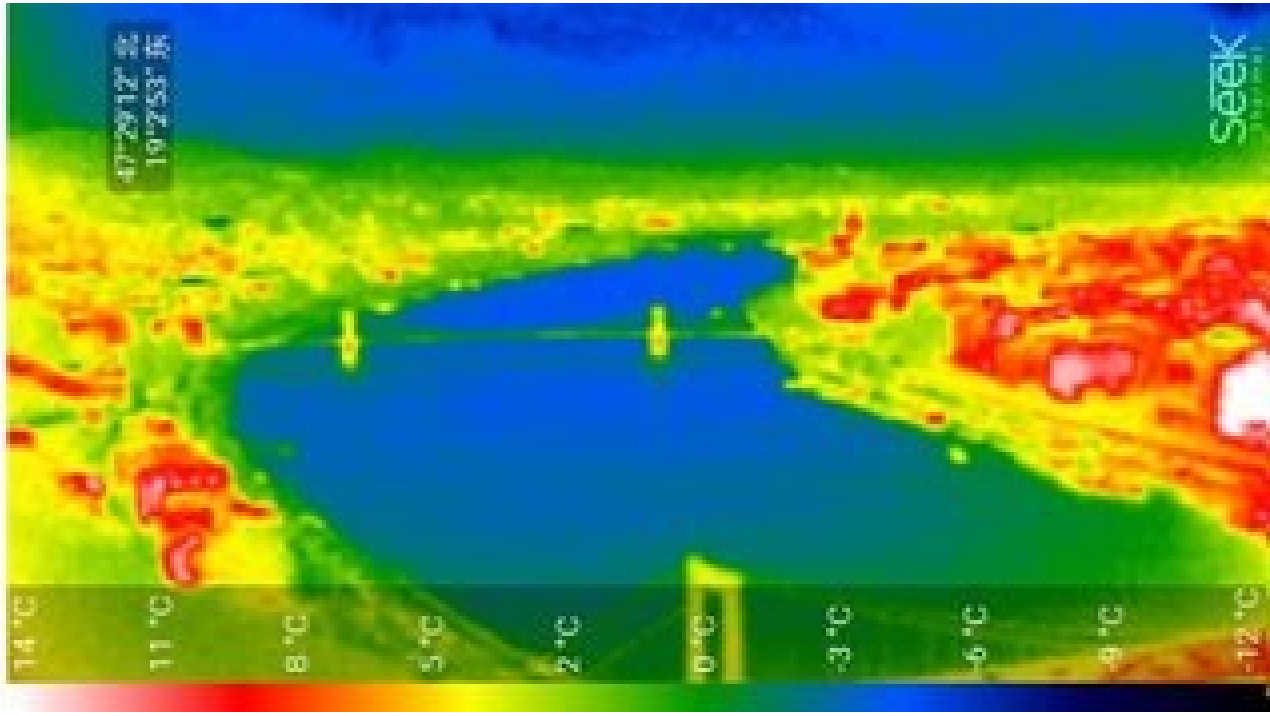

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Motivation, goals, RQs

- Thermal imaging advantage: instant visual feedback on temperature distribution
- However, thermograms and thermal imaging videos can easily be replaced with animations.
- So, do thermal imaging cameras provide any benefits for students?

RQ1: Is there a difference in situational interest triggered by practical work and animation-based learning?

RQ2: Is there a difference in conceptual understanding triggered by practical work and animation-based learning?

Where to get so many thermal imaging cameras?

Lab IR Edu

Infrared Camera TIMI Edu

- infrared camera designed for schools to support polytechnic education
- large touchable 7” display, 160×120 px
- 3 analysis (point, line, area)
- saving pictures and sequences to USB
- up to 5 hours of operation on a single charge

Where to get so many thermal imaging cameras?

