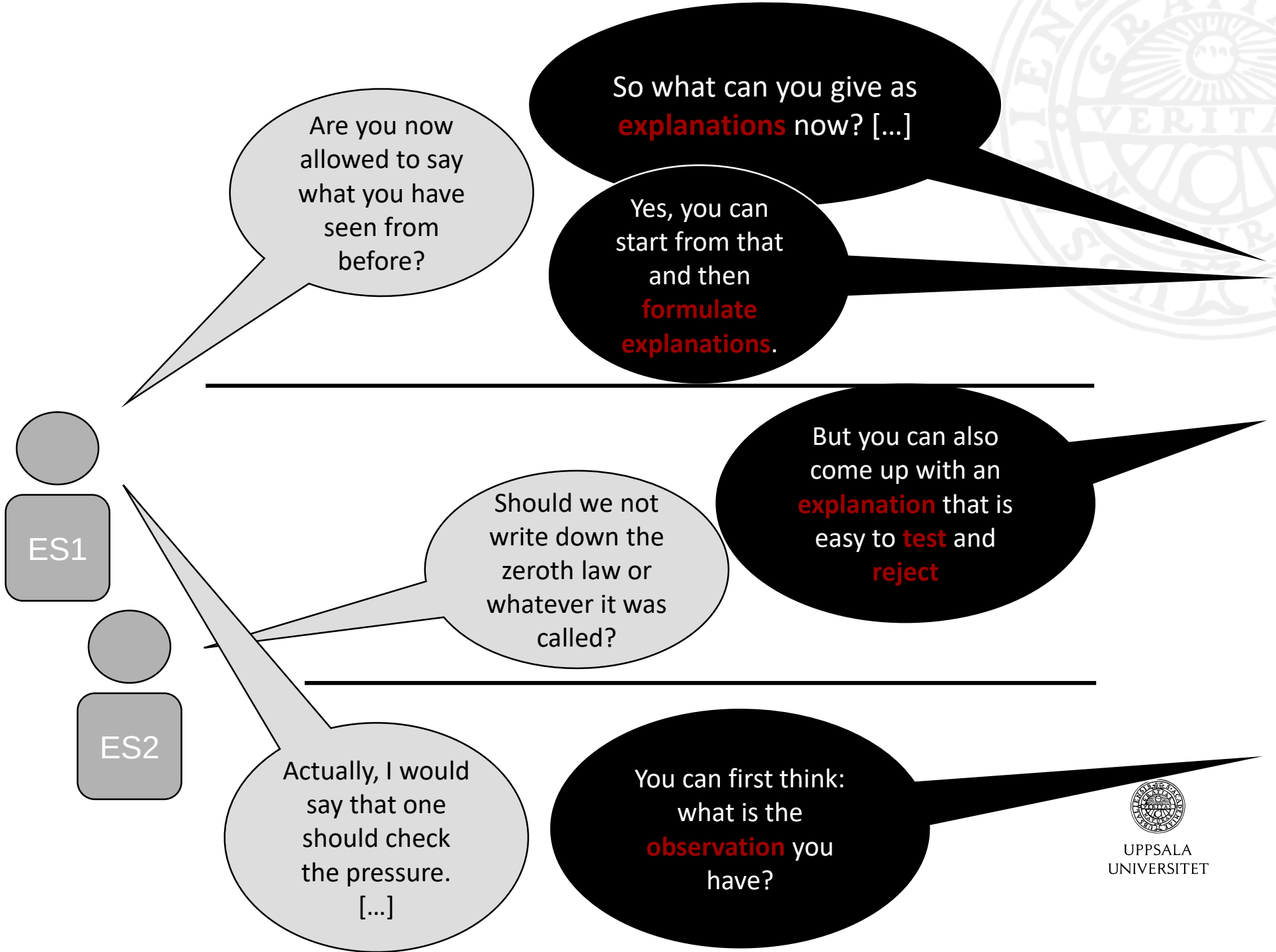
Activity: Sharing practice

External regulation –

ISLE as a framework for the students to regulate against



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Conclusion:
Productive epistemic games

Productivity seems to be associated to two patterns.

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Conclusion: Productive epistemic games

Productivity seems to be associated to two patterns.

