AALBORG UNIVERSITY
DENMARK

Prototyping Mediation

How can a technological artefact be designed to mediate local data stories and evoke reflective thought in a learning situation?

Aalborg University - June 2018
A Technoanthropological Master's thesis
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Acknowledgements

First of all, thanks to our project supervisor Anders Koed Madsen for the guidance we have received in relation to this project.

Also, a thanks to Niels Gorm and the 10th grade at Gentofte 10. Klasse Center for allowing us to visit and test our ideas on you.

We would also like to thank Franka Oroza for the beautiful front page, and Sofie Naylor for her support with proof-reading the report. Thank you both for putting your time and effort into it.

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Abstract

In this thesis we unfold the design process and test phase of a mediating technology, designed in an international project called SaveOurAir. The project was a research project funded by the European Union, with the purposes of designing creative solutions to the complex issue of air pollution.

During two data sprints, we both observed and actively participated in the design and development of a prototype, called "*myAir teaching kit*". The prototype included a particle sensor, a teaching guide, and a web platform that merged data from the particle sensor with the pupils' geolocation data from their smartphone device.

Air pollution has a negative effect on human health, ecosystem, and economics in society, wherefore we find it relevant how educational programs can be designed in a way that encourages pupils to be reflective on the matter. To do this, we unfold John Dewey's theories about reflective thinking and how learning is best facilitated. Dewey's approach to learning was based on pragmatism and constructivism and advocated that learning must be experienced rather than passed on. Dewey believed that empirical data could be manipulated or parts of it be neglected, to force the learner into reflection or experiments to account for the missing data.

Through a design thinking perspective, we analyse the design of the prototype. Through postphenomenological mediation theory we analyse and discuss how the prototype mediated new understandings of the air they breathe to the pupils.

We conclude that the pupils were susceptible to the educational programme and the concept of the prototype. From observations in the field and interviews with participant actors, we document how the pupils were able to mediate new understandings in the programme. The prototype offered the pupils a way of gathering empirical data about their own daily lives and challenged their understanding. The data gathered by the pupils were not always enough to draw conclusions, but in return forced them into reflective thinking and experimentation.

Resume

I denne afhandling tilgår vi designprocessen og testfasen af et medierende teknologisk artefakt, der blev designet under et internationalt projekt kaldet SaveOurAir. Projektet var et forskningsprojekt støttet af den Europæiske Union, der havde til formål at undersøge kreative måder at tilgå fænomenet luftforurening.

Projektet SaveOurAir var et internationalt projektsamarbejde mellem europæiske universiteter og relevante aktører. Projektet blev udført over fem dages data sprint i London og fem dages data sprint i København. Under projektet var vi deltagende observatører og med til at designe og udvikle en prototype på et læringsprogram. Prototypen, som vi kaldte *"myAir teaching kit",* er en kombination af en online platform, en partikel sensor og en undervisningsguide til læreren, som faciliterer undervisningen. Platformens funktion er at sammenkoble data fra partikelsensoren og data om geolokalitet fra elevens smartphone, og visualisere data for eleven.

Luftforurening har store konsekvenser for det menneskelige helbred, samfundsøkonomien og naturen. Vi finder det derfor vigtigt at undervisningen i danske, så vidt som internationale, skoler er engagerende og udbytterig. I denne opgave tager vi derfor et dybere kig ind på hvad det vil sige at lære godt og hvordan elever kan udfordres til at tænke refleksivt og selvstændigt på området. Vi gør dette ud fra John Deweys teorier omkring hvordan læring skal opleves og sanses, frem for udenadslæres. John Dewey var pragmatiker og konstruktivistisk i sin måde at tilgå refleksion og læring på. Han mente at læring ikke kunne overleveres, men i stedet måtte erfares af eleven. For at facilitere læring kunne man med fordel undlade dele af empirien eller forvrænge den for at tvinge eleven til at reflektere eller opstille eksperimenter, der skulle svare på den manglende viden.

I denne afhandling gennemgår vi designet af læringsprogrammet ud fra et design thinking perspektiv. Vi tester læringsprogrammet i en 10. klasse i Gentofte, og analyserer og diskuterer hvorledes prototypen medvirkede til at mediere en ny verdensforståelse hos eleverne. Vi gør dette gennem Deweys teorier om læring og gennem Post-fænomenologisk mediations teori.

Vi konkluderer ud fra testen af prototypen, at eleverne var modtagelige for undervisningsformen og læringsforløbet. Gennem observationer i felten og opfølgende interviews med aktører, dokumenterer vi hvordan prototypen i situationer gav eleverne mulighed for at mediere verden på en ny måde, som de ellers ikke ville have været i stand til uden prototypen. Prototypen giver dem mulighed for at samle empirisk data om deres eget liv, ved at samle data i

hverdagssituationer. Elevernes målinger er ikke altid nok til at de kan drage konklusioner og de bliver derfor nødt til selv at reflektere over flere faktorer og opstille eksperimenter, hvilket fremmer deres refleksive tænkning.

Forskningsspørgsmål oversat fra engelsk:

Hvordan kan et teknologisk artefakt blive designet til at mediere lokale data historier og vække refleksiv tænkning i en læringssituation?

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Introduction

Deaths from environmental conditions is one of the biggest killers in the world (European Environment Agency, 2017: 12-13). It is estimated by the World Health Organisation that 12.6 million deaths in 2012 were due to environmental conditions, corresponding to 23 % of all deaths that year (Prüss-Ustün et al., 2016). In Europe, air pollution is the most significant health risk caused by the environment (European Environment Agency, 2017: 12). The risk of air pollution resulting in disease is substantial and causes lowered quality of life or even premature death (ibid). Air pollution occurs naturally from volcanic eruptions, desert dust, pollen, wildfires, and more, but human made technologies contribute to air pollution as well and are possible to minimise. Combustion engines emit a complex mixture of air pollutants, including fine particulate matter, that are associated with a broad palette of life threatening diseases such as cardiovascular disease, cancer, respiratory disease, diabetes, and more (Hertel and Ellermann, 2018: 21).

Through stricter regulations and political action, both nationally and internationally, the levels of air pollution have been decreased in Denmark. The levels of air pollution are currently below the recommendation of the European Union, with the exception of nitrogen dioxide, but studies have shown that even low levels of pollution still have documented health risks (Ellermann et al., 2014: 7-8). In Denmark alone, anthropogenic air pollution is responsible for 4000 premature deaths yearly (Hertel and Ellermann, 2018: 21).

Air pollution has an effect on the ecosystem and reduces the quality of the water and soil of the earth. This leads to less efficient soil for farmers to grow crops on and death of life in the oceans (European Environment Agency, 2017: 13). Gases and particles in the air contribute to the greenhouse effect and thereby global warming and the threats associated with it, such as decreased biodiversity, natural disasters, increased temperatures, and rising water levels that lead to a climate refugee crisis (Hertel and Ellermann, 2018: 21).

Analysing air pollution from an economical perspective is a depressing affair. Society spends vast amounts of money on regulating and counteracting air pollution, and for good reason. In Denmark alone, the effects from anthropogenic air pollution cost the Danish state 30 billion Danish kroner yearly (Hertel and Ellermann, 2018: 21). 30 billion Danish kroner is equivalent to more than three times the budget of the Danish Police (Dansk Politi, 2018), money that could be used to build new schools, hospitals, or other welfare investments. Even non-acute impacts from air pollution have been shown to have a negative economic effect. As such, it has been documented that a small increase in air pollution slow down workers and make them less efficient (Zivin and Neidell, 2017: 39-40).

Measuring air pollution is a comprehensive and complex procedure. Many different types of pollutants are in the air and they cannot be measured in the same way. In Denmark, ten official measuring stations are placed in the three biggest cities to measure pollution levels at highly trafficked streets and two are placed in rural areas to measure background levels (Ellermann et al., 2017: 12-15). The measuring stations are taken care of by the Danish Centre for Environment and Energy (DCE) that processes the data and calculates how much air pollution is in the entire country using mathematical models. The modelled calculations of the levels are also based on traffic information (ibid). Modelled air pollution data is useful and according to the DCE it accurately represents yearly averages, which can be used to monitor the development and use for policy making. But from an individual perspective it is not possible to know from this data how exposed you are to air pollution. Individuals move around geographically and do so at specific times, where traffic might be more or less saturated, while a yearly average of a street is stationary both geographically and in time. To truly know how exposed you are to air pollution, you would have to use a portable sensor.

