RESEARCH ARTICLE

Introducing Infrared Cameras in the Study of Pigs' Physiology and Health as Cognitive Apprenticeship in Vocational Education

Jesper Haglund*
Karlstad University, Sweden
jesper.haglund@kau.se

Frida Henriksson
Lillerudsgymnasiet, Sweden
fraj.henriksson@gmail.com

As part of a participatory action-research project, students at the vocational upper-secondary Natural Resource Use programme in Sweden were introduced to infrared cameras in their courses. Students were video recorded as they used infrared cameras in the investigation of pigs' physiology and health in the school's pig house and explained generated infrared images in whole-class dialogue, together with involved teachers and researcher. Students found that a pig's injured leg has high temperature, but also, more surprisingly, udder abcesses with lower temperature than the surrounding healthy udder tissue. Students and teachers expressed excitement in explaining the results. From the perspective of seeing vocational education as a kind of cognitive apprenticeship, students' investigations and dialogue with the teachers and researcher are characterised as an example of authentic activity in a community of learners, where expertise was distributed across all participants.

Keywords: biology education, secondary education, educational/instructional technologies, ICT, TPACK, instructional design, action research

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Introduction

The present study was conducted at an upper-secondary school in Sweden, which gives the vocational education Natural Resource Use programme with a focus on farming and animal husbandry. In 2018, the school management launched an initiative, 'teachers doing research', encouraging teachers at the school to engage in small-scale research projects in relation to their teaching. One year into the initiative, Jesper Haglund, in his capacity as science education researcher, approached the school with the suggestion that some of the teachers might focus their research on the introduction of infrared (IR) cameras in their teaching. He has previous experience of conducting educational research on the use of IR cameras, primarily in physics and chemistry education, and has found opportunities with using the technology in supporting student inquiry (Haglund et al., 2015; Haglund et al., 2016). In this project, he was particularly interested in exploring the potential of IR cameras in the study of biology-related phenomena, such as animals' physiology and health (Haglund & Schönborn, 2019), in collaboration with teachers at the school (Berg et al., 2020). Frida Henriksson was one of eight teachers who expressed interest in focusing on the introduction of IR cameras in their teaching. She has long experience from the school, both as a former student, and as teacher in both theoretical subjects, such as Animal biology, and vocational subjects, such as Agricultural animals 2, the course in focus in this study. Here, we analyse an activity in which students were invited to study pigs with IR cameras in the school's pig house, including sows with udder infections, as an example of cognitive apprenticeship in vocational education.

Vocational education as cognitive apprenticeship

Assuming the perspective of situated cognition, J. S. Brown, Collins, and Duguid (1989) argue that school teaching traditionally does not prepare students very well for participation in society. Rather than being given the opportunity to engage in authentic activity, characteristic of the culture of the surrounding society, students are left with ersatz school activity. In response, they suggest that school teaching should adopt *cognitive apprenticeship* methods, which "try to enculturate students into authentic practices through activity and social interaction" (Brown et al., 1989, p. 37), as a parallel to apprenticeship in learning a craft (Lave & Wenger, 1991), also in theoretical subjects such as mathematics. As another aspect of taking advantage of the social nature of learning, Brown and Campione (1994) point to the power of forming a *community of learners* consisting of students and teachers, where expertise is distributed among the different members as they choose to focus on different areas of interest.

The notion of cognitive apprenticeship has received attention within vocational education. Ideally, vocational students should be able to benefit from an integration of theoretical and practical subjects in authentic activity, such as applying taught concepts and skills when taking on external commissions from customers in the local community. Unfortunately, this is often a missed opportunity, as, in reality, teaching of general subjects tends to be disconnected from vocational studies and practice (de Bruijn & Leeman, 2011). However, Lindberg (2003) has identified that the tradition of school-based upper-secondary vocational education in the Nordic countries, characterised as a hybrid between school and work, may be well suited for such practices. In an observation study of interaction between teachers and students in vocational education at different vocational study programmes in Sweden, she found that the teaching was often based on vocational tasks, similar to workplace assignments, but with less pressure on quality and delivery on time. Situations that arose in performing such tasks were often the starting point of discussions:

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* Corresponding author

> If the teacher thought the situation important enough for all the students s/he brought it up when they were in class or at the end of the day. In these situations, the students were a part of interactive social processes where they were involved in using the vocational language with their teacher – a person well acquainted with the vocation (Lindberg, 2003, p. 176).

