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LOOKING FOR SOLUTIONS: UNIVERSITY CHEMISTRY AND PHYSICS STUDENTS INTERACTING WITH INFRARED CAMERAS

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Infrared (IR) cameras can be used to support the learning and understanding of thermodynamics. Previous research shows that the technology enables university physics students to observe otherwise invisible thermal phenomena. In the present study, the focus is extended to the use of IR cameras in an educational chemistry laboratory setting with a comparison to the physics labs. Depending on the communicative actions made to interact with the cameras, different affordances of the IR cameras are accessed. For example, some students compare what they see with the IR camera with their sense of touch. The kinds of actions students make depend on aspects like their disciplinary experience and the discipline of study. Predict-Observe-Explain is used to probe students' potential actions for interaction with the IR camera. Data is collected by video recording and iterative transcription to find contrasting or shared patterns of interaction across the groups. A multimodal approach to conversation analysis is used to find these patterns. The result shows that the physics and chemistry students use the technology to confirm or disconfirm predictions made, but differ in the coordination of actions to achieve that goal. The physics students move around and use the sense of touch together with IR-camera observations, while the chemistry students focus on IR-camera observations from one perspective alone.

Keywords: laboratory practice, infrared cameras, affordance

INTRODUCTION

Learning how to use scientific concepts and connecting them to the associated processes in communication can be difficult for novice learners in any educational field. If novices would be asked to use their knowledge in an educational environment like a laboratory, they may have hard time "talking science" (Lemke, 1990). Apart from what they actually say, this difficulty could be observed through different communicative activities (Flewitt et al., 2017), like their gesture, gaze, posture and intonation. Non-linguistic vocalization (like laughter) can also reveal such difficulty.

Thermodynamics is an area of physics and chemistry where students have been found to have communicative challenges, not least due to its many abstract concepts and invisible processes (Bain, Moon, Mack, & Towns, 2014; Dreyfus, Geller, Meltzer, & Sawtelle, 2015). In particular, research has touched upon students' understanding of calorimetry (Ebenezer & Fraser, 2001; Greenbowe & Meltzer, 2003) and spontaneous endothermic reactions (Thomas & Schwenz, 1998). However, research studies have typically focused on one single discipline (e.g. physics, or chemistry), but rarely compared across disciplines (Dreyfus et al., 2015).

It has been suggested that infrared (IR) cameras could support the understanding of thermodynamics (Haglund, Jeppsson, Melander, Pendrill, & Xie, 2016) and empirical studies have been conducted exploring the potential and affordances of IR cameras in school (Haglund, Jeppsson, Hedberg, & Schönborn, 2015; Haglund, Jeppsson, & Schönborn, 2016) and university teaching (Haglund, Jeppsson, Melander, et al., 2016). By studying students' interactions with IR cameras in authentic laboratory settings across undergraduate chemistry and physics courses, we hope to contribute to this field of research. Although the disciplines of physics and chemistry have distinct approaches to thermodynamics, they share many concepts and processes, sometimes referred to as boundary objects (Christiansen & Rump, 2008), like heat, entropy and spontaneity.

METHODS

Data were gathered from laboratory activities in a thermodynamics course in physics and in an introductory course in chemistry, which have been developed in more student-active directions. In the physics course, students were asked to select and study one thermal phenomenon, concept or apparatus each, such as thermal radiation, entropy, or a heat pump. The chemistry students investigated endothermic and exothermic reactions when dissolving different salts in water.

In conjunction with their laboratory activities, students in both courses were introduced to the phenomenon of sprinkling table salt on ice cubes, which counterintuitively leads to the temperature decreasing as the ice melts (see Figure 1). The procedure Predict – Observe – Explain (POE) (White & Gunstone, 1992) was used to probe the students' understanding and encourage investigation of the phenomenon. We introduced an IR camera as a part of the situation with the aim to make possible observations of phenomena that would otherwise be invisible. In this case, the IR camera affords discernment of spatially confined melting in combination with a temperature decrease.

Figure 1. Students use an IR camera to study chemical reactions (left); an IR-camera image of temperature decrease after table salt has been put on an ice cube (right).