Since the origin of computing, transistors in microchips has doubled for each year following Moore's Law (Waldrop, 2016: 145-147). Computer technologies are constantly and rapidly advancing, making computers smaller and more powerful. It is now possible to build microchips into almost anything, from cars and kitchen tools, to wearable devices like watches and clothes. Transistors are becoming smaller than certain virus and cloud-based storage and processing is becoming more accessible as well (ibid). This paves the way for a more datafied world with numeric data on most aspects of our lives and our surroundings,

Most governments and municipalities have not let these technological advancements slip and are investing in technologies that monitor public behaviour and environmental conditions to manage assets and resources more efficiently (Woyke, 2018). Future needs of efficient cities and better resource management is necessary as the cities around the world expand and populate more people each year. In 1950, 29% of the world’s population lived in cities, in 2009 the number was 50%, and it is estimated that 70% of the world's population will live in cities by year 2050 (Rassia and Pardalos, 2017: 169-171).

With more computational power it is possible to record more data about air pollution, and with the use of mathematical algorithms it is possible to calculate and predict future levels. This creates valuable information for scientists but still leaves the public unknowing of the situation and its effects. This demands we ask the question on how to engage the public in such debates where decision makings are vital to our existence and well-being.

This type of debate, however, is hyper complex and difficult to comprehend. To encourage political change in a good democratic way, society requires educated leaders and citizens. Education is one of the foundations of a good democracy and through change in habits and mindsets it is possible to change the society for the better (Dewey, 1916: 115-116). This brings along the question of how learning is best facilitated to encourage this change.

In this thesis, we will address this question with a case study on how pupils can be taught about air pollution through their own experiences mediated through technology. During January and February 2018, we participated in two data sprints under a project called SaveOurAir, a project about how to tell local data stories around air pollution. While participating in the first data sprint in London, we heard from local activists how data that evoke political action is hard to encounter. The activists used measuring tubes to measure air pollution around schools in Camden, London, but since the data were collected as monthly averages they were still not able to say anything about a specific time a pupil was in proximity. If they were to evoke political action, more granular data were required. During the data sprints, we helped to design a prototype to teach pupils about air pollution by using data around their own daily lives. The data sprints were part of an interdisciplinary project and the prototype was designed along with university professors, designers, and programmers.

The result was a teaching kit that takes its offset in the use of technology as a mediating artefact to facilitate learning. It was designed with the interest of promoting positive change in the pupils' habits. We have been inspired by the theory of postphenomenology and its claims that technological artefacts have intertwined moral and ethics and thus are able to provide material answers to ethical questions due to its design (Verbeek 2006: 119). The thinking behind postphenomenology is not to see technology as a threat to the human freedom, but rather to see the opportunities it creates for us. Don Ihde (2003; 2010) explains how the human-artefact inter-relation is an embodiment of technology and that our different devices are getting more and more entangled in our daily lives. Furthermore, technological development has opened new ways to see and understand the world, which may be used to evolve the standardised way of learning. We see an opportunity to investigating how emerging technologies can mediate learning in a classroom. Making pupils aware of their own position within a certain subject with the use of technology may create a knowledge foundation where personal data stories ensures a subject attention creating a personal incentive to act and change.

We see in this thesis, and the development of the myAir teaching kit, a coherence between, and a unique opportunity to combine, postphenomenology, Dewey's experience theory and his notion of *learning by doing*.

Research Question

How can a technological artefact be designed to mediate local data stories and evoke reflective thought in a learning situation?

DELIMITATIONS

In this thesis, we dissect how a mediating technology can be designed to foster new understandings of the experienced reality around air pollution. We will analyse how a prototype can be designed from a design thinking perspective and review the prototype from a perspective of postphenomenological theory. We will discuss how design features and visual outputs encourage certain mediations of the world, how data can be grounded in individual's own lives and if it encourages learning in a particular way.

Through an active participation during the design process in London and Copenhagen, participatory observations in a school in Gentofte, Denmark, and interviews with participants throughout the process, we study how a pragmatic approach, as made popular by the philosopher John Dewey, can be used to create teaching material grounded in data gathered by pupils themselves.

The Field of Study

The prototype is a teaching kit build as part of a European project that we test in a 10th grade class in Denmark. The teaching kit consists of an air pollution monitor, a web platform that combined geolocation data with air pollution, and a five-day teaching programme.

During this process, we have been deeply embedded in the field and been as much a part of developing the prototype as studying the process of designing it. This demands careful narrative navigation in this thesis. We aim to uphold a fairness and reflectiveness towards ourselves and the field with inspiration from strong objectivity and situated analysis. We will also include the use of narrative tropes to better translate our experiences to the reader.

In the following sections, we will introduce different organisations and topics that accounts for the foundation of our design and prototyping processes. We will account for the complex world of air pollution, to better understand the context to which the prototype has been designed. We will also present the organisations behind the SaveOurAir project, from which the prototype has derived, and give a short introduction to the project itself. We will then present our theories and methods surrounding our ethnographic field work, prototyping, and design processes. We will subsequently go in depth in the analysis on the data sprints and design testing in Gentofte and continue to account for our learnings, insights, and understandings of the design process and where we ended up.

The Air We Breathe and Ambiguity of Data

In this section we will introduce the reader to what air pollution is and the action of measuring it. We will then proceed to present the SaveOurAir *project, that was the foundation to this thesis, and the organisations behind it. In the end we present the* myAir *prototype and explain its context to creating local data stories.*

AIR POLLUTION

Air pollution is a highly complex topic, where many of the processes and variables are not yet fully understood. As air pollution is only the context of this case and not the main topic, the purpose of the following is only to enlighten the reader to such a degree that our issues, in regard to design and learning about air pollution, can be understood.

Air pollution is a combined definition of gaseous and particulate matter that have a negative effect on human health. Air pollution can both derive from human and natural causes. Air pollution is categorised into two major groups, primary air pollutants and secondary air pollutants. Primary air pollutants are defined as gases and particles directly emitted into the air, where secondary pollutants are formed within the atmosphere itself (WHO, 2005: 9).

According to the World Health Organisation [WHO], the primary pollutants are sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), volatile organic compounds (VOC), and carbonaceous and non-carbonaceous particles (PM_{10}, $PM_{2.5}$, $PM_{1.0}$, Black Carbon, etc.). Secondary pollutants are mostly created from natural chemical reactions in the lower atmosphere, like ozone (O_3), sulphates (SO_4^{2-}), nitrates (NO_3^-) among others (ibid: 9-24).

It is interesting to note that the definition between gaseous and particulate pollutants in the air is whether they can pass through filters or not. Particles are often in solid or liquid form that is suspended in the air but would be caught in a filter. So even though some gases are large by size, they do not count as particulate matter if they pass through filters. It should be noted that substances can change from particulate to gaseous matter depending on pressure and temperature among other things (ibid: 11).

Particulate pollutants are not defined by their substance and can be anything from sod to salt sprays from the ocean. It was shown by Dockery et al. (1993) that “inhalable particles”, defined as PM_{10} and $PM_{2.5}$ in the article, did have a direct correlation to premature mortality rates. This was later reconfirmed from European studies as well (Hertel, Brandt and Ellermann, 2016). It is not known if it is the size that causes the health effects or if it is specific types of particles within the size ranges that are the causes (ibid).

Particulate matter is therefore categorised by size. We work with three categories: Below 10µm (PM_{10}) in diameter, below 2.5µm in diameter ($PM_{2.5}$, also called fine particles), and below 0.1µm in diameter ($PM_{0.1}$, also called ultra-fine particles). Notice that the PM_{10} category also includes particulate matter of size $PM_{2.5}$ and $PM_{0.1}$. The smaller the particle, the more severe effect it has on the health, i.e. a smaller dose of $PM_{2.5}$ has the same negative effect as a larger dose of PM_{10} (WHO, 2005: 174; Brandt et al., 2016: 28).

Examples of PM_{10} particles are dust from roads or soil, sea water spray and road salt, and mechanical particles from friction like car and train breaks or from tires (Palmgren Jensen et al., 2005: 8). Pollen is also in this category. These particles don't travel far and are usually only spread in local environments (ibid). PM_{10} can penetrate to the lungs, causing irritation, asthma, or allergies.

Examples of $PM_{2.5}$ are bacteria and fungus spores, sod particles from exhaustion, energy production or wood burning ovens. It is also certain secondary particles like nitrates and sulphates, VOC, and polycyclic aromatic hydrocarbons [PAH] (ibid: 7). Gaseous substances can also be in this category, depending on the atmospheric conditions. Particles of this size can penetrate deep into the lungs and even cross the blood-air barrier (Brandt et al, 2016). Besides the symptoms from PM_{10}, $PM_{2.5}$ can also cause cardiovascular diseases and, in the example of PAH, cancer. Because of the smaller size, $PM_{2.5}$ particles can travel several thousands of kilometres.

Ultra-fine particles, $PM_{0.1}$, also called nanoparticles, are created in high temperature combustion or burning. Especially industrial processes, like energy or central heating plants, are a source of $PM_{0.1}$, but also private wood burning ovens can create these fine particles (Palmgren Jensen et al., 2005: 7). There are no current regulations on $PM_{0.1}$ in the EU, however recent studies have shown a correlation between ultra-fine particles and premature mortality, due to the highly chemical reactive nature of such particles (ibid). Just like $PM_{2.5}$, it is still not clear whether this is due to the size of the particles or the number of particles (Hertel, Brandt and Ellermann, 2016).