Lab IR Edu

Lending centres network

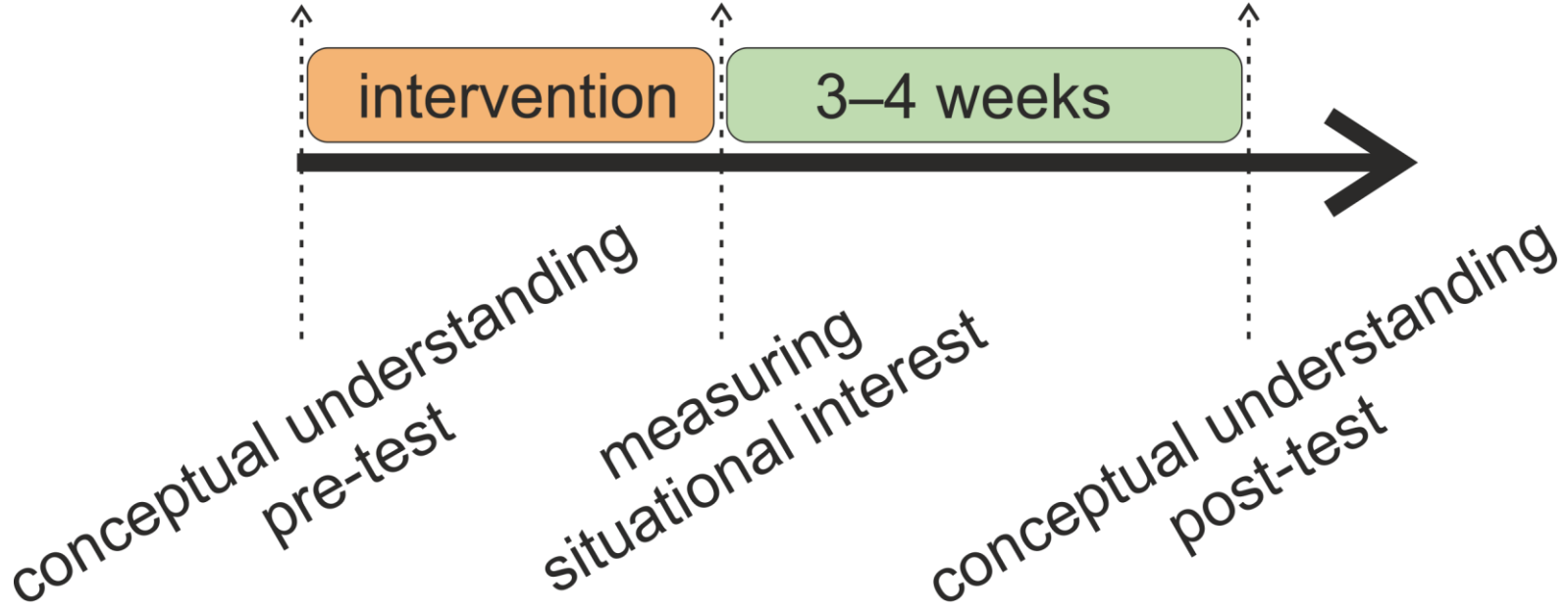
- a set of up to 10 cameras for a few weeks
- for free
- a larger number of cameras in the classroom
- regular software updates and service
- looking for partners to expand the network

Methodology

- quantitative research approach
- randomized control group design
  - the thermal imaging (TI) group vs. the animation-based learning (ABL) group
- intervention:
  - a single 45min lesson on thermal conductivity, external lecturers
  - small-group work (both TI and ABL)

Methodology – what we measured?

