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Vocational students' meaning-making in school science – negotiating authenticity through multimodal mobile learning

Abstract
This article presents a qualitative study focusing school science in two vocational classes, upper secondary school, Norway. The fact that many vocational students find little meaning in school science forms the backdrop. The students were introduced to teaching combining an excursion to a district heating plant and classroom lessons, with the use of mobile phones for documentation. Thematic analysis is used to explore the students' experiences by analysing their behaviour and utterances. A multimodal semiotic analysis is used to examine the students' digital stories. By offering the students teaching in a real life vocational facility, we found that the students engaged in the related school science subject matter. They do perceive the use of phones for documentation as personal authentic and relevant working method. The learning potential arising when the mobile learning bridged the two learning venues overshadowed the possible pitfalls of using smartphones.

INTRODUCTION

Traditional school science is often presented to students as fragmented concepts lacking contextualization (Osborne & Dillon, 2008). By traditional, we mean teaching characterized by "*a mixture of teacher-led whole class instruction and plenary talk, individual seatwork and laboratory work*" (Klette & Ødegaard, 2016). Many argue that the increased use of out-of-school learning could make the subject more relevant to students (Braund & Reiss, 2006; Feder, Shouse, Lewenstein, & Bell,

2009; Stocklmayer, 2010). Research has shown that even short excursions can support learning, both cognitive and affective, and can «*enhance motivation, spark interest, and encourage social interaction and to access original and authentic settings*» (DeWitt & Storksdieck, 2015). Elstad and Turmo (2009) showed that vocational students have lower mastery expectations in science than students in general studies programs. Learning science in less formal environments may be particularly important for developing these students' "*positive science-specific interests, skills, emotions, and identities*" (Feder et al., 2009). Being exposed to a concept in an authentic situation would increase the likelihood of deeper learning if the students encounter this concept in a second setting such as the classroom (DeWitt & Storksdieck, 2015).

Internationally, vocational education and training have been "*oddly neglected and marginalized in policy discussions, often overshadowed by the increasing emphasis on general academic education and the role of schools in preparing students for university education*" (Field, Hoeckel, Kis, & Kuczera, 2010). This also holds for Norway (Gjelstad, 2015), and even more for common core subjects in vocational programs, as school science is (Iversen, Stene, & Haugset, 2014). Iversen et al. (2014) report that a vast majority of the common core subject teachers are using other working methods in vocational classes than in general studies classes, but they say less about what this means in practice. The natural science curricula for students in general studies level 1 includes thirty-one competence aims (Utdanningsdirektroatet, 2016). Thirteen of these competence aims constitutes the natural science curricula in vocational programs, verbatim, i.e. they are not adapted to the different vocational programs. Many of the vocational students find the common core subjects demanding and of little value (Hiim, 2013; Kunnskapsdepartementet, 2009). At the same time, the students state that the common core subjects are necessary, but too theoretical (Høst, Seland, & Skålholt, 2013). Knain (2003) investigated in a case study the views of vocational students on science and their textbook in science. The study concluded that these students experienced school science, the textbook and the learning situation, as: boring, without meaning, and as a theoretical counterpoint to the way they like to learn. Utvær (2015) reports that the vocational students see school science as the second least meaningful common core subject in relation to the students' future occupations, and that the teaching is not adapted to their abilities and interests. After lower secondary school many students choose vocational studies because they want more practical education (Iversen, Haugset, et al., 2014; Olsen & Reegård, 2013). In Norway, students who enter vocational studies have lower average school points from lower secondary school than students who enter general studies (Utdanningsdirektoratet, 2014). This starting point creates multiple challenges for the science teachers who have to teach theory-tired students that may have mastered the subject poorly earlier and sought to distance themselves from (Iversen, Haugset, et al., 2014). Meanwhile, it is important to say that that these students do not have learning difficulties, rather, they opted for vocational education and a practical approach to learning.