Students' interaction with the activities was audio and video recorded, and clips were selected for further preparation and analysis (Derry et al., 2010). Assuming a social semiotics perspective (Lemke, 1990), conversation analysis (CA) with a fine-grained multimodal approach was used for analyzing the data (Jewitt, Bezemer, & O'Halloran, 2016). Multimodal CA requires a diverse data set that involves other means of communication than speech, such as use of pictures, gestures and posture, which is made possible through video analysis. We started by transcribing all the video data from speech to text to find patterns of similarities and differences across the studied student groups. Shorter clips of episodes of interaction were iteratively re-transcribed, specifying other involved actions than speech, like gaze or posture, as examples of these patterns.

RESULTS

Our data indicate that students used the IR camera either to solve conflicting ideas about the thermal phenomenon presented to them in the study or to confirm their ideas. Most of the students in both groups had problems with predicting the outcome of sprinkling table salt on ice. In the process of finding solutions to the problem set up for them, students drew upon shared everyday memories, like the Nordic practice of putting salt on roads in the winter to melt ice and snow, but tended to predict that the temperature would increase. When later observing the phenomenon through the IR camera, they expressed surprise and struggled with explaining how the ice could melt at the same time as the temperature decreased: Student 1: "Wow! It says, like, minus…", Student 2: "What the f**k!?". However, some of the students came close to satisfactory explanations, which involved interpreting the situation as a case of spontaneous enthalpy decrease by breaking bonds in the ice, made possible through entropy increase.

There were also patterns of differences between the two groups: the chemistry students held a firm posture focusing on the image of the phenomenon through the IR camera. The physics students, in contrast, touched and moved the studied object and their bodies to vary the distance and the angle from which they studied the phenomenon and wondered what would happen if they put other substances than salt on the ice.

DISCUSSION AND CONCLUSION

The present research shows that infrared cameras can be used by undergraduate students in confirming or disconfirming predictions made in relation to a thermal phenomenon, across physics and chemistry labs. Through multimodal conversation analysis, differences in interaction with the studied phenomenon were revealed across the physics and chemistry students. A more playful attitude among the physics students may be due to encouragement of creativity and playfulness within the physics culture (Hasse, 2002), or simply that they were further into their university studies than the chemistry students.

ACKNOWLEDGEMENTS

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Looking för solutions:
University chemistry and physics students interacting with infrared cameras

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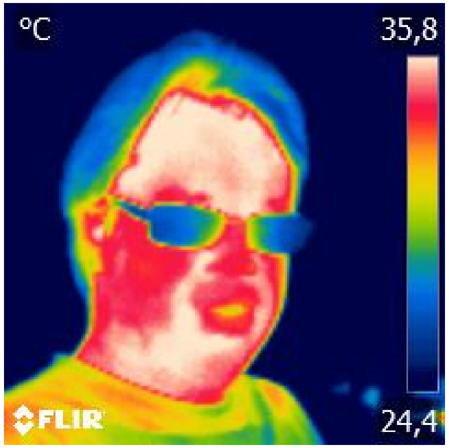


Thermodynamics is hard…

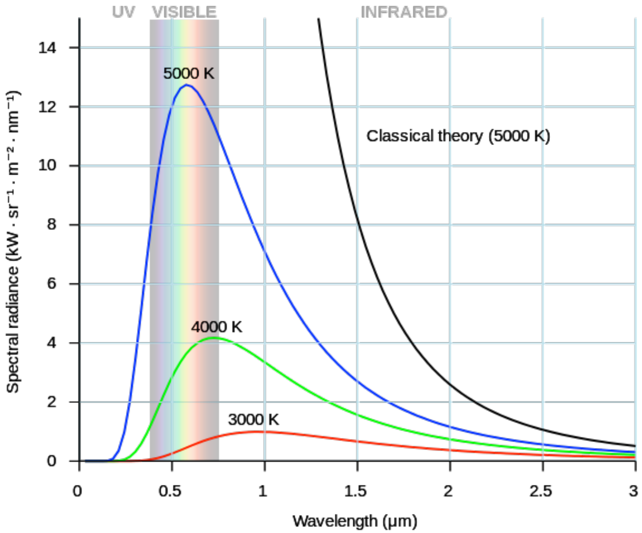
- Thermodynamics is abstract
  - Many notions are not directly accessible to our senses or measurement, but are derived mathematically, e.g. entropy, enthalpy, free energy, and chemical potential (Dixon & Emery, 1965)
  - Thermodynamics courses tend to focus on mathematical formalism, but not on conceptual understanding (Carson & Watson, 2002)
- University students have challenges with conceptual understanding and problem solving, e.g.
  - Entropy and second law of thermodynamics (Sözbilir & Bennett, 2007; Christensen, et al., 2009)
  - Solution calorimetry (Ebenezer & Fraser, 2001; Greenbowe & Meltzer, 2003)