1. The talk is explicit, coherent and confident
2. The use of the structure from ISLE to structure the activity

Conclusion: Productive epistemic games

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1. The talk is explicit, coherent and confident
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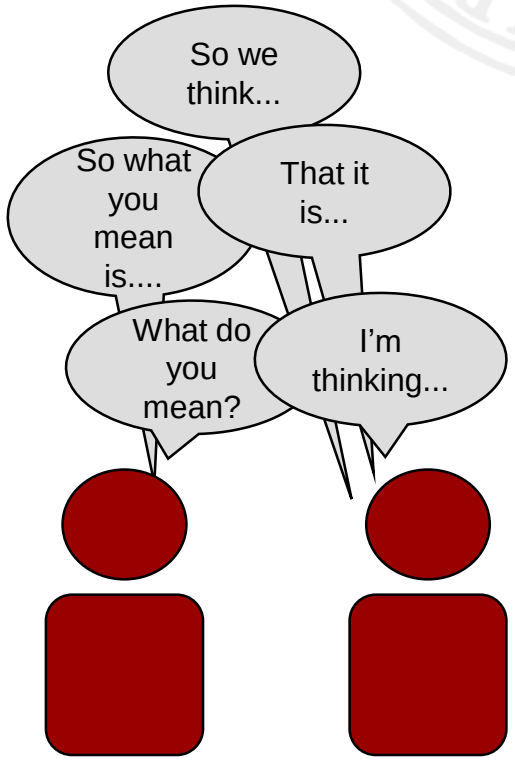
Possible to identify two epistemic games:

1. **Exploratory talk**



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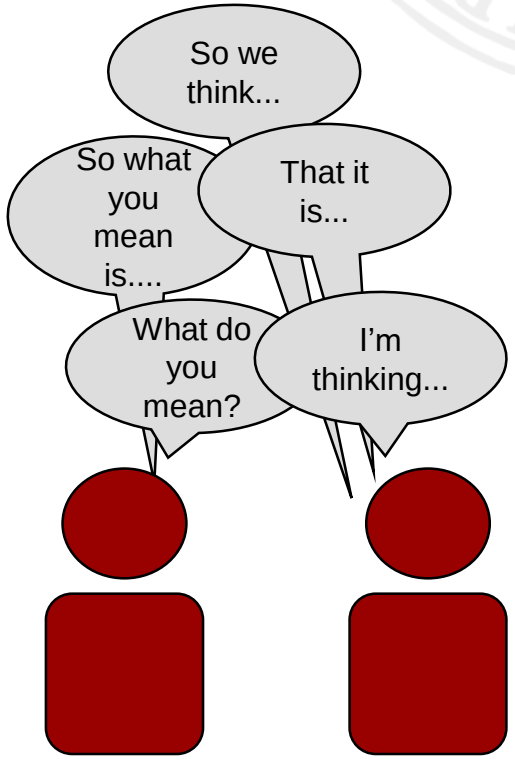
Conclusion: Productive epistemic games

Productivity seems to be associated to two patterns.

1. The talk is explicit, coherent and confident
2. The use of the structure from ISLE to structure the activity



Possible to identify two epistemic games:

1. **Exploratory talk**

2. **Self-regulation toward [ISLE]**

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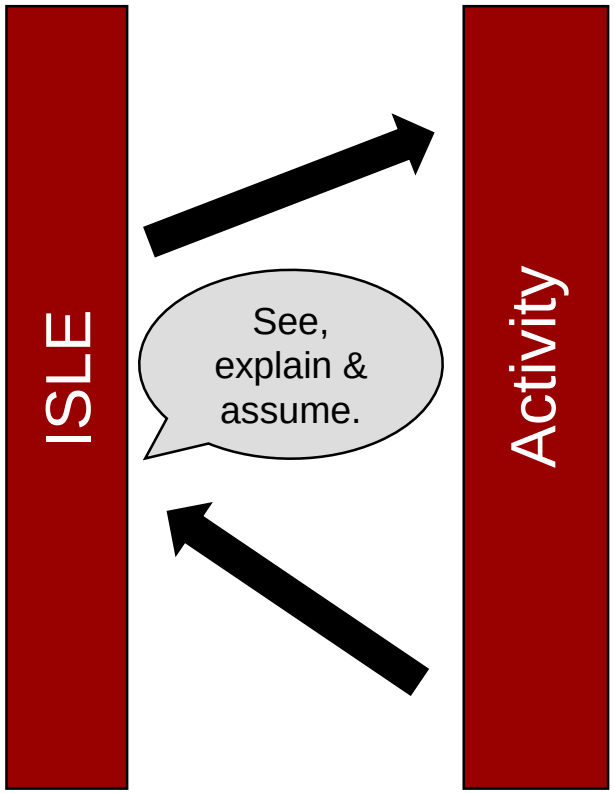
Conclusion: Productive epistemic games