The study aims to explore the experiences of two classes of vocational students when introduced to a teaching sequence comprising an excursion to a district heating plant. The teaching included the students' use of their own mobile phones to document the trip and later production of a digital story about bioenergy and district heating. Experiencing science in authentic surroundings may affect these students to seeing the purpose of the subject. Furthermore, there are high expectations for the learning potential of mobile learning (Cristol, Choi, Mitchell, & Burbidge, 2015). By offering contemporary technology, authentic environments, and various modes for learning, less literate students may find a way to cope with the subject matter and make school science more interesting. At the district heating plant the students were given the following task; "*Take photos that describe the process at the district heating plant. Later you will use your photos to create a digital story on bioenergy and district heating*". During the excursion, the students were first met by an expert guide in a meeting room who introduced them to the concept of bioenergy, including the technology, costs, and environmental issues. They were then given a guided tour of the plant. Once they had returned to the classroom, the students began to create their digital stories using the following guidelines; "*Use the freeware Movie Maker to create a digital story with the title From wood to hot water*".

Both the excursion and the students' use of phones are prominent elements in this teaching program, and need to be investigated both separately and together in order to trace the students learning experiences.

Research questions

- RQ1: How can a mobile phone help students connect learning venues?
- RQ2: How can an excursion to an external vocational facility such as a district heating plant offer opportunities for authentic learning in school science?

Theoretical background

Authentic learning

To delve into the students' experience of meaning in school science, the concept of authenticity is useful. It is however, a term which takes on a range of meaning in the research literature (Buxton, 2006). At the heart of the term lies the notion that there is some kind of resemblance between the learning experience and the world outside school. Held as important to the students' learning, much effort has been put into designing learning environments that are authentic in one sense or another (Petraglia, 1998). However, Petraglia problematizes the notion that authenticity can be predefined, and argues that authenticity "*can be neither predetermined nor preordained*". It cannot be taken as an inherent characteristic of a learning context experienced similarly by all students.

Brown, Collins and Duguid (1989) describe the idea that authenticity is embedded in culture and that authenticity is "*most simply defined as the ordinary practices of a culture*". School science is also realized in institutionalized practices and has a culture of its own. Consider the IRE exchanges (Cazden & Beck, 2003) or the writing of a laboratory report. These practices are authentic in their relevance to school science practices, but may not be authentic to the students in the sense of being personally meaningful. Therefore, there is an important distinction to be made between personal and cultural authenticity (Murphy, Lunn, & Jones, 2006). When a learning experience is said to be personally authentic, it is relevant and meaningful to the student in terms of the student's interests and identity. Obviously, we can have one without the other.

Shaffer and Resnick's (1999) review outline four categories of authentic learning: a) learning that is personally meaningful to the learner, b) learning that relates to the real world outside of school, c) learning that provides an opportunity to think in modes of a particular discipline, and d) learning where the means of assessment reflect the learning process. They conclude that these authenticities are mutually supportive. You cannot really achieve one without the other.

Authenticity is a phenomenon that can be observed and defined from the outside, in the case of cultural authenticity, and additionally as something that can be experienced from the inside, as in the case of personal authenticity. Shifts between personal and cultural authenticities are a way of creating contextual tensions in students' meaning-making. Students need time and space to negotiate such tensions, in order to co-construct and transform meaning in light of new experiences. By facilitating lessons, a teacher can emphasize that teaching should be experienced as authentic in all phases, but only the individual student can decide if it is.

Multimodal learning

Recent educational research (Bezemer & Kress, 2015; Brown et al., 1989; Selander, 2016) criticizes the notion that learning mainly occurs due to the transfer of knowledge via textual medium. If we follow Jewitt, Kress, Ogborn and Tsatsarelis (2001), learning is realized through an interaction between visual, action-based and verbal communication. This view of learning is founded on social semiotics

that consider communication as an inherently social phenomenon. Transformation of information can occur across different communicative systems, such as text (speech/writing), images, music/sound, action and visual communication. Learning is conceived as processes that include selection, adaptation and transformation, motivated by the students' interests and the context where the learning is taking place. The meaning-making is resulting from, or made possible by, people's usage of different communication systems (modes) to interpret a situation and negotiate social purposes. In a traditional science classroom, a teacher's narrative, the textbook and laboratory equipment (different modes) would be resources that communicate scientific meaning. Signs of students' meaning-making can be seen through how students choose the resources and exploit the inherent characteristics of the various modes to get them to play together in order to form meaning.