The *Natural Resource Use* programme is one of the vocational upper-secondary study programmes in Sweden, preparing students for jobs in areas such as farming, animal husbandry, forestry, and outdoor tourism (Skolverket, 2012). Säfström (2019) has conducted an ethnographic study of students at the programme at a school with a focus on farming. The school runs a farm as a part of its operations, which delivers produce to the school restaurant and customers in the surrounding area. Using the notion of a community of practice (Lave, 1991), Säfström describes how the students are engaged in authentic work together with the vocational teachers. In certain aspects, the teachers become colleagues and friends with the students and thereby serve as role models. The students express a sense of belonging to the study programme and each other, and responsibility toward the animals and machines, and running the operations. The students acknowledge the value of theoretical subjects, such as biology and entrepreneurship, but particularly appreciate practical aspects:

> It is reflected in stories by the students, of how it makes sense to them to learn in "real-life situations" – when they experience that they do "something useful". Like taking part in spring and autumn tillage; where activities contain driving to actual fields and croplands where you sow or harrow. Or like taking part in the daily routines of tending to animals (Säfström, 2019, p. 8).

The potential of using IR cameras to study pigs' health

Udder infection is a common disease in lactating sows, caused by bacterial infections of separate udder parts. Studies have found that up to 20 % of sows suffer from this disease, causing a large economic drawback since piglet mortality increases and slaughter of the sow is a common result. Udder infections (mastitis) are highly contagious and can be seen in different forms: acute, subclinical and chronic infections. Acute mastitis occurs mainly during early states of lactation. The acute inflammation causes clinical signs of disease, such as fever, decrease in feed intake, milk production and a reduced general condition. Subclinical mastitis is harder to detect, due to a lack of visible symptoms, which results in a low degree of treatment. If detected, udder infections can be treated by providing antibiotics, pain relieving medicaments and oxytocin. Chronic mastitis is a result of a non-treated subacute form, where bacteria causing the inflammation are capsulated within the udder. These capsules, or abscesses, appear after the lactation period and give no clinical signs of disease, so repeated palpation of the empty udder is important to discover chronic mastitis. It is non-treatable due to that blood flow through the abscesses decreases and provided antibiotics is unable to reach the infected area (Swedish_Veterinary_Association, 2017).

The usage of infrared cameras in agriculture is increasing, with applications in areas such as animal husbandry and machinery surveillance (Gilbertsson et al., 2019). IR imaging in animal production is a non-invasive method for monitoring health, which could be especially useful in animals that are less used to human contact. Soerensen and Pedersen (2015) have reviewed the usage of infrared imagery in pig reproduction and health. The authors conclude that IR cameras have a high potential in research as well as on-farm management, although standardised methods needs to be set in place. Most studies are done on estrus, fever detection, wounds, leg, joint and claw health. However, the results are still inconclusive between studies, which can be partly explained due to differences in methods and environmental factors. Given the lack of visible symptoms of subclinical and chronic udder infections, however, detecting such infections is a potentially interesting application of the technology.

Purpose of the study and research question

The purpose of the study is to provide the introduction of new digital technology in vocational education of animal husbandry as an example of cognitive apprenticeship in a community of learners. Against this background, the study was guided by the following research questions:

- How can infrared cameras be used to stimulate authentic activities in students' investigation of the physiology and health of pigs?
- What different types of roles do participants adopt when novel digital technology is introduced in vocational education in an action-research project?