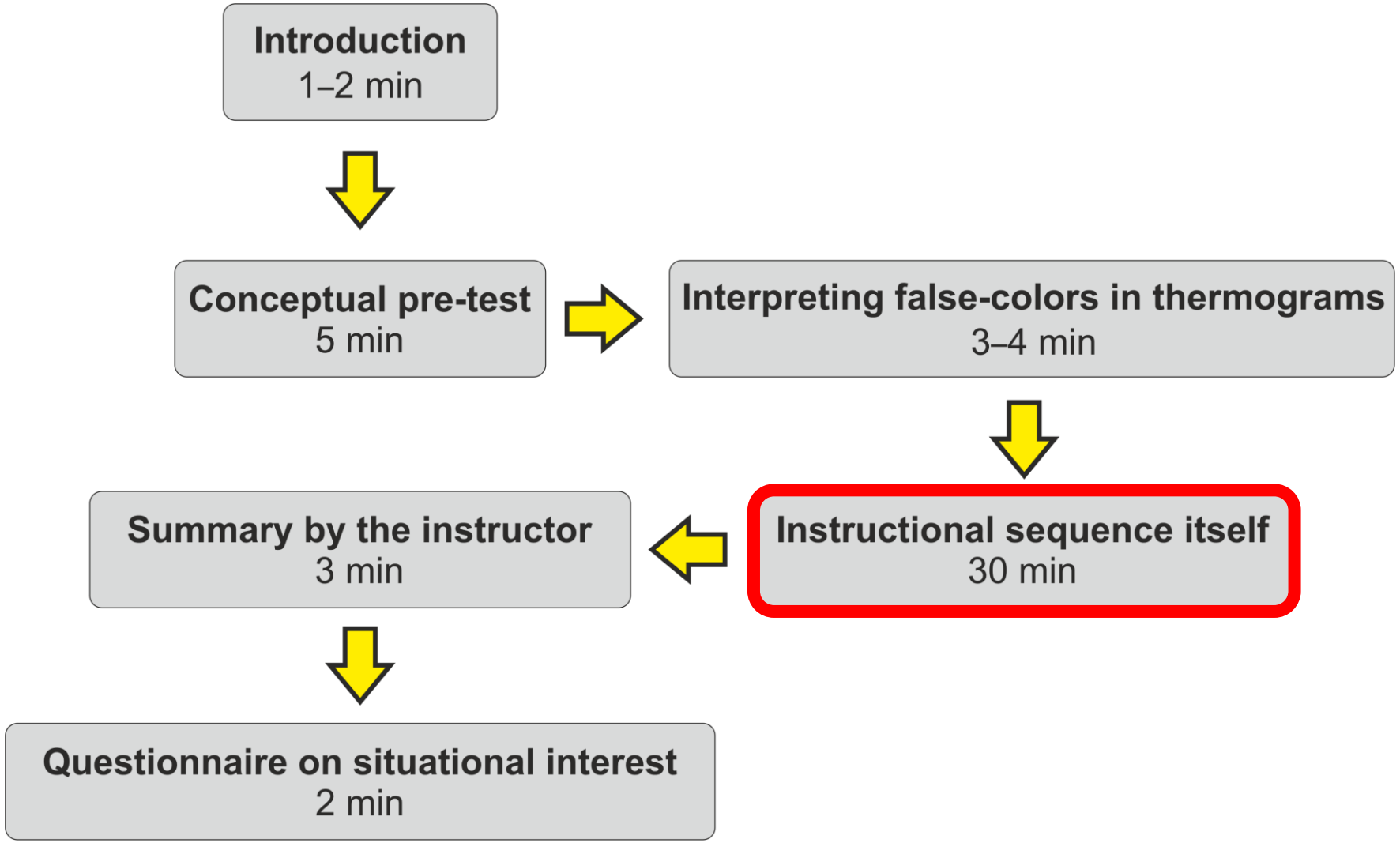
- situational interest: post-test only
  - 4 items adopted from *Intrinsic Motivation Inventory* (IMI)
- conceptual understanding: pre-test–post-test
  - 4 MCQ adopted from *Thermal Concept Evaluation* (TCE)



Participants

- 8th graders (14-15 y.o.), 4 schools, 13 classes, Oct–Dec 2024
- collected: 267 responses
- after cleaning: 254 responses
- succefully paired conceptual pre-test and post-test: 196 responses
  - TI 94
  - ABL 102

How does the intervention (45 min) look like?