Particulate matter of a larger size is not considered in newer reports, since the regulations for measurements were changed (DCE, 2016), as they are only suspended in the air for very short amounts of time (WHO, 2005: 11). Unless standing next to the source for longer periods or having the source in a confined room, these pollutants do not accumulate to dangerous levels (ibid).

Air Pollutants

In this thesis, we will mostly be working with PM_{10} and $PM_{2.5}$ as these were the type of air pollutants the air pollution monitor in the prototype could measure. However, since the topic of air pollution was part of the teaching kit presented to the pupils in Gentofte, we will give a short introduction to the most common or relevant pollutants here. The reference will mainly be the WHO report *Air Quality Guidelines* (2005: 11-24) unless otherwise stated.

Sulphur dioxide (SO_2) is mostly emitted through combustion or burning of fossil fuels that naturally contain sulphurs. Nowadays most of it is removed either through refinement before combustion or filters after combustion. Although a primary pollutant, sulphur dioxide can also chemically change into secondary pollutants.

Oxides of nitrogen (NO_X) is both nitrogen monoxide (NO), or nitric oxide, and nitrogen dioxide (NO_2). They are a natural product of combustion with atmospheric oxygen and nitrogen at high temperatures. However, since coal has high amounts of nitrogen this is an important source of NO_x. Typical 5% of human made nitrogen oxides are nitric oxide.

An important conversion between nitric oxide and nitrogen takes place in the air that either breaks down or creates ozone. This is an important factor in urban pollution, as high level of nitrogen dioxide quickly turns into ground level ozone as a secondary pollution with sunlight or VOC reactions. For this reason, concentrations of NO_x and ozone are directly inverse.

Ground level ozone is considered one of the current most widespread pollution problems, even though ozone rarely concentrates at surface levels for more than 8 hours (ibid: 47). This is because ozone can have severe effects on human health and mortality from short term exposure (Brandt et al., 2006: 28). As mentioned above, the ability of nitrogen oxides to travel thousands of kilometres and the conversion into ozone, makes it a global pollution problem. Even though ozone emission has dropped in the EU we still see an increase in ozone related premature deaths.

Carbon dioxide is not an air pollutant, as it does not affect human health negatively, however **carbon monoxide** is a very dangerous and usually comes from the combustion of petrol cars.

Volatile organic compounds (VOCs) are a wide spectrum of organic chemicals that are involved in chemical reactions to produce secondary pollutants, such as ozone or nitrates. They usually come from unburned or partially burned fossil fuels, or leakage from gas pipes or drilling platforms.

Black carbon, also called carbonaceous particles, consists of a wide range of sod particles usually in the $PM_{2.5}$ range, like graphite microcrystals, PAH, and low volatile organic compounds. Most of it is derived from combustion and exhaustion, but also industrial processes, lubrication oils, and atmospheric reactions. Another type of similar particles are non-carbonaceous particles like fly ash and metal or mineral fragments from car breaks or road wear. Construction and demolition are also large sources.

Other worthy mentions, that we will not get into here, are heavy metals mostly from fossil fuels, and acidifying or nutritional compounds like nitrates and sulphates that have a heavy impact on farming and aquatic environments.

Thresholds set by the EU and WHO

As we have already established, air pollution has a negative effect on the human health. To counter the problem the European Union has developed standards, based on the health risks, to legislate the amount of pollutants in the air. As the amount of time exposed to air pollution is an important factor, the objectives are dependent on this variable as well (Ec.europa.eu, 2018). The World Health Organisation is heavily involved with the issue of air pollution as well, and have created guidelines and recommendations, also based on health risks (WHO, 2005). In Table 1 we have compared the thresholds set by the two organisations.

Table 1 - Table of guideline levels from the European union and World Health

		WHO	EU
PM2.5	1 year	10 µg/m^3	25 µg/m^3
	24 h	25 µg/m^3	n/a
PM10	1 year	20 µg/m^3	40 µg/m^3
	24 h	50 µg/m^3	50 µg/m^3

Both the objectives set by the EU and WHO are based on scientific studies about the health risks associated with air pollution, but they recommend juxtaposing numbers. The thresholds set by WHO are more ambitious and suggest lower levels of pollution before the thresholds are surpassed. In Appendix V – Air Pollution Threshold Levels we have included a more detailed overview.

A geographic perspective

Besides knowing what types of air pollutants are important, there is also a geographical question to the complex issue of air pollution. During our fieldwork, it was common that the student most readily thought of local sources when asked about air pollution. Road traffic, industry, and construction were some of the most common sources mentioned, however the issue is much more global than you would think.

Air pollution is not only local but comes from regional or global sources. A great deal of the $PM_{2.5}$ particles measured in Denmark are carried with the wind from large emission areas in Germany, Belgium, and the Netherlands (Brandt et al., 2016). Likewise, even though the ozone levels have been dropping in Denmark, due to strict EU regulations, the premature mortality rate has been increasing (ibid). This is however due to the increase rise in NO_x on a global scale. As the gases can stay in the lower stratosphere for weeks this is enough time for it to be transported with the wind from as far as China and be transformed into ozone on the way (ibid: 30)

In this report, we will work on five geographical levels, all from the perspective of the user(s) of the prototype. These levels are relevant both in an air pollution, social, economic, and cultural context.

Local is the near area of the individual. It is around the individuals' living accommodations, the route from home to work or school, where the individual shops, or does free time activities. Local is highly personal and frequently visited.

Urban is the city and surrounding area that the individual lives in. In the design process during the sprints, this was mostly London or Copenhagen, but also Paris, Rome and Berlin were used as cases for the prototype.

National is the country the individual lives in. This was especially relevant to a cultural and legislation context.

Regional refers to a continental or cooperative entity, like the EU, Asia, the United States, or China.

Global or **Hemispherical** is mostly in reference to pollution spread across regional zones.

Measuring and reporting air pollution

The location of our fieldwork took place in London and Copenhagen. At the onset of this project, both the Danish and English regulations around air quality was set at the EU level by the 2004/107/EC directive (European Parliament and Council, 2004), later replaced by the

2008/50/EC directive (European Parliament and Council, 2008). In both, the EU set standards not only for levels of air pollution allowed, but also on how to measure and share data about air pollution (European Commission on Environment, 2018). The directives also defined which types of air pollution should be monitored and set goals for air pollution reduction for 2020 and 2030, revised and extended in 2013 (ibid). This means that most European countries have a unified understanding on what air pollution is and what goals to aim for.

However, how to reach these goals are set on a national level. This means that there are certain local regulations that differ between countries. An example of this is the use of wood burning ovens in private homes. Since 2010 there has been a ban on older types of wood burning ovens[1] in Germany, which needs to be replaced before 2020 (Wittrup, 2017). The same is not the case in neither Denmark nor England, though talks have recently been had on implementing a wood burning ban on certain days in London (Greenfield, 2017). Although the plans are nationally set, they are still countable to the EU regulations and goals.

In Denmark and the United Kingdom information and data about air pollution comes from two major universities. In Denmark, the monitoring and supervision around air pollution falls under the Danish Centre for Environment and Energy (DCE) at Aarhus University. The department has made an agreement with the Danish Ministry of Climate and Energy, as well as with the Danish municipalities, to conduct research and consultancy within the area of nature, environment, climate and energy (Danish Centre for Environment and Energy, n.d.). This institute delivers and manages most if not all of Danish air pollution monitoring data as well as modelled prognoses. They are also the main source of information about how air pollution has affected health in Denmark, current and past pollutions reports, and education around air pollution (ibid).

In the United Kingdom, the University of King's College London has a similar role, although on a regional level. Their Environmental Research Group (ERG) conducts measurements, modelling, science policy, and more (King's College London, 2018). They are responsible for the London Air Quality Network and the Regional Air Quality Network, in cooperation with the local governments of Kent and Medway, Hertfordshire and Bedfordshire and Sussex (Kcl.ac.uk, 2018). These two networks constitute most of the regions in southeast England. They also manage 15 other regions in affiliation with UK Department for Environment, Food and Rural Affairs (DEFRA) (ibid). Besides

[1] Wood burning ovens are a high source of 2.5 PM particles

monitoring, the University of King's College London also conducts research on pollution sources and management, and also engages in public communication about air pollution, especially in London (King's College London, 2018).

Both the DCE and the ERG are the main sources of local information regarding air pollutions. They not only decide how to measure air pollution, but also to a degree how it is visualised and communicated to the public.

ORGANICITY

Organicity is a project funded by the European Union to explore and experiment with ideas about how future cities should be built and adapted to its citizens. The project evolved from a rephrasing of the phenomenon "Smart Cities". A city is often referred to as a smart city when it is in transformation to embrace digital technologies. City authorities often embrace new technologies in the hope of changing the city for the better. The Organicity project asks the question of what the smart part in smart cities is and what are best practices when innovating cities with digital technologies (Organicity, 2018).