Mobile learning

Mobile learning is defined as "*the learning activity on mobile devices or learning anytime and anywhere*" (Zhang, 2016). This definition is twofold; the first part focuses on the technology and the second part focuses on the learner and the learning process. We follow Sharples, Taylor and Vavoula (2005) who argue that the essential thing is the learner's mobility between different learning contexts, with relevant technology at hand.

DeWitt and Storksdieck (2015) underscore the need for pre- and post-activity to maximize the cognitive, affective and social learning outcomes from excursions. Mobile technology is proposed as a suitable liaison between an out-of-school venue and the classroom (Vavoula, Sharples, Rudman, Meek, & Lonsdale, 2009), and thereby as a possible link between the excursion and later learning in school.

In this article, we use the term *phone*, as a synonym for *mobile phone* and *smartphone*. We may even have used the term *recording device,* as the documenting feature was being utilized, and not its connection to the internet.

Method

The analysis follows a socio-cultural view of learning (Ludvigsen, Lund, Rasmussen, & Säljö, 2010; Säljö, 2006). A central idea is that learning takes place as a result of participation in interactional processes. Equally important is that this perspective emphasizes that learning and knowing are cultural phenomena, i.e. human practices. The analytical lens is not only single utterances or single actions, but rather the interaction between people, and between people in interaction with tools and environments, and the notion of *mediated action* (Säljö, 2009) plays a fundamental role in our view of learning.

The analysis follows an interpretative perspective (Angen, 2000). Interpretive research "*is predicated on the desire for a deeper understanding of how humans experience the lifeworld through language, local and historical situations, and the intersubjective actions of the people involved.*". The aim is to understand learning processes by closely following how participants engage in meaning making. In an interpretive inquiry, the validation of a study "*depends in many ways on the characteristics and abilities of the researcher*", the ability to display the method and to make probable interpretations. In the end, the validation lies in the ability of research to transform future actions.

We also assume that learning takes place over time and across contexts. To answer the research questions, we have studied: 1) students' utterances and actions, and their use of tools at the excursion (head camera video data), 2) the students' experiences with the excursion and the use of tools (interview and survey data), and 3) student products produced after the excursion (digital stories).

Data collection and analysis

Head-mounted cameras have a great potential to contribute to the understanding of social practices (Frøyland, Remmen, Mork, Ødegaard, & Christiansen, 2015; Myrvang Brown, Dilley, & Marshall, 2008), and allow us to observe students' situated talk and action. Together with interviews and a survey, headcam recordings are suitable for investigating *"the dynamics of how meaning is created, space is composed, and identity reflected through the exhibit"* (Allen, Whitehead, Paiva, Descure, & Bak, 2014). The survey and the interviews comprised 16 questions designed with three types of questions; yes/no, rating scales, and open-ended. Examples of question posed are: *If you could choose, would you have chosen teaching out in the community combined with classroom lessons, or would you prefer just classroom lessons? What do you think might be DISADVANTAGES of using mobile phones as learning tools?* Interviews provide an opportunity for the researchers to ask *follow-up questions, probing questions* or *specifying questions,* and to check whether the informant's response is a product of a leading question (Kvale & Brinkmann, 2009). Examination of student products (digital stories) gives us insight into their transformation of experiences and knowledge between the two learning venues.

We have developed analytical approaches adapted to the different data types.

Table 1: Analytical approaches adapted to the different data types

Method of analysis	Data type	Analytical lens
Thematic	Headcam video	1 What do the students orient themselves towards? 2 What do the students talk about? 3 How do they interact in the context?
Thematic	Interview	What are the students' concerns about the excursion and the use of mobile, in relation to their own interests and learning preferences?
Thematic	Survey	What are the students' concerns about the excursion and the use of mobile, in relation to their own interests and learning preferences?
Multimodal semiotic	Digital stories	1 What kind of resources (visual, text, sound) do the students use? 2 How do they make meaning through the different parts? 3 How do the students tie information and experience from the excursion into the digital story? 4 Moreover, based on the foregoing questions, how do the students transform experiences from the excursion into their digital story?

Headcam video data, survey data and the interview data were structured and analyzed with thematic analysis (Braun & Clarke, 2006).