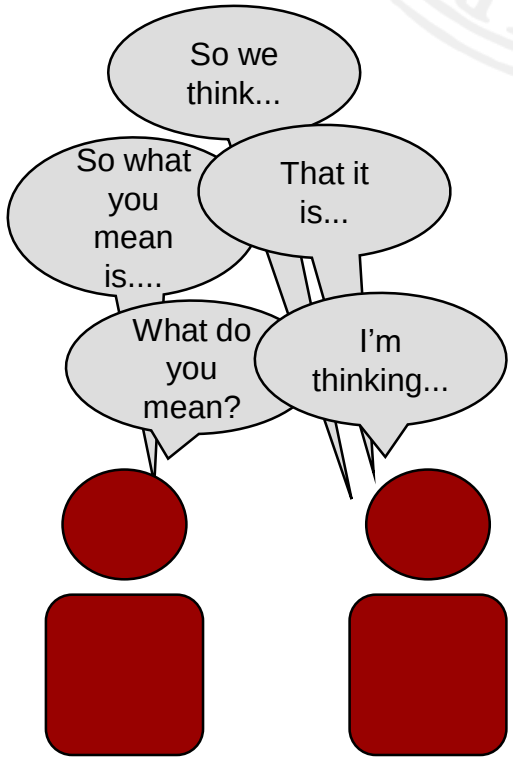
Productivity seems to be associated to two patterns.

1. The talk is explicit, coherent and confident
2. The use of the structure from ISLE to structure the activity

Possible to identify two epistemic games:

1. **Exploratory talk**

2. **Self-regulation toward [ISLE]**



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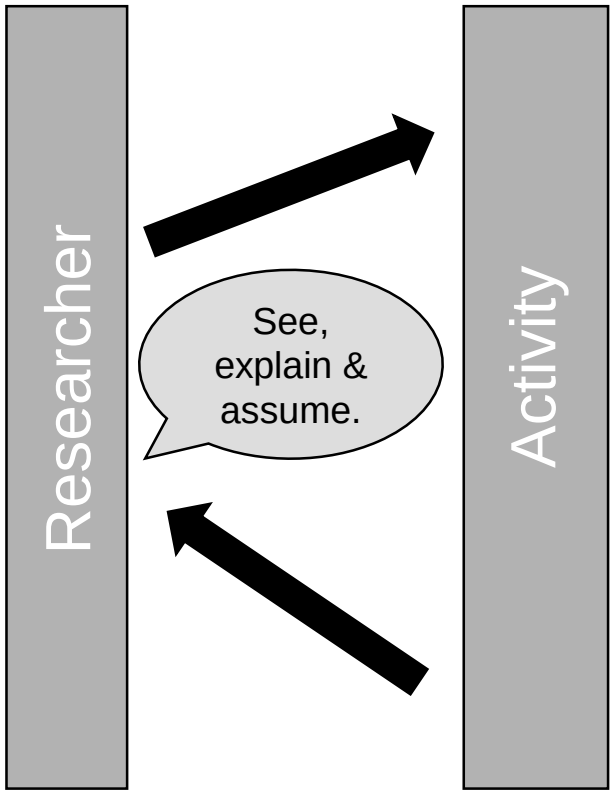
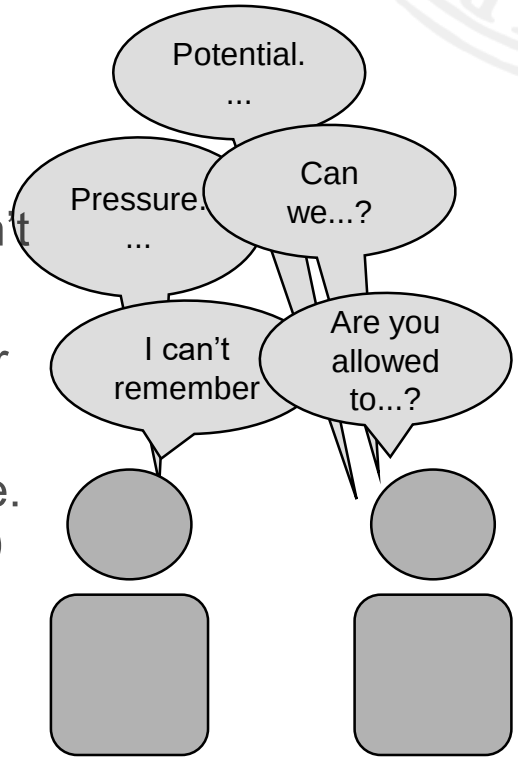
Conclusion: ES



Conversly, the difficulties for ES seems to be associated to two patterns.

1. The talk is incoherent and hesitent (it often doesn't lead anywhere)
2. The students often ”get stuck” in their practice or forget what they are supposed to do.

This is somewhat helped by **external regulation** (i.e. they rely on the researcher/instructor for regulation)



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Thanks for listening!
Questions?

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