Infrared cameras: Making the invisible visible!

- Vollmer et al. (2001) have proposed a range of uses of infrared cameras in secondary and university teaching
  - Thermal science, mechanics (friction, inelastic collisions, etc.), electrical circuits, etc.
- Xie (2011) suggests the use of IR cameras for solution calorimetry
- We have found IR cameras useful for promoting physics understanding in empirical studies with students of different ages, from grade 4 up to university level (Haglund et al., 2016)

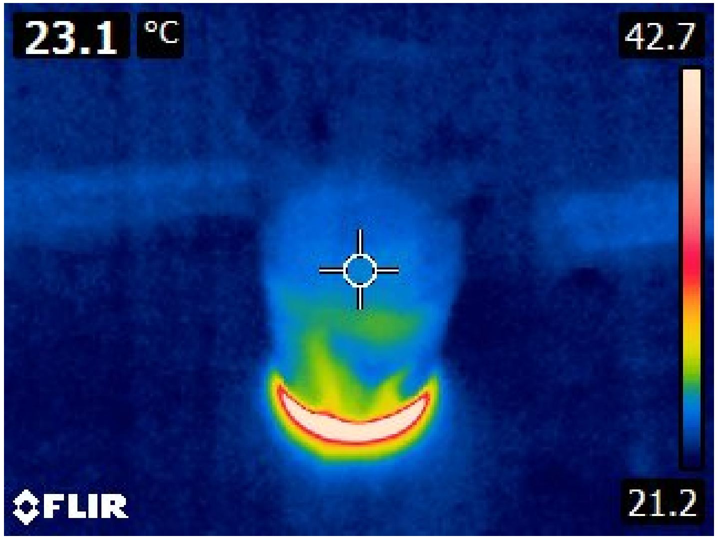
Infrared cameras: How do they work?

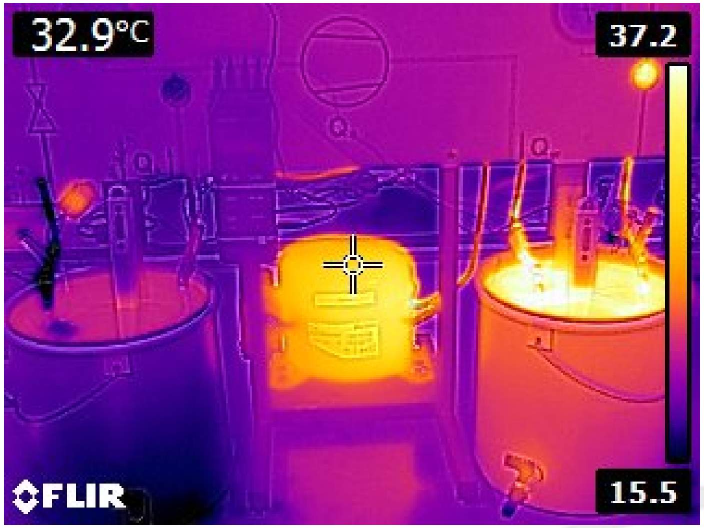
- All objects emit electromagnetic radiation, for objects at room temperature predominantly in the infrared (IR) range
- IR cameras detect IR radiation
- Surface temperature derived from the radiation spectrum through Planck's law of blackbody radiation, with assumptions of the emissivity of the surface