First, we conducted an inductive data driven coding (Derry et al., 2010) by using the analytical questions in Table 1 to identify themes/patterns that may contribute to elucidate the research questions. These analytical questions were chosen because they focus the analysis towards students' interactions, and the students' interactions with technology. We coded the video events in accordance with our interpretation of what happened. Interview- and survey excerpts were coded verbatim by selection of meaning units (Burnard, 1994). Codes interpreted as belonging to the same overarching theme were then grouped in categories and named in accordance with the phenomenon identified. For example, all codes including the students' inquiries to the expert guide were gathered in the category

"*Inquiries to the expert-guide*". We then wrote descriptions of each category in terms of their relation to the RQs. In the next step, we searched across all the categories for answers. Here, we looked for interaction effects and contradictions. Finally, we wrote up the analysis as a coherent text presented in the Findings. To make our analysis visible, we underpin findings with representative single codes, as verbatim student utterances. All phases in the thematic analysis required a re-reading of the data and an openness to possible new codes.

The students' digital stories were analyzed with a multimodal semiotic approach (Jewitt et al., 2001). First, we made a multimodal transcription by examining the digital stories frame by frame. Then, we analyzed the stories by studying single frames, and the coherence between them, guided by the questions in table 1. These stories are evidence of the students' sense-making; of negotiation between the perceived authenticity at the district heating plant and the school task, explaining the process taking place. The relationship between an event and a multimodal text describing the event will rest on what is selected and foregrounded as important and interesting, given the students' interests and their interpretation of the task. In the students' texts, there will be differences in how much is left to the reader to interpret, and what is stated explicitly. We especially look for whether the students depict things as they are (naturalistic, iconic representation), or if the students have tried to explain how things relate (more abstracted, scientific principles). The latter would create coherence with the scientific domain by making connection to the district heating process in general. Self-produced photos will show more presence at the excursion than pictures/illustrations picked from the plant's website. In addition, the website illustrations have reduced modality in that the drawings have focused on the details of the process. It might seem that this makes these illustrations more suited to describe abstract and general processes.

In the current teaching sequence, there were several scheduled learning resources. The expert guide's oral presentation along with a written PowerPoint in a meeting room. The guided tour through the various steps in plant, and the possibility for students to ask questions to the expert guide was also scheduled. Informal conversations during the guided tour constituted a spontaneous resource for learning. In addition, the physical location at the plant serves as a resource, as it includes sounds, smells, spatial designs, the machinery, and tactile phenomena like heat from the furnace. Along the guided tour, the students took photos. These photos also constitute scheduled resources for learning. Back in the classroom there will be other salient resources for the students' meaning-making. The assignment will guide the direction of how the students adapt impressions from the excursion. In addition to the students' self-produced photos, the expert guide's written presentation (made available for students), the plant's website, the teacher's reflexive classroom talk, students' collaborative talks as well as their individual memories, will be probable resources. Moreover, the students' prior experience on what counts as "good work" in school will influence the production of their digital story. Students' adaption and re-working of resources into a digital story can be seen as traces of how they establish connections between the learning venues.

The first author mainly conducted the thematic analysis. The first and second authors conducted the semiotic analysis. All authors discussed and criticized the performance of the analysis, and concluded on findings. To evaluate the robustness of the categories in the thematic analysis we have conducted an interrater reliability test on 50 random selected codes (Lombard, Snyder-Duch, & Bracken, 2010). We found the percent agreement between the first author and the two co-authors to be respectively 69 % and 86 %.

Participants

The study is part of a one-year lasting project exploring vocational students' learning in science, conducted by two science teachers and the first author. The data presented are from one of the developed and implemented teaching sequences. During lessons, the first author was a participant observer.

Data are collected in the two teachers' classes; one electricity class (12 boys), and one healthcare class (8 girls/3 boys) in upper secondary school level 1. Classes from two different vocational programs were selected because it was assumed that students in different programs may have different interests and therefore may provide richer data. The study is conducted according to approval from the Norwegian Centre for Research Data (NSD).