Method

Context of the study

Using Eilks' (2018) categorisation of different types of action research, we consider our initiative to introduce IR cameras in the teaching as a case of collaborative, participatory action research. All stages of the research were conducted as a joint effort between the involved researcher and eight teachers, which are all considered co-researchers in the study. Jesper, as an external researcher, seeded the idea to focus on IR cameras and was responsible for design of the data collection approach. The involved teachers were responsible for design and conduction of teaching in their lectures. Data collection and analysis, and evaluation of the potential of IR cameras in teaching in the studied subjects, were collaborative responsibilities across the research team. All participating teachers were invited to contribute as co-authors of academic texts, and Frida chose to collaborate with Jesper in further analysis and writing of the current article.

Apart from in Agricultural animals 2, IR cameras were introduced in the courses Animal biology, Horses 1, Service – natural resources 1, Science studies 1, and Physics 1. Across the courses, we shared experiences of designing and conducting the teaching. We established a way of structuring the lectures and data collection:

- Students were acquainted with IR cameras
- Students were divided into small groups and decided what phenomenon to investigate with IR cameras (with different degrees of teacher guidance in the different courses)
- Students conducted investigations in their small groups, which involved taking IR images of studied phenomena. The teachers and researcher followed the students and provided guidance. The interactions of some of the groups were video recorded.
- All students, teachers and the researcher gathered together at the end of the class to look at collected IR images and discuss together what they mean.

As mentioned, the current study took place in the school's pig house, which serves as a good example of a hybrid context in Swedish vocational education (Lindberg, 2003). In the pig house, students are given the opportunity to learn animal husbandry, in collaboration with pig managers and vocational teachers. They are taught rules and regulations, and novel working methods and technologies, but without the time pressure and financial constraints of a commercial pig farm.

Participants

Five students at the second year of the Natural Resource Use programme, specialising in animals in agriculture, have given informed consent to participate the study. However, from the point of view of a community of learners (Brown & Campione, 1994) or community of practice (Lave, 1991), the students provide only part of the story. Apart from the authors of this paper, two other teachers, acting as co-researchers in the research project, and the manager of the pig house were involved in the study, contributing with guidance of students in conducting the investigations and interpretation of the results. Therese Karlsson teaches in the course together with Frida, and provided important experience of pigs' physiology and health, as well as relevant knowledge for evaluating the potential usefulness of IR cameras in this area of study. Per Mogren is a teacher in social sciences and joined the project to engage in reflection on the teaching practice with his colleagues. He contributed with filming students' activities, and encouraged them to probe deeper and explain what they saw with the introduced IR cameras. Names of involved students have been anonymised for ethical reasons.

Collection, selection and analysis of data

Video data of the students' small-group investigations and whole class discussion were recorded with handheld video cameras. The analysis of the video data was performed in a qualitative research tradition, in which we searched for salient video clips with particular narrative power (Derry et al., 2010). After the lesson, the researcher and teachers identified an episode where students took IR images of a sow with an udder infection, and the joint effort of students, teachers and the researcher in explaining the IR image, that:

- involves a high degree of engagement from all involved participants, due to surprising findings,
- provides insight into students' understanding of pigs' physiology and health, part of the content of the course, and,
- shows how IR cameras can contribute to understanding of the phenomenon

We therefore chose to centre our analysis around this episode. However, we start the account of the results with the less surprising finding that a pig's injured leg has high temperature as a background to the case of the udder infection.

Results

Students investigate a limping pig

At the beginning of the activity, the students are divided into two groups. After having acquainted themselves with the IR camera by looking at, among other things, sheep in the sheep house, one pair of students, Anna and Johanna, go to the pig house. They look at groups of pigs in different pens, and notice with the IR camera that visible wounds on the pigs tend to have higher temperature than the rest of the bodies. The students come to a pen where many young pigs, so called weaners, lie close together, and Johanna looks on them with the IR camera (**Figure 1**).