Data is a valuable tool in building future cities better. Understanding the behaviour of citizens by collecting data about their movement through the city, energy consumption, visits at stores, etc., can be useful to design better solutions for the future. Cities and companies already collect data about citizens which is being used to design cities. Organicity has a vision of making this more transparent for the ones contributing to this data gathering, i.e. the citizen (ibid).

Organicity works from a value of transparency. They believe that it is important to be transparent about the data collected and used. They also work from a value of being inclusive. The project is to support innovations that better the lives of the masses instead of the few. As technologies evolve, some segments of the population are often left behind. The value of Organicity is to foster development of solutions that embrace innovation for all layers of society. To support this value, Organicity make use of co-creational methods to involve the public in discussions and design choices (ibid).

Projects included in the Organicity programme are experimental. They are encouraged to revolve around an iterative approach that tests solutions in the hope of making them future proof (ibid).

PUBLIC DATA LAB

Behind the initiative to apply Organicity for research funds for the SaveOurAir project stands the Public Data Lab. It is a multi-national and multi-interdisciplinary collaboration between fifteen different universities, including the Institute for Policy Research at Bath University, the Department of Digital Humanities at King's College London, and the Techno-Anthropological Lab at Aalborg University in Copenhagen (Gray, 2017). At the two data sprints, participants from the Density Design Institute from Politecnico of Milano, the Médialab from Sciences Po Paris, the IXXI institute from the University of Lyon, the University of Arts London, the University of Warwick and the University of Ghent were also part of the process and a part of the Public Data Lab as well (Madsen et al., 2018a). It was this group that initiated the SaveOurAir project, in cooperation with Organicity, Gehl Architecture and the Camden Council (ibid).

SAVEOURAIR

As part of the Organicity project the subproject SaveOurAir was born (Madsen et al., 2018a). The project ran from the 22nd January 2018 till 30th of April 2018. The theme for the project was air pollution and the initial scope was to make it easier for citizens, city planners, and civil society groups to find or tell *data stories* about air pollution (ibid). The premise for such a project was that data about air pollution today, is either very personal, without any quantitative measures to support it, or very quantitative without any relation to the personal story in the data. The idea was then to create or find data that would support both a personal story, and numeric or quantitatively significant data.

As part of the project, it was important to localise the found solutions to a specific city, but at the same time make them general enough so they could be implemented in different European cities. To do this, the project consisted of two so-called data sprints; one in London around January and one in Copenhagen in end of February. This served as an opportunity to find general problems and test them in local context. Both data sprints were five days and consisted of a multidisciplinary scholarly team of designers, anthropologists, programmers, researchers, and various students. The participants were associated with a multitude of universities and research laboratories in Europe (ibid). We also took an active part in these data sprints.

The first day of the data sprint in London, we met up with several activists and politicians from the Camden borough in London. This was a sort of 'meet-and-greet', to localise the sprint in a specific context. The idea was to be situated in the problems and concerns of people living or working in London. At this meet-and-greet, we met two local activist, Pamela and Rachel, from the activist group called *Camden Air Action*, a group dedicated to lowering levels of air pollution in the local community in London. This activist group have implemented several projects, e.g. closing down roads to invite parents and children to play on the street, as a way of giving the streets a different purpose. They are also engaged in collecting air pollution levels from around the 104 schools in Camden. Their case highlights a good reason for investigating how to tell local data stories. They reported on how they struggled with questions, like when is data granular enough to tell local stories about air pollution adequately, or when is data quantitatively enough to engage a change in politics in their local community.

During the data sprint in London we discussed what local actually means in an air pollution context. Obviously local often refers to a geolocation area, but local has additional meanings as well. It was concluded that local data is also about participation of the community. When inviting local citizens to participate in debates and data collection, the result is engagement and awareness and it also encourages ownership and further participation by the local citizens. Local also relates to the specific context of each individual interested in the debate about air pollution. It was discussed, after the meeting, that the activists were not always interested in every aspect of the air pollution debate. They had a tendency to only focus on the aspects that they were directly involved with or that personally affected them the most. This was another kind of localising. Even though air pollution rarely has borders, the issues brought up were mostly of local nature. Which road had too much traffic, or what construction site added more pollution to the local school. Air pollution is a complex matter and the causes and effects are as well. However, it was mentioned in the debriefing of the first day, that localising solutions in relation to interests in the debate is also a way of engaging more people effectively.

From the initial meet-and-greet on day one, the sprint evolved into three projects. One was called *Mobilising Our Air*, a platform for activist groups that would be able to tag themselves and other groups in relation to interests and also geolocation. The purpose of the platform was then to support activist groups to connect and also to share knowledge about air pollution on the platform. Another project called *The Hot Potato Machine*, was interested in how politicians, activists, and businesses would blame or point fingers at each other instead of taking action on air pollution. They would “pass on the hot potato” so to say. The project dealt a lot with how to visualise this finger pointing in a way that could provoke action or change. The last project was called *myAir*, the project we ended up participating in. During the SaveOurAir project, myAir was changed several times and ended up as a prototype of a teaching kit, with the goal of making pupils aware of their personal air pollution exposure.

Localising data through geolocation

During the data sprint in London, the myAir group were confronted multiple times with the problem of localising data in relation to geolocation. It was discussed on whether a platform could be developed that would do just so. The app Google Maps has a function called Google Timeline that when enabled allows the user to see historical data about the whereabout of their smartphone. The idea of the myAir teaching kit started from an idea to utilise this function and combine it with air pollution data. The discussion surrounded how this could be used to localise data about air pollution. The activists, that had been invited on the first day of the sprint, had aimed several of their initiatives at school pupils. They saw a big potential in educating young people about air pollutions as they were more perceptible to change. This made them good advocates to get their parents to change behaviour as well. This outlook was included in the initial idea, and it was decided to design the prototype for school pupils as the intended users.

During the week in London there were many great discussions and debates about the politics involved with measuring levels of air pollution. Information about air pollution are not free from this influence. One question is who collected data about air pollution. Local authorities were accused by the activist to only put up immobile sensors to measure overall air pollution. According to the activists, air pollution monitors do not show temporary pollution hot spot, like construction sites. They were also rarely located near areas that they were concerned about, like schools.

Another issue was how air pollution is measured and what is measured. Air pollution is a general term for a multitude of pollutants and the pollutants that the local authorities choose to measure will also be the ones that they will try to reduce. The technology used to measure and analyse the levels of pollutants would also have a political effect. The local authorities in Camden, London would for instance use test tubes, located in various streets, to measure levels of air pollution on a street level. But this type of measuring only collects data accumulated over a time period of a month and do thereby not show the effects of rush hour in relation to normal traffic on the street. This type of data would not be granular enough to conclude what time of the day is the most toxic and what causes it, it was said.

As a citizen in both London and Copenhagen, where the project had its point of origin, it is possible to find data online about the amounts of air pollution on a particular street. This is called *"Luften på din vej"* (Strangholt, 2016) (Lpdv.spatialsuite.dk, 2016), Figure 1, and LondonAir in London (King's College London, 2012), Figure 2. Although the two maps look similar, there are two major differences between them. The DCE map (Figure 1) shows the average amount of pollution at a specific location based on data from 2012. This data is very static, meaning it does not change over time. Contrary, the LondonAir map (Figure 2) gives different experiences to the user and fundamentally changes their perspectives on local air pollution from the DCE map. The way the two maps are modelled is also key in this.

On the DCE map, it is possible to see how much air pollution each cadastral in Denmark is exposed to on a yearly average.