Data collected

Four students, two boys from the electricity class and two girls from the healthcare class, volunteered to wear head-mounted cameras during the excursion, resulting in four videos of approximately 60 min each. We only analyzed one video from each class for two reasons: firstly, there was technical problems with one of the recordings in the electricity class, and secondly, in the healthcare class the two recordings were very similar. Here, we observed the same phenomena in both recordings, so analysis of both would not provide substantially more information. All students answered a post-survey with 16 questions. Two boys from the electricity class and two girls from the healthcare class (not the same as those wearing the head-mounted cameras), were interviewed. This resulted in four soundtracks lasting approximately 25 min each. Four students' digital stories were examined (the same four students that were interviewed).

Findings

Thematic analysis

During the analysis, we identified 378 codes, which we then systematized into eleven categories according to themes/patterns identified: Inquiries to the expert-guide, Prefer learning outside the classroom, Orientation towards the locus of the guided tour, Social contact between students and students' small talk, Images and words play together, Phone as focusing and structuring tool, Photos as cognitive tools, Learning by doing, speaking and hearing, Prefer traditional learning methods, Relations to their own phone and phone usage and Cons of the use of smartphones in schoolwork. In different ways, these themes capture elements of how the students experienced the teaching program. Our analysis of the eleven categories resulted in an eight-page text describing each category successively. Here we present a synthesis of that eight-page text. All eleven categories contributed to answering both research questions.

How can a mobile phone help students connect learning avenues?

At the heating plant, the students were actively taking pictures. All students, except two (the camera wearer in the electricity class and one of the students who was interviewed (Student B below)), took photos. The camera wearer reported technical problems with his phone, and student B said she did not like taking photos. In the survey, on a Likert scale from 1 (disliked taking photos) to 6 (really liked taking photos) the average was 3.9. Therefore, it appears that the majority think it was all right to take photos. We have observed many instances where the phone serves as a focusing tool. Holding their phones in front of them, in camera mode, the students were actively looking for the right composition for their next photo. E.g., when the expert guide was showing a heat exchanger, the students at the back stretched to capture photos of the installation. The phone acted as a lens through which the students actively sought to frame and capture the desired motive. They take a photo, review it, and if it is not good enough- i.e. relevant to serve their purposes- they take another one. During the tour, the students were also talking about the act of taking photos, as when the camera wearer asked a fellow student who had just peeked into the furnace peephole, "*Did you get a good photo?*". In the survey, some students talk about how the shooting was directing their activity; "*Then I had to do something practical myself. Not just listen to someone talking*". In addition, the phone was a focusing tool in itself simply because the youth enjoy using it; "*the phone is important to us youngsters, and we know a lot about how to use it*". This also shows that the phone brings in an aspect of personal authenticity,

represented by a student-centered working method. Many of the students uttered that to use the phone was positive in its own right; "*it becomes more fun when we are allowed to use something we often use by ourselves*".

One issue brought up by many students, was the use of the phone as an archive; "*The files on the phone will be saved for later use.*", and "*You know you have it in one place and it is easy to retrieve, as a refresher of what happened*". They also used the phone as a timeline organizer; "*It is helpful with photos because then you have the order, and you know what you've gone through.*" The phone structures and supports their later work with their digital stories; it functions as a link into the classroom. We also find many statements on how photos refresh the memories of the excursion. One student said, "*The photos make you remember more of what the man said when he explained the different machines*". Another student said that with photos you "*remember what you saw, and recall some of the memories from the trip*". The students use their phones as cognitive tools to organize and structure, and furthermore, to recall and recreate memories from the excursion.

Eighteen of the students uttered that it was helpful to use both words and images when producing their digital stories; "*It is easier to explain what's there, and what the thing in the photo is doing, or not doing*". Some students claimed that this helped them gain an understanding; "*It became a bit more understandable with both photos and words*" and "*I feel that I learn more from images than from text only*". This indicates that the students were aware that images add an extra channel for sense-making. Images and words together provide extended possibilities for interpretation and expression. On the other hand, some students' utterances can be interpreted to mean that these students believe that images without accompanying text are able to explain and show processes; "*I used images that explained what I wanted to say*" and "*these photos say more than words*". This indicates that some students may use photos as an excuse for not explaining with words, but instead entrust their photos to tell the whole story.