Figure 1. Johanna looks at a group of young pigs with the IR camera

Anna whistles to get the pigs' attention and touches one of the pigs, lying in the corner. She sees that it is limping on the left, hind leg.

Anna: He's got some pain, you know... [comes to Johanna and asks for the IR camera] Can I have a look?

Anna gets the IR camera and tries to look close up at the leg. The pig hides in the corner, so it's difficult to get a good picture.

Jesper: Was it the hind leg... where it's limping...?
Anna: Yes. Can you see it straight from behind...? [hands the IR camera to Johanna]
Jesper: But the limping one, that's exciting to see...
Anna: Yes. If there's a big difference. There should be, because you feel that they are warmer.

While they are waiting for the limping pig to come out of the corner, Jesper is curious about whether injuries or infections can be cured, and Anna tells him what can be done:

Jesper: What can you do with pigs when they are limping...?
Anna: Well, it's antibiotics... and pain killers... and hope that it will turn out well... usually, it gets sorted out...

Frida joins the students and asks what they are doing:

Anna: [points to the wounded pig] The small one in the corner has great pain in the leg... if there's a difference with that... and the other ones, in temperature...
Frida: Yes. And do you find anything? /.../
Anna: [looks at the screen of the IR camera that Johanna directs to the pig] Yes. It's actually shining white there... /.../

Johanna moves closer to the pig and takes IR images (**Figure 2**).

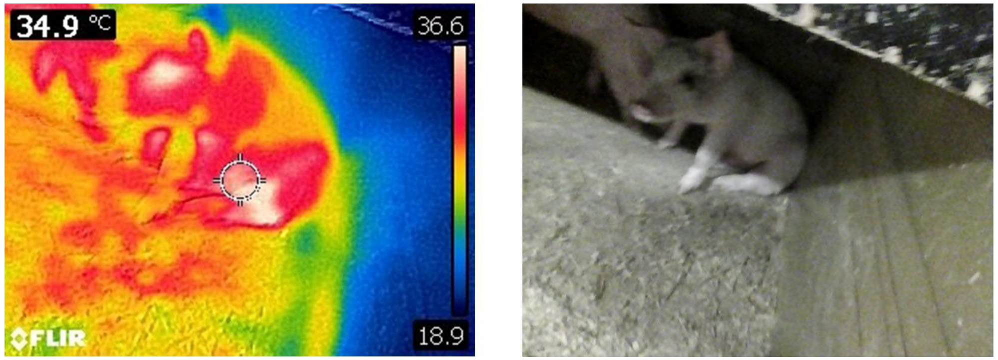

Figure 2. IR image and photo in visible light of a pig, where the wounded left hind leg has higher temperature than the rest of the body.

Frida removes the roof under which the pig is hiding, so that it starts to limp forward.

Johanna: [looks at the pig with the IR camera] He's a bit warmer.
Frida: He is, right...?
Jesper: Can you see clearly that the legs are warmer?
Johanna: Yes. It's, like, white...
Jesper: Yes.
Frida: How come?
Anna: Infection, or... you see that he's really swollen... well, it's trying to kill what's...

In this episode, the students try to take good IR images of the wounded pig. They predict that it will be warmer compared to the other pigs, due to the wound. Even though it turns out to be difficult to get good pictures, the students persevere, and Frida assists them in getting the pig out of the corner where it is hiding. Jesper and Frida are just as curious as the students to see what the temperature is. When they confirm that the pig's hind legs are warmer than the rest of the body, Frida asks the students to explain why that is, and Anna gives a reasonable explanation, that high temperature helps curing infections.

Students and teachers investigate a sow with an udder infection

The students in the other group, Lisa, Sara and Jenny, take an interest in a sow with a known udder infection. The process of producing milk normally increases the temperature of the udder (**Figure 3**).