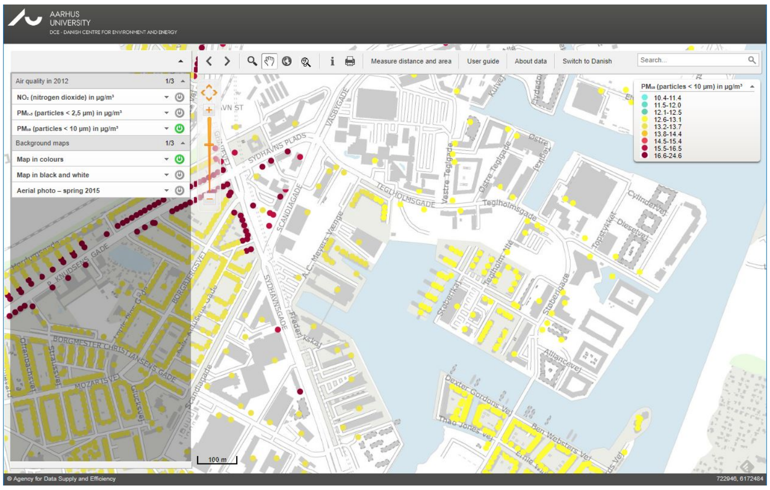

Figure 1 - Screenshot of the DCE "Luften på din vej" air pollution map, focused around the AAU Campus in Copenhagen. The dots indicate a cadastral and the colour indicates daily air pollution levels, based on yearly average. (Lpdv.spatialsuite.dk, 2016)

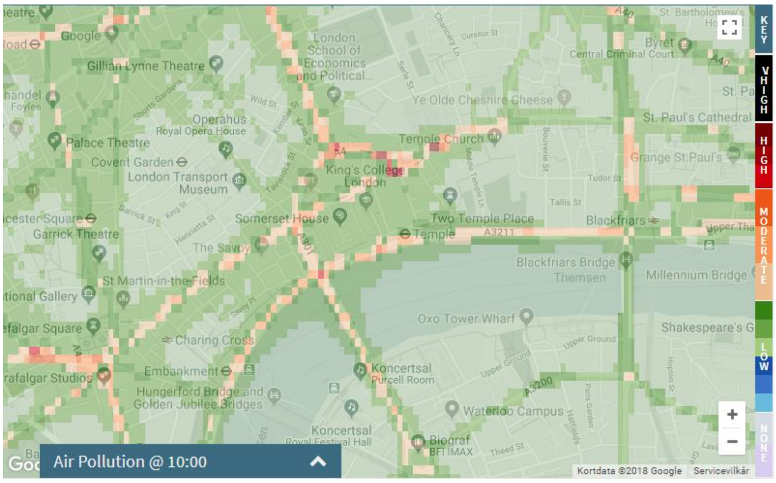

Figure 2 - Screenshot of the LondonAir air pollution map around the King's College London, Strand campus, where the data sprint took place. The data is from 24th of May 2018 at 10.00 am. The data is "combined", meaning a combination of four major pollutants held against the UK Air Quality Index. The colours indicate air pollution levels, red being high. (King's College London, 2012)

The information is done by modelling data from 12 stations placed around Denmark (Strangholt, 2016). The measurements are shown in µg/m^3, which is the standard way of measuring air pollutants and gives a straight comparison to the EU limitations as stated in the *directive 2008/50/EF on Ambient Air Quality and Cleaner Air for Europe*, although the colours are not based on the EU limitation values and do seem to be somewhat arbitrary.

The LondonAir map (Figure 2) visualises approximate hourly data with a slight delay. This gives a much more dynamic visualisation of the current air pollution situation. However, this map is not as close to a real time visualisation as might be thought. The data is mostly modelled, based on nearby monitor stations, which gives a highly differentiated precision depending on how many monitors are near the area of interest.

Coincidently, the air pollution visualisation in Figure 2 is based on three roadside monitors and one background urban monitor around the King's College Strand Campus (King's College, 2012). It is also based on four different pollutants, each measured in either quarterly-hour mean, hourly mean, 8-hourly mean, or 24-hourly mean intervals. These are each converted to an index number and then combined. The index categorisation of the values is a mixture of WHO levels, EU levels and UK Air Quality Strategy levels (Baker, Grieve and Hepburn, 2012).

Since the data behind these air pollution maps are based on modelled data they do not show how much you are exposed to on an individual level. The visualisations produced from the data provide a static picture of a dynamic world. In real life people move around and they do so at a specific time on a specific day, which makes data from the Danish maps, based on yearly averages, hard to utilise to answer such questions. The same goes for the UK map. Since many of the measuring stations do not collect real time data, they do not show the actual pollutants in certain areas, but instead give a modelled visualisation.

It was thought in the myAir group that it would be appealing to be able to gather data that is more local, more personal, and more contextual. If pupils would be able to know exactly how much pollution they were exposed to during a normal commute to school, during football practice, or visiting a friend, it would maybe spark a reflection and a change in behaviour (Madsen et al., 2018b).

The myAir prototype

The prototype was mostly inspired by interviews with local activists, knowledge from the sprint participants, and a prototyping process that we will go into later in the report. During the sprints in London and Copenhagen, the idea was iterated, and the prototype changed from an app to a teaching kit. The teaching kit was to make it possible for pupils to learn about air pollution through their own data that they gathered during a learning situation. There was a sense among the sprint participants that to facilitate a proper change of behaviour, the device would have to be accompanied by a series of information, experiences, and insights. It was discussed that a pragmatic approach, akin to the works of John Dewey[2], would be beneficial to achieve this output.

The prototype was thus extended to contain a five-day teaching programme, a teacher's guide on how to implement the programme and what outcomes to expect, and a monitor for the pupils to measure levels of air pollution. During the period of the teaching programme, the pupils were to collect data both during school hours and in their spare time. The pupils were to bring the sensor wherever they went during the programme. The pupils would also be asked to turn on the feature on Google Maps called Google Timeline that allowed them to track where they were and export this onto a web platform which was developed during the Copenhagen sprint.

Figure 3 - Top picture is the myAir devcie. Bottom right is the visualised air pollution graph. Bottom left is the visualised geolocation over time. Colours are indication of air pollution levels - red is higher levels (Madsen et al., 2018c).

The web platform would parse[3] and merge the data from the sensor and the data from Google Timeline and then give a visual output as a graph showing your exposure to air pollutants and a map showing where you had been at the time of exposure (See Figure 3). By clicking on the website, it was possible to interact with both the map and the graph, so you could focus on a specific time or place and see how much pollution you were exposed to. The web platform was also able to tell how much you had been exposed to according to the data from "Luften på din vej". The idea behind this was to make it possible for

[2] The relevant works of John Dewey will be explained in the chapter 'Deweyan pragmatism'
[3] Parsing is a process of transforming data from one structure to another. This is often needed what extracting data from one type of platform and adding it to another type.

the pupils to ask questions on how data is collected and how modelled data works, maybe even challenge how it works.

The sensors we used in the prototype to measure levels of air pollution is made by the Danish company Airlabs (Airlabs.com, 2018).

During this project, we visited their labs in Copenhagen three times. Here, we interviewed Johan Schmidt, Head of Sensors at Airlabs, who gave us a thorough introduction to the inner workings of the device. The device is a 3D printed shell with two sensors inside. One sensor sucks in air and measures particles with a laser and refraction sensor. This allows it to detect the size and quantity of particles coming through it. The other sensor is a tiny lab-on-a-chip that measures temperature, relative humidity (RH), and pressure (hPa). The sensors were set to measure and save data every ten seconds, which gives a highly detailed timeline of data.

The teaching kit prototype would make it possible for pupils to record and visualise their exposure to air pollution and the time and places they were more or less exposed. As the sensors were able to output data every ten seconds, the pupils would be able to see a difference from one street to another on their way to school, or even from the doors opening on a bus.

Theory

In the following chapter, we will explain our chosen theories and how we will use them in the report.

POSTPHENOMENOLOGY

During our design and sprinting phases, we gave a lot of thought on how to position us epistemologically, to best interpret and present the observations we gathered. Not only did we look at what theories might best be used to describe our experiences, but also what theoretical framing the participants in sprints seemed to be using in their explanations and perceptions. While actor-network theory is excellent at describing the relations between actors, both human and non-human, we were more interested in how our prototype could be used to mediate new understandings and experiences through technology.

How to engage the user through the experience of data was often discussed during the sprint, the development, and the designing of the myAir teaching kit. An "ethical design"[4] process, what we describe as the inherent morality that is added to the prototype through design choices, was in the forefront of the debates when talking about how to represent data visually. It became clear to us that the talks were not unlike the postphenomenological understanding, where mediations happen between the user and the technology. We found that using such a theoretical framing for our field work would better help guide testing of the prototype later on and not only be a good way to situate us in the field, but also to describe it in this report.

In the following chapter, we will present our interpretation of postphenomenology and how we will use it throughout the report.

What is postphenomenology?

In its core, postphenomenology is part of the field of phenomenology which has been present within philosophy in many different forms. Phenomenology can be defined as the study of the perceived experience from a person's point-of-view:

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[4] The design of the prototype was not directly talked about as an ethical design during the sprint, however the conversations about the user experience and understandings were comparable to the "ethical design" reflections, as further down.

> *"... [it is the] appearances of things, or things as they appear in our experience, or the ways we experience things, thus the meanings things have in our experience." (Smith, 2013)*

It is the study of the structure of experience when that experience is intentional or directed towards something specific, a phenomenon. Phenomenology is not only the sensory experience about an object, but also the person's understanding behind and meaning towards a phenomenon. Thus, it also encompasses the ontological, epistemological, logical, and ethical placement of an experience in relation to the phenomena (Smith, 2003).