When asked what could possible drawbacks of using smartphones in school could be, the students were quite unambiguous. Thirteen students mentioned that it is easy to get distracted. In the interviews, all four students uttered that using phones on excursions is good, but not in the classroom, because it is easy to slip into non-academic activity. One of the students elaborated; "*Drawbacks could be that you become unfocused and start doing other things on your phone: sending messages, logging onto Facebook and stuff. However, I think the excursion went okay. I thought it was interesting to follow the tour, so I focused on that. However, if I had been left in a really boring situation, and not bothered to pay attention, I could easily slip away.*". In our study, we have not observed this as a major problem. Video data from the excursion shows two different instances where two students wrote and sent text messages. We also observe a few instances where the students take photos of each other. Social contact between students can itself contribute to make the learning situation appear positive, and may help to create connections between excursions and the classroom. On the other hand, if this type of phone usage becomes extensive, it will probably not promote academic links. Five students also imagined technical problems as a possible disadvantage.

In the survey, fifteen of the students are positive to the idea of continuous use of phones as a tool for learning in schoolwork. In the interview, a student summarized, "*Yes, it's really all right. Especially on the kind of excursions like this, where it is very convenient to carry around, so, the phone is a very good tool* ". However, in the survey, four students said they preferred traditional classroom lectures. We observed two females making notes during the expert guide's presentation, one on her phone and one in her notebook. We also observed a third girl requesting to borrow the other student's paper notes once back at school. This indicates that traditional working methods do not necessarily have to be entirely replaced by new ones, but rather can work in conjunction with the traditional ones.

How can an excursion to an external vocational facility such as a district heating plant offer opportunities for authentic learning in school science?

The first part of the excursion occurred in a context similar to the school environment as the students were following a lecture in a meeting room, but in contrast, the lecture was given by an expert. The presentation had authentic commonalities with both the school context and district heating plant context. Several students pointed out this difference in stating that they liked to learn from an expert and not just from the teacher. Some students recognized and were attracted by both contexts.

When observing the video data, we see students who are to a great extent bodily oriented towards the locus of the tour; the expert guide and the machines. Students in both classes are aware of their surroundings; seeing, hearing, being directed toward; smell, taste, touch; be close to and be curious about. The students are geared towards the guide's talk and turns towards what he points out, for instance when he points to a diesel generator behind five of the students who then all turn around to view it. Moreover, they are continually taking photos, as when a girl takes a photo into the ash container and shows the photo to a fellow student, who then comments and smiles. They shoot and share the moments. However, towards the end of the tour, some students became less attentive.

The students posed fifty-five questions to the expert guide during the excursion. Fifty-two of them were rooted in the electricity class, of which thirty-one were questions posed in the meeting room and twenty-one during the guided tour. In the meeting room, the questions were comprehensive and relatively abstract in their formulation: "*Do you deliver just hot water or do you deliver AC power too?*". During the guided tour, the questions were more directly linked to the installations; "*How much wood chips do you use then?*". The students also posed more personal questions; "*Is there a limit on how much hot water you can deliver to each customer? Because, my mum stays an hour in the shower, so I get no hot water.*" The three inquiries in the healthcare class were of the same type; "*Like, for a regular customer, do you earn back what you spend on installations?*". The video data show that students' internal conversations predominantly have close bonds to the situations and to what the students are experiencing. The authentic setting may facilitate the students to ask specific questions related to the site and the expert guide's talk.

During the guided tour, we are given good access to what is happening with the two camera wearers. The boy in the electricity class was active and talkative. He repeatedly comments on a very noisy pneumatic sound; "*Damn, that noise from the cleaning of pipes was fucking creepy, suddenly boom!!*". He was obviously startled by the noise because he comments on it eight times. Peering into the furnace was exciting too; "*Huhuhu, damn cool!*", and he did this two additional times. In the healthcare class, the camera wearer was very concerned with a frog in the wood chip funnel who was facing an imminent death. "*Poor frog! I am glad I am not that frog*". We have registered eight different affective statements about the frog. Much of the students' small talk was connected to situated experiences. They commented on what they saw and what they could feel. Like another boy commenting on the furnace; "*I have to look into those flames again. They were awesome!*" and a girl saying "*Pretty hot, I'll say!*" waving her hand in front of her face.