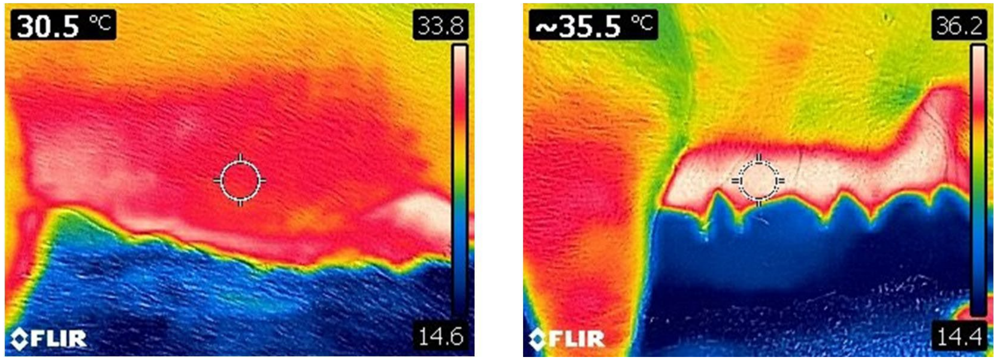

Figure 3. IR image of the udder of a non-milk-producing sow (left). IR image of an udder, where milk-producing tissue has higher temperature than the rest of the body (right).

In this case, however, the students notice red colder spots against the white background of the udder (**Figure 4**). This is puzzling, as we saw from the other group's investigation that infections typically cause an increase in temperature.

The students and Frida engage in analysing the IR image shown to the right in **Figure 4**.

> Lisa: [points to the red spots] These red ones...
> Sara: But they are not as warm as the white ones... /.../
> Frida: What do we think of that, guys...?
> Jenny: What?
> Lisa: That it is...
> Jenny: ...an abscess. /.../
> Frida: Here we see that they are not as warm, but they have about the same temperature as the non-milk-producing parts of the udder up here [points to the screen].
> Lisa: Uhum.
> Frida: It is these parts here [points along the udder on the screen] where there are milk-producing cells... where it is running like crazy... it's there that it is absolutely warmest.
> Sara: Uhum.
> Frida: So now I feel more certain that these are abscesses... /.../ But that's a really exciting picture, so we're going to look more at it.

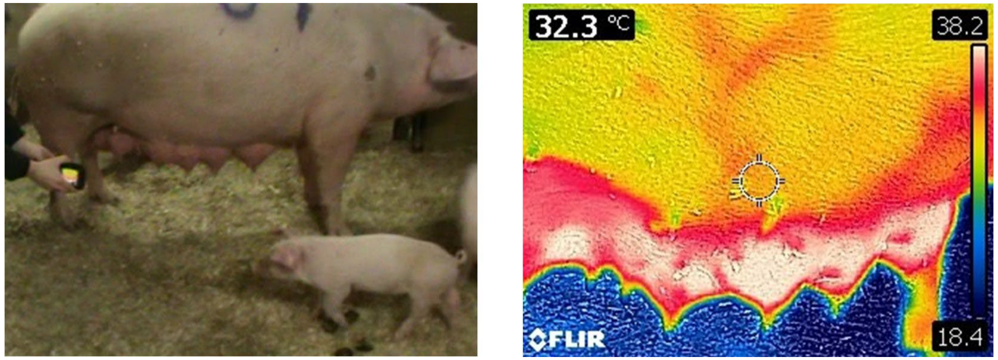

Figure 4. Lisa takes an IR image of a sow with a known udder infection (left). IR image of the udder infection, where abscesses appear as red spots against the background of white milk-producing tissue (right).

With access to this IR image of the udder infections, the students see the red spots and identify them as udder abscesses. Frida adds to the interpretation in contrasting the abscesses to the warmer surrounding milk-producing tissue.