Phenomenology as a specific movement within philosophy was mainly established in the first half of the 20th century. (Smith, 2003). There are many different aspects and interpretations of phenomenology, which will not be elaborated further in this report, instead focusing on the specific aspect we have chosen to use as our framing, namely postphenomenology. Around the 1960's to 1970's, the idea of technologies influencing our experience of the world became more prominent within philosophy of science and science and technology studies (STS) (Introna, 2017). It was during this time that the school of postphenomenology started to appear (Ihde, 2003). The main addition to phenomenology was the inclusion of how an experience can being *mediated* between human and non-human interactions, inspired by such as Latour's and Haraway's early work within social constructionism (ibid).

Don Ihde explains mediation by the example of scientific instrumentations. Since scientific instruments are highly specialised in science they dictate scientific endeavour as much as science dictates the forming of the instruments. As such, science has *embodied* technology and instruments into its understandings and meanings. They are not only a tool in science, but an integral part of it, to the degree where you cannot have one without the other (Ihde, 2003; 2010).

Through the interactions and mediation, instruments have a large role on how scientists understand and experience their field and their *reality*. The same undergoes human interactions with technological artefacts. Through the usage of a technology humans are able to extend their experience of a phenomena. You cannot separate the technology from the experience as it is the relation between the human and the non-human artefact that together create the experience. The technology is embodied in the experience through an *inter-relation* (Ihde, 2010: 111). In here lies an important point about the hermeneutic skill involved in experiencing a phenomenon, and how this is not inherently present in people, but achieved by learning.

Don Ihde calls the exchange between Galilei and his telescope for a *magnificational mediation*. Examples of this also includes spectacles and hearing aids as they also extend our bodily capabilities. When this extension goes beyond our bodily capabilities, Ihde defines this as a *translational mediation* (ibid: 115). As our scientific instruments have become more advance, we have increasingly moved our understanding about the universe from the bodily spectrum into the infra- and ultra-spectrum, as in what is beyond what our body can sense even with aid. The instruments no longer only magnify our experience of reality, they now translate it. This is especially relevant for our usage of postphenomenology as we are dealing with devices that are translating the world of particles beyond what we can sense with our body.

These types of instruments are designed to either translate the data into relative equivalences of our own senses, e.g. 'fake colour' images of infrared radiation from the sun, or to create representation of the data that we can then interpret, e.g. graphs and numbers.

An interesting point made by Ihde is that when this relation between reality and humans change, e.g. when new experiences are mediated through new technologies, it is not only the relation that have changed but also us as well (ibid: 116-117). To bring back the example of Galilei and his telescope, what he saw changed his understanding of the world. As such, when we extend our bodily capabilities through technologies and artefacts it is not only an entry into a heretofore unknown part of the world it is also an expansion of our understanding and experience of reality:

> *"[...] there is an implied inter-constitution as the dynamics of the ontology. Put simply, inter-relationality implies that human >< world changes are such that for every change in a 'world' there is a correspondent change in the 'human.'" (Ihde, 2010: 116)*

This is relevant in our case, i.e. when designing and implementing a technological artefact in a specific context, because we want to intentionally create a change in the person's worldview about air pollution. As framed by Galilei above, when teaching how to use his telescope, the skill involved in experiencing a phenomenon has sometimes to be taught before this change can happen. Likewise, it is expected that any new prototype, designed to facilitate a specific type of translational mediation, often needs an introduction or explanation for the change to happen.

The question then comes forth, to what extent does technological artefacts influence the behaviour of people. When artefacts can dictate actions are they then agents of morality or could we even go as far as stating they have agency in the outcome of the action. And if so, how does human choice factor into this. Peter-Paul Verbeek takes up this debate in his text *The Morality of Things* (2006), comparing the approach of general symmetry by Latour, where human and non-human agency should be described as equal, to the mediating explanation of Ihde, where the inter-relations can change understandings and therefore actions. Verbeek clearly states that:

> *"[...] it would be a mistake to describe the influence of things on human actions in terms of morality. Steering behavior, as well as showing steered behavior, is something entirely different than making moral decisions."*
> *(Verbeek, 2006: 119)*

In this way, he distances himself from the symmetrical approach. However, he does not write off technological artefacts as moral influencers. Since artefacts do mediate the world to people they therefore also influence the actions people take, the difference from the symmetrical approach being that this influence is not intentional by the artefact and thus it is not a moral actor. Artefacts are still part of the "moral community", according to Verbeek, as they provide *material answers* to moral questions (ibid: 119). Verbeek brings up the case of Robert Moses 'racist bridges' to explain this. Robert Moses was the main architect in New York City from the 1920's to the 1960's and had great autonomy and influence on the public spaces built around that time (Campanella, 2017). One of his more infamous constructions was the Southern State Parkway, an expressway from the city to Long Island and its many new public beaches built for the enjoyment of the city dwellers. It was told that Moses intentionally made the overpass bridges extra low so that public transportations, such as buses, could not pass underneath. This, it is said, was in order to keep the poorer part of the public away from the beaches, back then being mainly African-American and people of Puerto Rican descent (ibid). But does a racist design make the bridge inherently racist? Yes, says Verbeek:

> *"The fact that these bridges cannot be held responsible for the racist practice they install, does not imply that their role in this practice cannot be judged in moral terms" (Verbeek, 2006: 121)*

It is thereby implied that artefacts, the bridges, gives material answers, buses cannot drive under them, to moral questions, should poor people be allowed on the newly build beaches. This reading, of artefacts' influence on human actions, is closely tied to the changes in experiencing reality created in the inter-relations between the two. As objects are embodied in this experience so are the moral practices installed in them.

This brings a new important point onto Ihde's translational mediation by artefacts. As artefacts not only extends our bodily capabilities but also translates reality into perceivable phenomena we would argue that they encompass a higher degree of influence on the actions taken. It is no longer just what they mediate to the user, but also how. There is a higher level of interpretation designed into the translation that rarely is chosen by the user of the artefact. As such, technologies help shape moral questions and suggest how to answer them (Verbeek, 2006: 124), which brings us onto the questions on whether there should be an ethical design practice when designing technological artefacts, what Verbeek coins as "the ethical turn" (Verbeek, 2006: 121-122) (Selinger, 2011), a call to move forward from the *empirical turn*, which in itself is a move away from the deterministic interpretation of technological development, from philosophy of technology in the first half of the 20th century, into a more pragmatic and descriptive stance towards technology in the 1980s and 1990s (Brey, 2010: 40).

The ethical turns should be understood as a call to philosophers of technology to also look at the inherent ethical values when interpreting technologies, and not only when the technologies are used but also when they are being designed. If things are already part of the moral community is it then not the responsibility of the architect and designer to actively insert certain ethical values into their design, or at least to be aware of what moral practice their design might ensue?

Verbeek debates a series of major critiques to this notion in his *A Postphenomenological Inquiry* (2006); the autonomy of human morality, freedom of choice, and democracy vs technocracy. We find it relevant to include these points here as they become relevant in our later analysis and discussion. It also goes to explain some of the more pragmatic aspects of postphenomenological thinking.

The question of human autonomy over morality is a challenge to the idea that artefacts have an equal role in morality. In classical philosophy the moral question has been solely attributed to humans. Both Ihde and Verbeek, however, state that things are part of the moral equation as they cannot be separated from the action and thus the ethical choices done by humans.

> *"When actions of human beings are not only determined by their own intentions but also by the material environment in which they live, the central place of the autonomous subject in ethical theory needs to put into perspective." (Verbeek, 2006: 121)*

Humans have never been truly autonomous in their actions since their experience will always be embodied and mediated by technological artefacts. This even more so when the mediation is translational. An argument can be made that moving morality onto objects removes the freedom of people to choose their own line of actions (Verbeek, 2006: 125). We equate this argument to arguing against limiting cars to a maximum speed or installing alcohol sensors in them. Verbeek states that designing limitations into artefacts, for example installing speed bumps on roads where children are playing, are no different than the already agreement to have a law about a certain speed limit on said roads and thus is no more limiting in the freedom of choice (ibid). The ethical turn, of designing technology with morality in mind, does not have to threaten freedom because a mediation from artefacts does not have to be compulsory. Instead, there can be designed a suggestion or nudging into the artefact to do things a certain way (ibid). In *What Things Do* (Verbeek, 2005: Chap. 1) there is the example of a design company, Eternally Yours, that wishes to create longer lasting furniture. For them, this is a moral question of reducing waste of resources. They decide to implement a design that creates more value for the owner of the furniture by making it more attractive with age. By using materials that looks better over time or include hidden patterns in the fabric that are only revealed when the fabric has been worn down to a certain degree, they suggest to the user that wear and usage increases value instead of decreasing. Unlike the Moses' racists bridges, where the design restrains freedom, this type of design enhances your experience of the artefact and still maintains the same level of freedom.

As a third argument, Verbeek says that since there is always a mediation between artefact and human, is there really a true or absolute freedom to uphold?