In the interviews, the four students elaborated on their experiences with the excursion. They said they learned more than in a regular lesson. They appreciated the situatedness; "*See what happens for real and hear from those who work there*" and "*Much more interesting when you get it in front of you*". The students liked to listen to the expert because "*he explained very well*". Moreover, "*You get a more overall impression*", "*I learned more than just school science*" and "*I learned other things than in a regular science lesson, how big it is, what kind of equipment they are using, how much they deliver, etc.*"». Here the students explain that they see unity and coherence in this way of learning. One girl elaborated; «*The alternative learning venue allows you to get an experience that affects you, and then it is easier to remember. Instead of just sitting and writing or just getting lectures,*

here you get instruction from others who makes it more interesting in a way. So you get a different surrounding and then you get to, like, see the practical, rather than just the teacher».

We have identified several affective events (including the frog, the furnace, and the pneumatic sound) in the video data, i.e. times when the students are showing emotional involvement. The event with the frog that ended his life in the wood chips infeed funnel was momentous. Even in the following lesson back at school, a student commented, *"I've been thinking of the frog all night. I feel so sorry for him".*

Several students enjoyed playing an active part; *"I'd say I do my best learning when I'm on-site. Just sitting down and writing doesn't really work for me, so that's probably why. I learn best by being hands-on and hearing the material, and by doing things myself."*

Along with the academic focus, the students were interacting socially. To some degree, the students were hugging or pushing around, for instance when two girls were embracing while the expert guide was talking about the waste product of ash. The students also took photos of each other. These interactions happened mainly towards the end of the tour, and the healthcare class dominated this type of behavior. Excursions like this allow social interaction (DeWitt & Storksdieck, 2015). If this is a motivator or a disruptor for learning in an overall perspective, we cannot say. They related themselves to the location through social interaction and picture taking, thereby negotiating who they are in relation to the authenticity offered by the heating plant.

Multimodal semiotic analysis

We now present the analysis of the digital stories. Students A and B are healthcare class girls, and students C and D are electricity class boys. There are some similarities and differences regarding which resources the students are using in their stories, see table 2.

Table 2: Resources used by the students in their digital stories

	Own photos	Illustrations from website	Borrowed photos	Narrative voice	Written text	Music
A	x	x		x		
B			x (from A)		x	
C	x			x		
D	x	x			x	x

How can a mobile phone help students connect learning venues?

Three of the students are using their own photos when telling their stories. Student A does this in combination with a narrative voice and website illustrations. She tells her story twice, first with the aid of the website's illustrations, and then with her own photos. The student uses the illustrations to inform about the overarching principles of district heating, circumstances, sequences and causalities. She creates a coherent story by repeating the same words or phenomena when switching pictures. In the second part of her story, she uses self-produced photos. The story then becomes less general and more connected to the excursion. She is referring to her experiences and makes connections to the general principles she outlined earlier in her story. The story has relatively good coherence with the excursion in making connections between own experiences and district heating in general. She also presents information provided exclusively during the excursion, which indicates a direct link between the two learning venues. Student C uses his own photos along with a narrative voice. There is a strong

cohesion between each picture and the narrative because he explains each photo in detail. Further, he establishes cohesion throughout the story by always ending one picture with an introduction to the next one. There are many specific references to this district heating plant, such as: "*down to a feeder that pushes the wood chips ..*". The explanations are related specifically to this combustion plant and will likely not be generally applicable to other plants. Student D uses his own photos in combination with illustrations from the website. The very first picture shows the screen of a computer controlling the plant, indicating his interest in the automatic management system. He then uses website illustrations with self-written text to inform about the process of district heating. The texts have independent messages that go beyond the "message" of the illustrations by relating environmental and economic issues. Student B's story shows a weak connection to the excursion. She has borrowed photos from Student A, and she presents them with short written texts such as "*Pipes with fumes*". The fact that the order of the photos is asynchronous with the timeline of the excursion establishes a weak connection between the venues. One possible inference is that this student would benefit from using self-produced photos. The narrative voices in Student A and Student C's stories contribute to a strong cohesion between the venues by using deictic statements such as "*Here you can see ash...*" and "*Here is a peephole into the furnace*". When comparing the four stories, the two stories that had adopted multiple modes were interpreted to be the most meaningful when telling the story of district heating. In this way, the analysis shows that the students' phones and their photos have made connections between the two learning venues.