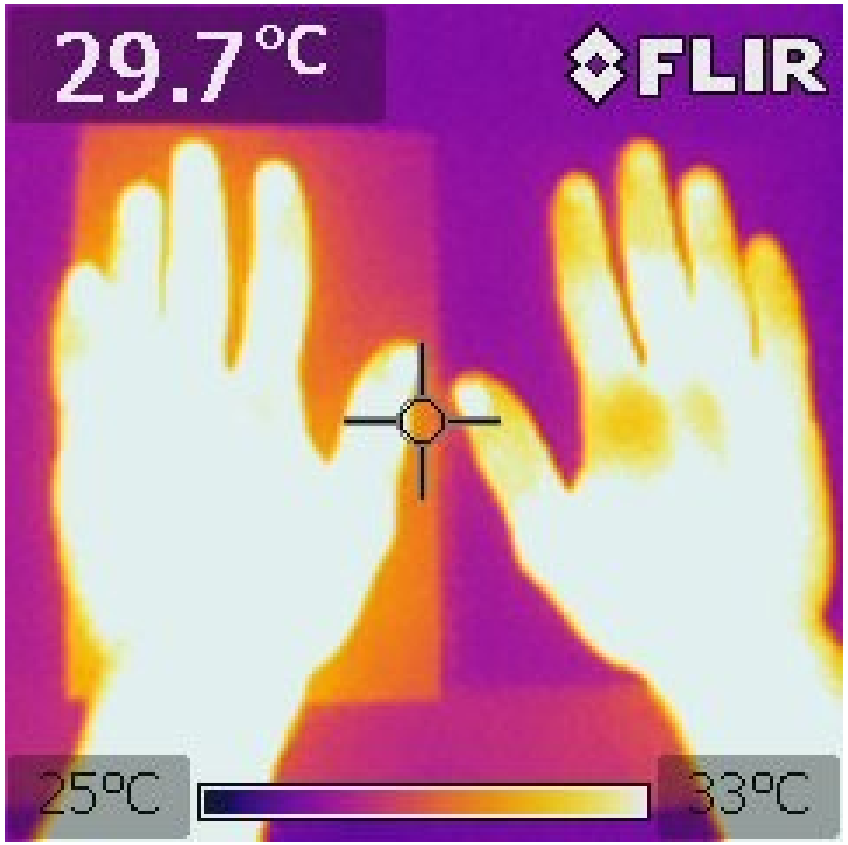
Instructional sequence on thermal conductivity

- in two versions (TI, ABL)
- same tasks and some questions for both TI and ABL
  - for ABL, four animations/videos were designed in Energy2D software to visually correspond as closely as possible to the outputs provided by a thermal camera

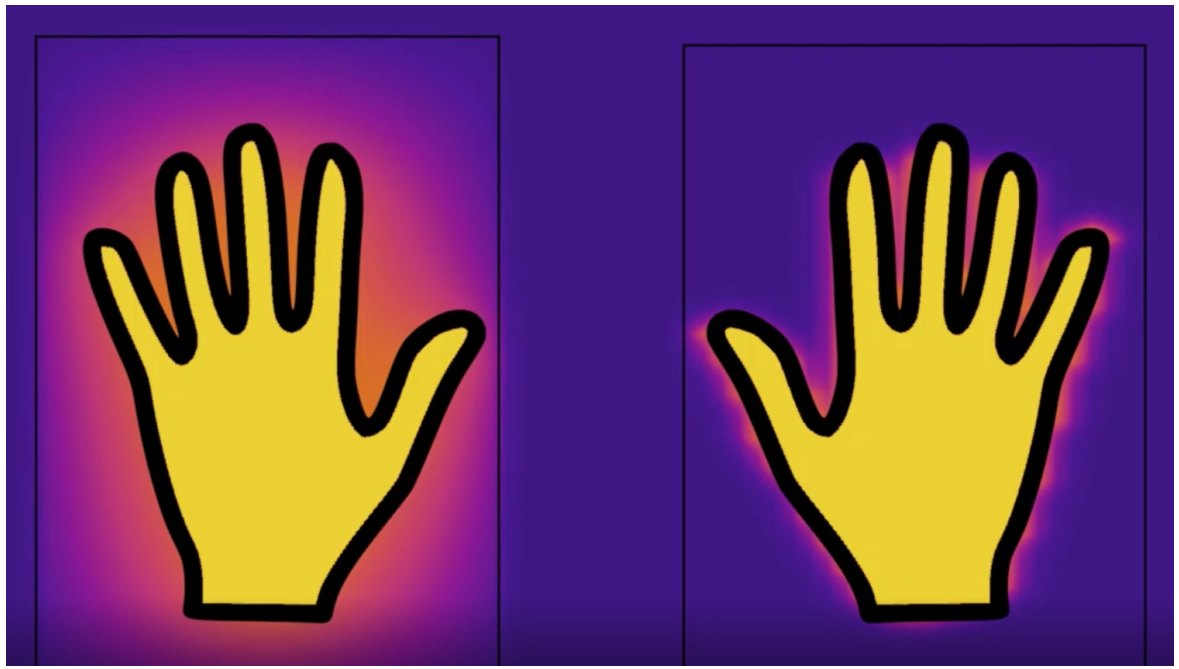
Energy2D software freely available at: https://intofuture.org/energy2d.html