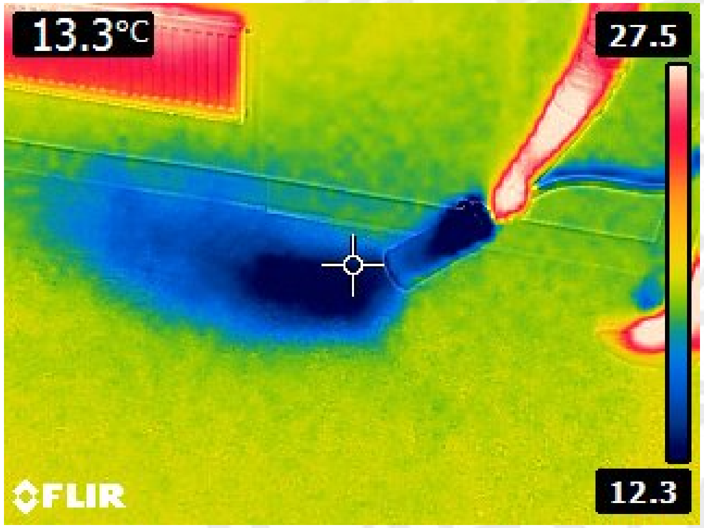


Research context

- Undergraduate labs in thermodynamics in physics and introductory chemistry have been redesigned in a more open-ended fashion (Domin, 1999)
- Year 2 physics students select a phenomenon, concept or apparatus and present to their peers (Melander et al., 2013)
  - e.g. heat radiation, entropy, or a heat pump
- Year 1 chemistry students take an active role in the design of experiments on solution calorimetry (Ho et al., 2015)
- Students have access to IR cameras during the labs


23.1 °C
42.7
21.2
FLIR


32.9°C
37.2
15.5
FLIR


13.3°C
27.5
12.3
FLIR

Methodology

- Data collection
  - Video and audio recording of selected student pairs' laboratory work
- Data analysis
  - Social semiotics perspective (Lemke, 1990)
  - Multimodal approach to conversation analysis (Jewitt, et al., 2016), involving e.g. spoken language, gaze, posture, touch
  - Differences in approach to thermodynamics across physics and chemistry disciplines (Christensen & Rump, 2008)

Practical activity

- During the labs, pairs of chemistry and physics students were invited to perform a practical activity that was distinct from the regular laboratory tasks
- Predict – Observe – Explain (POE) (White & Gunstone, 1992)
- ”What happens when you pour table salt on an ice cube? What happens to the temperature?”

Infrared cameras

Let's try out!

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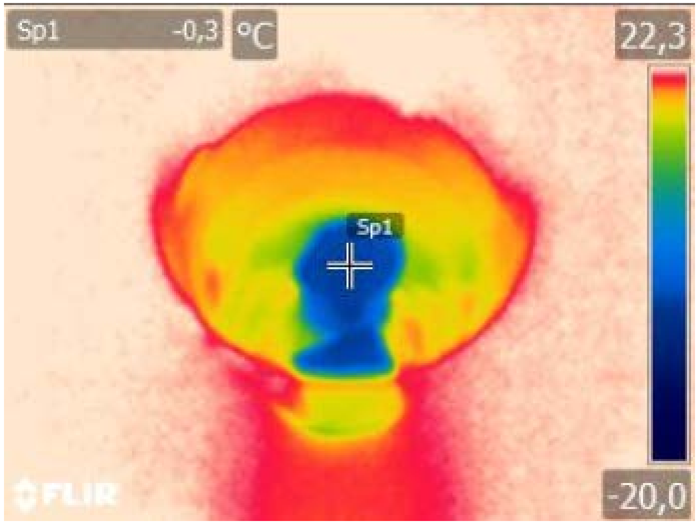
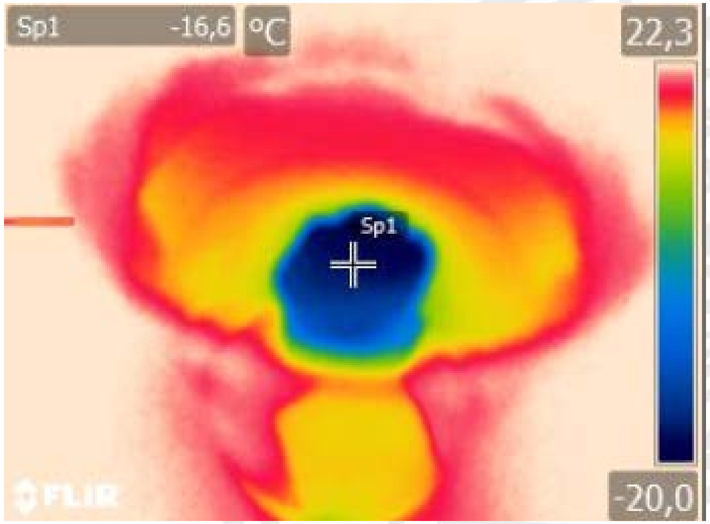