After their IR-camera investigations, the students and teachers, and the researcher gather in class to tell the other students what they have been doing, look at the IR images projected onto a screen, and try to analyse them together. Frida leads the discussion, and when they come to the IR image of the infected udder (Figure 4, right), she is still excited:

> Sara: There's that picture!
> Frida: Here it is! Hey, this is so pretty! This made me so happy. This made me so d... extremely happy! [laughs]
> Jesper: Schadenfreude towards the poor animal...? [laughs]
> Therese: No, not in that way. It's rather one of those aha things.
> Jesper: Yes.
> Frida: Yes, really an aha thing! Because, what is this...? [looks at the screen]
> Sara: All the abscesses.
> Frida: Yes. Here! [points to the red spots on the IR image with the cursor]

Frida openly shares her enthusiasm about the image, which Therese and she express as an "aha thing", an image that all of a sudden makes things clear to you in a eureka moment.

Now, Sara expresses that it is strange that the abscesses have a lower temperature than the surrounding, supposedly in contrast to infections typically causing temperature increases:

> Sara: But it's still strange that they show a lower temperature.
> Frida: Is it, really?
> Lisa: But doesn't it always get more compact...?
> Anna: I also imagine the milk around it... I mean, it's not one of those abscesses that are filled with pus, for example... [gestures holding an object with her both hands] but it's different... if there's milk around, it gets warmer than the abscess itself...
> Per: There is no milk flow, is there...?
> Frida: No, exactly. Exactly. There's no milk flow here [looks at the screen] and these [the abscesses] are, like, capsulated...
> Students: Uhum
> Sara: There's at least seven of them...
> Therese: There's a bit of a difference between an active and not active process... if it's capsulated...

Anna, who did not take part in the investigation of this sow in the pig house, provides a reasonable explanation, by contrasting these abscesses with open infections, which is expanded upon by the teachers.

After some continued discussion, Jesper wonders whether there is a cure for such abscesses:

> Jesper: How can you treat one of these…?
> Sara: You can't.
> Therese: That one can probably not be treated very easily…
> Frida: No [shakes her head]
> Therese: …I'd say… when they're capsulated. If you have an active one, possibly… but not capsulated…
> Sara: There's nothing against mastitis. /…/
> Frida: But they can also get udder abscesses for other reasons, and they are pretty hard to treat, because they are often embedded quite hard… even if you treat with antibiotics, the antibiotics can have difficulties coming through [the abscess walls], because the blood flow decreases… so it's a pretty hard condition to get at…
> Per: This is a really good picture for teaching…
> Therese: Yes, it really is!
> Lisa: Write up our names, so we can get a Nobel prize. [laughter]
> Therese: But it's also good from the perspective we have touched upon with the Global Goals [the Sustainable Development Goals] with decreased use of antibiotics… that picture can really show that there is no point treating that animal, because they [the abscesses] are lying where they are… /…/
> Per: So more IR cameras in Cyprus. [laughter]
> Therese: Yes, absolutely!
> Frida: I'm telling you. I will do my PhD on this stuff! [laughter] Let's go!

The discussion around the image ends up with the possibility to use IR cameras for clinical purposes, to help deciding whether animals with udder infections could be treated with antibiotics or not, with connections to the global goals of decreasing antibiotic use. The students and teachers show great enthusiasm about the possibilities to use the technology in practice, in teaching and in research. This enthusiasm prevails in the weeks after the activity, as the students investigate further the matter of udder infections by searching for literature in the area.

Discussion

As pointed out by Lindberg (2003) and Säfström (2019), the relationship between students and teachers in Nordic vocational education, and in particular at the Nature Resource Use programme, is characterised by the experience of working together in authentic activity, such as tilling the soil and taking care of the animals. We argue that also the present study is set in the context of shared authentic activity, albeit of a slightly different kind, the introduction of novel technology in the pig house. Against this background, we revisit the study's research questions in a discussion of our findings in light of theory on cognitive apprenticeship.

How can infrared cameras be used to stimulate authentic activities in students' investigation of the physiology and health of pigs?