How can an excursion to an external vocational facility such as a district heating plant offer opportunities for authentic learning in school science?

In the case of Student D, his story is accompanied by electronic dance music. The dubstep-sound may be interpreted as mirroring the soundscape of the plant, but is more likely an expression of this student's musical taste. This may be construed as a sign of experienced personal authenticity. As a common feature, the four stories are interpreted to exhibit a school genre, i.e. school authenticity has been influential during production. Further, Shaffer and Resnick (1999) state that in authentic learning the assessment has to reflect the learning process. In this line, we might say that the multimodal representations in the digital stories may have contributed to authentic learning.

Discussion and conclusions

In this study, we have investigated vocational students meaning-making in school science when visiting a district heating plant, while documenting the excursion with their mobile phones.

Our analysis shows that the majority of the students perceived this learning sequence (the context, the content, and the working methods), as both personally and culturally authentic. In line with Shaffer and Resnick (1999) we find the four categories of authentic learning mutually supportive. Students' utterances at the excursion show that they are engaged in the processes taking place, both scientific and social. We see *emotional events* (Lackéus, 2014) as signs of perceived personal authenticity. Moreover, the students' bodily orientation towards, and the dialog with the expert indicates that the students perceived the district heating context as a real world culture. The dialog allowed the students to participate (think and talk) in the discipline of district heating. Finally, when taking pictures, the students did this for a reason- the digital story- which was going to be graded afterwards. In the case of a final written test, the authenticity of school will predominate. Introducing a digital story to assess the students' learning processes allows the students to draw on a range of authenticities using e.g. audios and visuals. In addition, our analysis shows that the students' working methods, including the tools for learning, were an important factor when facilitating authentic learning. The external vocational facility offered a rich authentic learning environment. Furthermore, the use of phones as documenting tools offered personal authentic working methods. The phone was significant for students' learning by offering affordances in multiple modes, accessible and familiar to the vast majority

of the students. By enabling the students to frame events and make selections on what to foreground, the tool and the working method facilitated personal authenticity. Through this reasoning, we have identified several signs of authentic learning. Therefore, a reasonable conclusion would be that an excursion to an external vocational facility such as a district heating plant offers rich opportunities for authentic learning in school science.

According to Jewitt et al. (2001), learning is realized through an interaction between visual, action-based and verbal communication. The multiple modes, both at the excursion and in the classroom, offered the students multiple ways to interpret the situations and to make sense of them. While traversing between different cultural authenticities, the students had to negotiate the question of what kinds of knowledge and behavior are transferable and current in both cultures. The phones and the photos facilitated mobility between the learning venues, and offered ways to bridge current scientific practices into the classroom. The students have used the multimodal resources to interpret and conserve the situations, and later used them as recall tools to form meaning in the digital stories. With this reasoning, we claim that the students' use of phones has established durable links between the learning venues.

To elaborate on the findings, both the district heating plant and the classroom constitute an authentic practice. Moreover, both practices are construed and enacted through multimodal representations of installations/furnishings, sounds, smells, etc. The phones offer a multimodal way of working perceived as personally authentic by the students. Here, interactions between multimodality, multi-authenticity and mobile learning establishes a learning context which offers students ways to *transform* (Selander, 2016) information and experience into meaning in two stages; first at the district heating plant, and later in the classroom. In this way, this teaching sequence offers a *design for learning* that differs significantly from traditional teaching. This advocates a diversion from traditional teaching practices towards methods that include real life contexts and contemporary working methods, not just in vocational training, but for all students who find little meaning in school science.

As a closing remark, the challenges presented by adopting phones in school are obvious and mentioned by nearly all the students. How to secure the students' use of their phones only as a tool for learning and not for private purposes, is an issue. What is productive for the students meaning-making, may be difficult to delineate. To take advantage of the students' alternations of authenticities we advocate a not too strict demarcation.

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