Without salt



With salt

Chemistry student conversation

- Jesper: What does it look like? What happens?
- C1: Well, the temperature increases, or…?
- Jesper: …or it decreases… Yours is minus 14… on the left (IR) camera
- C1, C2: Wow! /…/
- C2: It was… it didn't melt…
- Jesper: Well, that is the question… does it melt, if you watch it with your naked eye, the ice and the salt?
- C1: No, I don't think so, no. /…/
- Jesper: Lean in and look a bit closer [directed to C1]
- C2: Are you allowed to do that?
- Jesper: Does it seem to be melting?
- C1: Yes. /…/
- C2: Isn't it dissolving?
- C1: Yes.
- Jesper: Or rather, dissolving. /…/
- Jesper: You've got minus 23 there on the surface [refers to the IR camera temperature measurement]
- C2: What the f**k?!
- Jesper: At the same time as the salt melts the ice… how can that be?
- C1: Magic… /…/
- C2: Well, it maybe nicks… energy from, like, the ice, so the bonds break, so that it gets liquid… I have no idea

Physics student conversations

- P1: Wow, it [the temperature] sinks!
- Jesper: What does it look like with the IR camera?
- P1: Freezing cold! [laughs] /…/
- P2: Can one… touch?
- P1: Touch.
- P2: [touches the ice] Yes, it’s cold.
- Jesper: So how can that be… that it melts at the same time as it is very cold?
- P3: Well, it should be… do you know any chemical…? /…/ If it was just one substance… it should be that the salt gets colder, but the ice gets warmer…
- P4: Well, if you look at the ice then… it seems to be a bit warmer on the ice [points at the side of the ice cube on the IR camera display]
- P3: [directs the IR camera much closer to the side of the ice cube] Let’s check just the ice cube. /…/ It’s still… also minus /…/ So the entire ice cube is cooled down, right

Tentative analysis

- The experiment is counterintuitive and surprising to students
  - Students (in Sweden) have experienced putting on salt on roads in the winter to melt snow and ice …
  - …but the temperature decrease is puzzling
- Passive engagement of introductory chemistry students
  - Watch the experiment passively with the IR camera from one position
- 2nd year physics students engage more with the experiment
  - Touch and move the ice, vary distance and angle of IR camera, etc.
- Due to difference in lab culture across disciplines?
  - Physics labs encourage playful, creative approach (Hasse, 2002)
  - Chemistry labs emphasise safety (data sheets, lab coats, glasses, gloves) (Andersson et al., 2016), but do not encourage embodied use of the senses of touch, taste and smell (Almquist & Quennerstedt, 2015)
- Or difference in confidence between year 1 and year 2 students?

Thanks for listening!

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What happens?

- The temperature decreases from 0 °C to about -20 °C…
  - …as the salt dissolves into the melting water
- Our explanation:
  - Energy is required to break bonds in the ice and the salt
  - The energy is taken from the ice (and other matter) which decreases the temperature
  - Increased entropy due to mixing salt and water causes freezing point depression