The use of IR cameras in agriculture is a novel application of the technology, and the question of its usefulness in the study of different species of animals and crops, in laboratory or commercial farm conditions, is still an open matter in research (Soerensen & Pedersen, 2015). Engaging vocational upper-secondary school students in the use and evaluation of IR cameras in the school farm is therefore quite different from the typical ersatz school activities that are detached from society as a whole, which J. S. Brown et al. (1989) describe and criticise. However, rather than being an example of how farming is done today, the authenticity lies in the potential contribution to how farming can be done tomorrow.

As we have found in other courses within our project (Berg et al., 2020), the students here showed an ability to use IR cameras when conducting systematic investigations of animals' physiology and health. They posed relevant questions, such as whether in injured leg has high temperature or what an udder infection looks like with an IR camera, and worked in a systematic way to answer them, by handling the pigs to get good IR images and engaging in explaining the images against their understanding of the phenomena. Starting investigations from students' questions contrasts with common recipe-like expository labs, where teachers instruct what to study, how to do it, and with an expected, correct outcome in mind (Domin, 1999).

The most exciting moment, undoubtedly, was when the second group noticed the red spots on the IR image of the infected udder, and, together with Frida, their teacher, came up with a reasonable explanation. This is an authentic challenging issue, from the point of view of animal physiology and health and the usefulness of the technology in farm conditions and in teaching the content of the course. The fact that the participants saw the findings as potential material for a Nobel prize or a PhD project – only half jokingly – shows the relevance of the use of the technology in the activity.

What different types of roles do participants adopt when novel digital technology is introduced in vocational education in an action-research project?

In the present study, all participants joined in the shared excitement of the IR images of the udder abscesses, however with different roles and assuming slightly different perspectives. From the point of view of communities of learners (Brown & Campione, 1994), all involved people contributed with different kinds of expertise. One of the student groups took initiative to getting close-up IR images, and tried to explain the surprising result that the infected areas had lower temperature than the surrounding udder tissue. Frida, as a teacher on the course, was genuinely intrigued by the image and engaged in trying to explain it with the students. The manager of the pig house, joined the discussion, and found the IR cameras a promising technology for detecting sick animals (although not part of the selected dialogues). In the whole class discussion, the other group of students and all teachers were involved in interpreting the image, and all joined in discussing clinical applications in detecting udder infections. Overall, this distribution of expertise provided the conditions for very fruitful dialogue during the observations and afterwards in whole class.

Apart from engaging in taking IR images and interpreting them, the participants' different areas of expertise were recruited in other ways, as well. For example, when Jesper asked students how you can treat a limping pig or an udder infection, the students assumed the role of experts on animal husbandry, a role for which they are training in their education. Similarly, Per, although he does not teach these particular subjects, assumed a general teacher role in encouraging the students to probe deeper for explanations of the involved phenomena.

Finally, from the point of view of conducting small-scale action research, the different perspectives and kinds of expertise all contributed to the relevance and trustworthiness of the study. Frida's and Therese's experience in running the course and knowledge of the taught content and the management of the school farm were central in designing the activity, and stimulating the students to look at relevant phenomena and develop their explanations for them. Jesper, as an educational researcher, seeded the idea of introducing IR cameras in the course, contributed with experience of using IR cameras in education, and early on identified the episode of studying udder infections as interesting for further analysis. We believe that the quality of our research, including the analysis and joint writing of this article, benefited from the collaborative effort in all stages of the project that is a characteristic of participatory action research (Eilks, 2018).

Conclusion

The introduction of an infrared camera in the teaching of the course Agricultural animals 2 was found to support students' inquiry into pigs' physiology and health. In particular, the investigation of an udder infection of a sow led to an engaged discussion between participating students, teachers and researchers. Establishing explanations in a collaborative fashion for the surprising finding that capsulated udder infections have lower temperature than the surrounding healthy udder tissue was considered an example of authentic activity in a community of learners.

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