Instructional sequence on thermal conductivity

TI group



ABL group



C Experimental Section – Group Work

C1: Metal and Plastic

1. We will work with two black plates, one metal and one plastic. Place your palms on both plates simultaneously (see picture on the right) and observe them with a thermal camera for approx. 20 seconds.
2. Sketch how the plates looked after lifting your palms (if you didn't notice it, let the plates cool down and repeat the experiment).

metal | *plastic*

3. Try to explain the difference in the behavior of metal and plastic.
4. Did the thermal camera measure approximately the same temperature for both plates before placing your palms? If you don't remember, observe the plates again.
5. Did one of the plates still feel colder to the touch? Which one?
6. Try to explain this apparent contradiction:
7. Now estimate and draw what image the thermal camera will show if we place two cups with ice or ice water on the same plates:

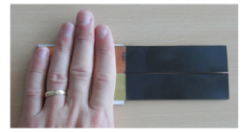
metal | *plastic*

8. Confirm or refute your hypothesis through an experiment. How would you explain the result this time? Does it match your prediction?

C Experimental Section – Group Work

C2: Different metals

1. Among the tools you have a plate that is half **brass** and half **copper**. By warming it with your palm, determine experimentally which material conducts heat better.

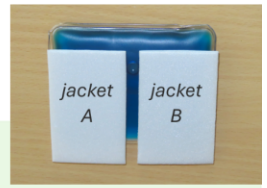


conducts heat worse — *conducts heat better*

2. Where do both materials, brass and copper, get their energy (heat) from? And how does this affect the sensation we feel by touch?

C3: To the pole!

1. A polar explorer is testing two jackets for a winter expedition. He stays outside in both at an ambient temperature of -20 °C. The surface temperature of jacket A was measured at -15 °C and jacket B at +5 °C. Which jacket would you choose for a polar expedition and why?
2. Now we will simulate the situation – the polar explorer will be represented by a heat pack, and the jackets by two white plastic cards. Break the metal disc in the heat pack, and once it starts to warm, place both cards on it (see image). Describe what you observe with the camera.