> *"Human actions always take place in a stubborn reality, and therefore the ambition to reach a state of absolute freedom would require that we ignore reality, giving up the possibility to act at all." (Verbeek, 2006: 126)*

We are already restrained by the limits of reality and by acknowledging this it is possible to design and create opportunities for new or different types of freedoms, meaning that an ethical turn in creating technological artefacts can foster mediations in certain ways that extends our experience of reality and thus the possibilities in our actions. However, if we go along with the idea that technological artefacts might not take away our freedom, any more than the restraints of law or nature already does, then is it not manipulative to install certain moral choices into the artefacts? This is especially relevant in the aftermath of the 2016 US election or the Cambridge Analytica scandal, where private data taken from Facebook is said to have been used to manipulate the opinions of millions of people. This was done in accordance to Facebook's API design, although maybe not in accordance to Facebook's intended design of it. Facebook has since closed down it's API to a degree that social and technological research through the platform is almost impossible.

The challenge to the ethical turn is thus, if technological artefacts are being designed with moral purpose, then is our actions being willingly or unwillingly steered?

> *"(...), this would threaten the democratic quality of society, the critics hold. After all, not human beings but material things would be in charge then."*
> *(Verbeek, 2006: 126)*

A world, where technologies and the people designing them, dictates how moral questions should be answered through material things, would be nothing more than a technocracy, so the arguments go (ibid).

However, it is not the design with morality but the lack of design with morality that would lead to a totalitarian threat to a free and democratic society (ibid: 127). Just like reality is always restraining our freedom, technological artefacts are always steering our actions, willingly or unwillingly, intentionally or unintentionally. To prevent this influence from degrading democracy society needs to be aware and participate in deliberation of what and how moral questions are being handled by technology.

The Postphenomenological call

Whether it is called scripting artefacts or ethical design, the idea, that artefacts steer the user through mediations and translations and not only changes the user but also the reality that is experienced, is why we find this theoretical framework so suitable in our study of prototyping and testing.

> *"[The] postphenomenological perspective offers a suitable framework for analyzing the mediating role of things - and especially of technological artifacts - since the process of mediation should be localized precisely in this relation between human and reality" (Verbeek, 2006: 122)*

However, we see postphenomenology not only as theoretical framework, to describe how technological artefacts are embodied in our experiences. It is as much a call for an awareness that morality in artefacts are unavoidable and therefore should be incorporated into the design process. There is a certain amount of responsibility when prototyping and designing technological artefacts. It is not only enough to design a certain usage of the artefact, there is also a need to be aware of the ethics behind both intentional and unintentional usage. As an artefacts' mediation is not only limited to its intended use, but more so to its specific context of use, the burden of responsibility on how an artefact mediates reality also lies with the designer of said artefact. By this thinking, a person cannot be completely held responsible for how they are using an artefact. Some of that responsibility would also fall on the design(er). This is clearly a break from most classic ethical philosophy, where morality decisions are typically put on human's shoulders. How else can they be held accountable for their actions? (Verbeek, 2006: 121).

Because we are both investigating a design process and part of said process, we not only use the postphenomenological framework to understand the inter-relations between artefact and user, we also adopt the consequences of said understanding; that there is a moral responsibility on us and the other participants in the design process. As such, phenomenology is no longer just a framework, it is also a method of designing.

This makes our active usage of postphenomenology a bit complicated, as it is suddenly two-folded. On one side we use it to construct a narrative on our observations and field work. On the other side we use it actively in our participatory role within our field work. This has demanded an extra vigilance in our methodology in engaging with the field.

DEWEYAN PRAGMATISM

John Dewey was an author who was very productive during his career. We have especially found his writings around learning and education relevant for this thesis. The goal for this chapter is therefore two-fold: firstly, to provide the reader with an overview of the Deweyan terminology that is important for this thesis and secondly, to give an overview of the literate landscape that this thesis will fit within. The aim for this chapter is also to access and unfold Dewey's terminology to create a common terminological platform for both reader and author. As a disclaimer we would like to emphasise that we have focused on How We Think (1910), and then supplemented with some of his other work. We have focussed on thoroughly understanding How We Think (1910), and we will use that as general reference throughout this thesis, while Democracy and Education (1916) together with Experience and Education (1938) is used to understand some of his terms more explicitly, and thereby used in a more referral and fragmental way. We will argue that How We Think functions as a prologue for his later works, where he present terms and arguments that he elaborates further in his later career.

Most of John Dewey's life was about improving and innovating the already existing educational system, which he believed to be a cornerstone in society, as understood by the quotation bellow.

> *"Education is not preparation for life: Education is life itself." (Dewey, 1916, p. 239)*

His work has left him to be one of the most influential educational thinkers of the 20th century. John Dewey was an American philosopher and educational theorist that through his work from the early 20th century have shaped a whole century of educational thinking. Dewey's published work spanned many topics, but one of his main focal points throughout his career was on how to improve education. Dewey was a student of the American philosopher and scholar Charles Sander Peirce (1839 - 1914) who is the founder of modern pragmatism (Bengt-Pedersen, 2018). Through his career Dewey published 29 book and five articles. Dewey brought the pragmatic way of thinking into his own work and further into the American educational institutions, where he challenged the classical way of teaching by encouraging to let students and school children try out hypotheses for themselves. His thoughts and theories have paved the way of teaching in societies all around the world and he has been acknowledged as one of the far most influential educational theorists of the 20th century (Bengt-Pedersen, 2018).

Dewey believed that learning evolves best through problem-based situations and by encouraging students to interact with both classmates and their surroundings, during class, would make them learn faster and more comprehensively*;*

> *'To "learn from experience" is to make a backward and forward connection between what we do to things and what we enjoy or suffer from things in consequence' (Dewey, 1916; 140).*

From this maxim he unfolds the connection between experience and education and puts it in relation to the rest of society.

Democracy, Experience and Education

The three main works that we find interesting for this thesis are *How We Think (1910), Democracy and Education (1916),* and *Experience and Education (1938)*. All three of them elaborate on how to evolve and structure learning better, and how the involvement of a student can improve the outcome of both education and student. Furthermore, they all describe Dewey's notion of *experience*, not to be confused with the experience of postphenomenology. Later we will create a common ground for the two interpretations of the term, but for now we only refer to the Deweyan term when mentioning experience.

How We Think (1910)

John Dewey's book, *How We Think*, is divided into sixteen chapters where he describes, in different layers, how the action of thought can be motivated to think more pragmatic. In the second chapter of *How We Think* he explains the difference between man and animal for which he challenges the notion:

> *"The traditional definition of man as 'the thinking animal' fixes thought as the essential difference between man and the brutes, -surely an important matter. More relevant to our purpose is the question of how thought is important (...)." (Dewey, 1910: 11)*

In the rest of the book he exemplifies how thoughts are built, how they are used, and how we reflect on them. For this, Dewey introduces the term *reflective thought* which is a key term for this thesis. He walks the reader through 'inductive' and 'deductive' thinking, 'abstract' and 'concrete' resonance, together with an ongoing thematic on how the training of thought can develop and evolve the way we, as humans, perceive and understand things. Dewey describes his notion of induction and deduction with the following:

> *"The inductive movement is toward discovery of a binding principle; the deductive toward its testing confirming, refuting, modifying it on the basis of its capacity to interpret isolated details into a unified experience." (Dewey, 1910: 41)*

The Deweyan school derives from the believe that the human mind evolves through education and that experiences within a learning situation have a huge impact on one's outcome. Dewey also makes it explicit that every man is born equal and can only be as good as the society he lives in. For that Dewey have been compared to John Rawls [1921 - 2002] (Weber, 2008). Here Rawls describes how it is only possible to build the perfect society if every citizen is equalised to a common state of mind (Rawls, 1971). Dewey and Rawls both advocate that democracy and education is the ground pillars of enlightenment that shapes our society (Weber, 2008). In *How We Think* (1910) Dewey unfolds how a setting defines the output of a learning situation, meaning that the way we learn, but also *where* we learn, has an influence on the outcome. Dewey have been credited for introducing the term *learning by doing* and *learning by inquiry* which ties back to his school of pragmatism. He advocates for a more naturalistic point of view where knowledge is perceived as something that evolves through an active interrelatedness between a person and their environment (Weber, 2008).

Democracy and Education (1916)

Six years after *How We Think* Dewey published the book *Democracy and Education'*, which is considered his most important work. It has been used by politicians and philosophers for more than a century (Weber, 2008). In "Democracy and Education" Dewey writes about how democracies, in every sense of the word, are entangled with education. How norms and knowledge are borne from generation to generation and from person to person. He underlines that:

> *"Even in barbarian and savage communities such direct participation (constituting the indirect or incidental education of which we have spoken) furnishes almost the sole influence for rearing the young into the practices and the beliefs of the group." (Dewey, 1916: 24)*

In this paragraph he refers to how young members of a tribe, or the likes, get handed the specific ways and norms of the community through education. This knowledge may get transferred by ceremonies or rituals, but it is mostly delivered by experience and interaction between the young novice and the elder members. The circumstances also have an impact on the education and he explicitly say that in a school setting the school itself has an impact on the education:

> *"(...) learning is the accompaniment of continuous activities or occupations which have a social aim and utilize the materials of typical social situations. For under such conditions, the school itself becomes a form of social life, a miniature community and one in close interaction with the other modes of associated experience beyond school walls. All education which develops power to share effectively in social life is moral." (Dewey, 2016: 418)*

In the quote above Dewey describe the idea of the school as more than just a place where people gain knowledge but as a community where the students' wellbeing is a mean to maintain a social life and social education. This notion made 'Democracy and Education' into one of the most famous works of Dewey.