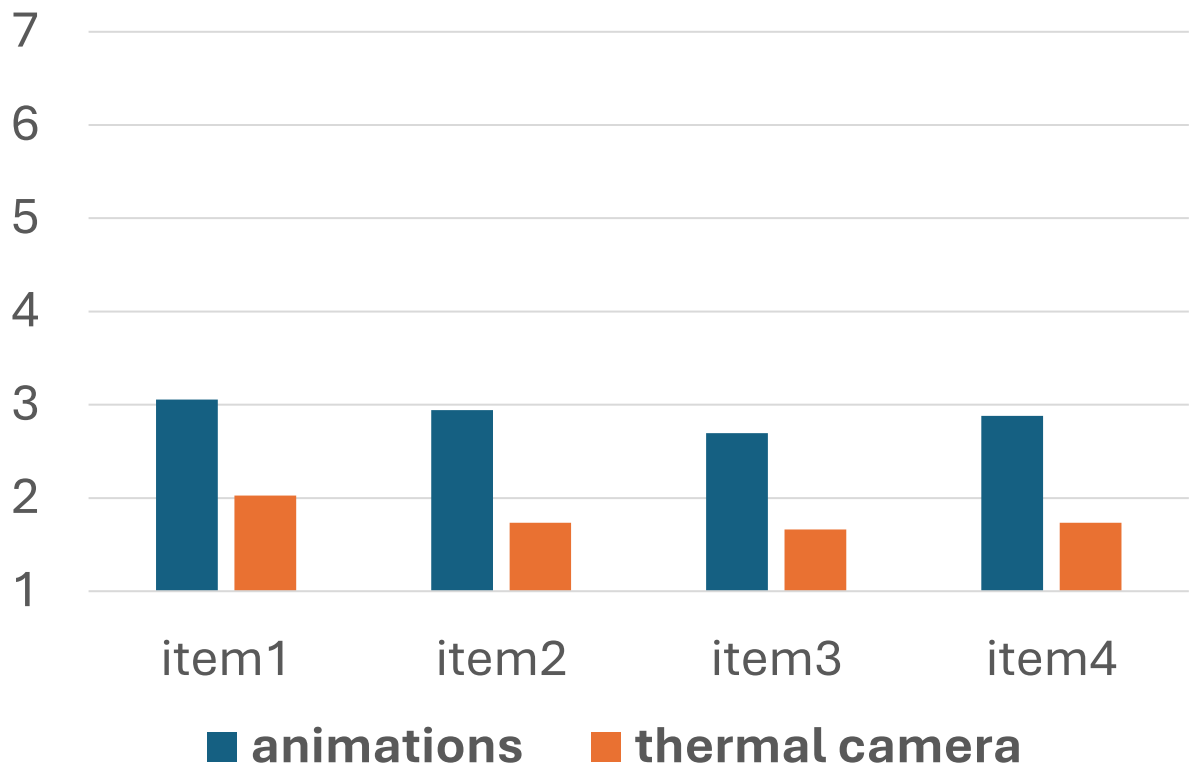


3. How did we achieve the different behavior of the 'jackets' (cards)? How are they different? Which one is more suitable for the pole – the one with the higher or the lower surface temperature?

Instructional sequence on thermal conductivity

Results: Situational interest (N = 254)

- lower score = higher interest
- Cronbach alpha: 0.938
- all differences significant at p = 0.001
- effect size (Cohen's d): 0.76–0.88



Results: Conceptual understanding (*N* = 196)

	ABL animations	**TI** thermal camera
pre-test score (max. score: 4)	**0.75**	**0.64**
post-test score (max. score: 4)	**1.59**	**1.30**
p-value	< 0.001	< 0.001
effect size (Cohen's *d*)	0.76	0.64

- Between the pre-test and the post-test, the pupils did not meet the topic of thermal conductivity in their regular lessons.
- Only in 1 out of 4 conceptual questions was there a difference in gain (ABL vs TI), and it was in favor of the animations.

Conclusions

- Thermal cameras are more effective in triggering situational interest, with pupils often evaluating them uncritically.
- Both methods significantly improved pupils’ performance on a set of four conceptual questions. Difference in their effectivity was negligible.

Limitations

- Only a single intervention (45 min) – too little to make conclusions

Further limitations of the conceptual understanding part:

- The gains in the pre-test were low; the questions were apparently quite demanding for pupils from the selected elementary schools (greater role of chance).
- Lack of concentration of pupils when answering conceptual questions.
- Observation: By coincidence, ABL groups were generally better concentrated and their behaviour was more disciplined (even before the start of the activity itself).

Thank you for your attention.

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