Experience and Education (1938)

In his work *"Experience and Education"* (1938) he introduces the reader to his thoughts of how to improve learning through engagement and interaction between students. To do this he introduces the term *experience*, where he differentiates between direct and indirect experiences. *Direct experiences* are the everyday experience through which a human undergoes a first-hand personal understanding of a given situation. *Indirect experiences* are according to Dewey the most common one. Basically, all knowledge that we gain from our education is indirect learning because it is being mediated. He describes it as our perception and intervention of a representative medium:

> *Much of our experience is indirect; (...) It is one thing to have been engaged in war, to have shared its dangers and hardships; it is another thing to hear or read about it. All language, all symbols, are implements of an indirect experience; (...) It stands in contrast with an immediate, direct experience, something in which we take part vitally and at first hand, instead of through the intervention of representative media." (Dewey, 1916: 271)*

Dewey states that all experiences arise from two principles: *continuity* and *interaction*. *Continuity* refers to that every experience a person has will influence her future for better or for worse. This means that every experience will influence the next, not necessary positively, but simply just change the quality of the subsequent experience (Na and Song, 2013). With *interaction,* he points out that there will always be a situational influence on what we experience, which means that the context of a certain behaviour or action will always influence the experiential output. In other words, a certain experience, e.g. a lesson within a certain topic, will depend on how the educator facilitates the lesson and past experiences within similar topics or lessons of the crowd will influence the individuals' outcome.

Dewey's relation to data

In his book "How we think", Dewey offers an interesting take on the notion of data and how to use it in a teaching situation. Dewey states that thinking derives from confusion, perplexity, or from being in doubt, which is also reflected in his relation to empirical data and how to offer it to students (Dewey, 1910: 10). Dewey found it useful to use incomplete or skewed empirical data in learning situations, as these encourage further reflective thinking. By only revealing partial data about a phenomenon, the student is forced to be reflective and to seek new additional information to a given problem.

Dewey states that reflection happens between what he called *The Double Movement of Reflection.* This dualistic property of his term lies in the movement between inductive and deductive method.

> *"A movement from the given partial and confused data to a suggested comprehensive (or inclusive) entire situation; and back from this suggested whole - which is suggested is a meaning, an idea - to the particular facts, so as to connect these with one another and with additional facts to which the suggestion has directed attention" (ibid: 40-41).*

To be reflective in this sense is to be able to seek a conclusion from incomplete or confusing data (induction), but at the same time keeping a cautious deductive approach, acknowledging that the object of study might be more complex than at first glance, and that more observations and experiments are needed. This shift between being inductive and deductive, is what Dewey believed to be the best way of learning, and why incomplete or confusing empirical data should actually be preferred in a learning situation (ibid: 40-41). Altering empirical data by magnification of it, to make it more obscure or removing parts of it, can be an effective tool to add complexity and stimulate reflective thought (ibid: 43)

LITERATURE REVIEW

In Dewey's book *How We Think*, he mentions data as something we all possess, we all strive towards, and something that evolves over time (Dewey, 1910: 10). As we find Dewey's way of understanding empirical data in learning situations interesting for the scope of this thesis, we wanted to investigate how his notion and use of data could be interpreted in a modern context.

Purpose of the literature review

We want to unfold the modern literature that surrounds the area of John Dewey and more specifically his understanding of experience and data in learning situations. Learning methods and teaching is one of the cornerstones in our society. It is the mechanism that transfers knowledge between cultures, social groups, and from human to human in general. It is a field that has evolved for centuries and gone from minimum interaction between teacher and student to problem-based and collaborative learning methods with a comprehensive amount of interaction, to the digital era where more or less every aspect of some educational programs takes place online (Fogarty, Strimling and Laland, 2011). We wanted to investigate how Dewey's thinking is used in contemporary times within the production of data and the use of data for learning purposes in general. We wonder if his data-term is still usable or needs to be translated to suit the way data is understood today. We will therefore investigate whether the work of John Dewey is still relevant now that we have moved into a more digital era where data is easier to collect, store, and access. Are the methods for learning still the same? Are John Dewey's thinking and publications used today, and if so, how?

Search query and methodology for choosing articles

To answer these questions, we have searched the database ERIC, short for *Education Resources Information Center*. ERIC is a search database with a narrow focus on learning material and educational purposes. It is part of the U.S Department of Education, and collects journals, books and works in educational science from around the world, and is the world's most used index for educational related literature (Proquest.libguides.com, 2018).

Based on a thorough discussion of what terms to include in the search query, we decided to focus on the parts of Dewey's own terminology, that were of special interest for the scope of the literature review. We ended on searching for the terms 'Dewey', 'data', and 'learning', with the Boolean operator "AND" between them, thus ensuring that the results returned would include all of three terms in each article.

The search query: "*Dewey AND Data AND Learning"*, returned 47 articles. As we wanted to study modern interpretations of Dewey's terminology, we filtered the query only to include articles newer than 10 years of age. We also narrowed our search down to peer-reviewed articles only, which returned 33 articles.

We then proceeded to read the headings of the articles to look for duplicates and articles that were obviously not of interest. We discarded 3 articles, thus leaving 30, only to read the abstracts of the remaining 30 articles and discard nine more articles. 21 articles were read in their entirety, 14 of which did not use Dewey's terminology as we sought for or did not study a relevant subject and were hence discarded. As an example, many articles focused on the teachers' experiences rather than the students', which was our point of interest. This ultimately left us with eight articles that we included in the literature review, as visualised in Table 2 bellow. An overview of both the articles that were included and discarded with their respective authors, are to be found in appendix IV.

Table 2 Table of article selection

	Action	Number of articles
First search	Dewey AND Data AND Learning	47
1. iteration	Less than 10 years of age, and peer reviewed only	33
2. iteration	Reading headings	33
3. iteration	Reading abstracts	30
4. iteration	Reading full articles	21
5. iteration	Articles included in the review	8

Results

Looking into the eight articles, different themes emerged that we will account for in the following sections.

Big data

In the search result two articles were found to include big data. When looking at the two big data-articles; "Big Data's Call to Philosophers of Education" (Blanken-Webb, 2017) and "New Data, Old Tensions: Big Data, Personalized Learning, and the Challenges of Progressive Education" (Dishon, 2017), they explain how big data can help to evolve and improve education. While big data is not part of this thesis, the articles still provide a good context for how data, as a general term, can be included in an educational setting. The two texts present a way for Dewey's 'learning by inquiry' and theory of 'experience' to be supported by using big data. In the text by Jane Blanken-Webb (2017), she states that:

> *"(...) big data opens doors for an unprecedented mode of analysis for understanding more about the form and rhythm of learning itself." (Blanken-Webb, 2017)*

Big data offers transcripts with a high amount of detail, which allow access to a kind of historical view upon the micro dynamics in a pupil's thinking (ibid). She states that, compared to traditional methods where the researcher made one observation of multiple people, it is now possible to make multiple observations about both multiple people as well as about a single individual. Capturing fine-grained data gives the possibility to see how a learner interacts with their environment together with how they acquire and improve their already existing skillset.

> *"By studying knowledge artifacts that learners create (…) such as a report on a science experiment (…) or a video story, traces of the knowledge production process become as important as the products themselves."*
> *(Blanken-Webb, 2017)*

This way of perceiving the use of data is not unlike the way John Dewey advocated for more than a hundred years ago. In *How We Think* (1910) Dewey talks about how data's most important usage is not as much the data itself, but more about how it can develop a curiosity for the learner (Dewey, 1910; 40). While there is a coherence between Dewey's notion and understanding of data and Blanken-Webb's (2017) encouragement towards the use of big data in a learning situation, they have two different focal points about its use. Dewey advocates for using data to evolve the student's abstraction levels, and thereby make them more suitable for doing research, while Blanken-Webb encourages to use big data to improve the learning programme itself for providing better education for the students.

The second text, by Gideon Dishon[5] (2017), unfolds the possibility of using big data as a way of personalising learning. Dishon argues that via big data it is possible to bring the student's social life from outside the school more into action when in class. In Dishon's text, he compares Dewey with the Austrian-French philosopher Jean-Jacques Rousseau (1712 - 1778), who also wrote about how education not only is dependent on the teacher but also on the context, which was very unusual in the 18th century (Wivel, 2018). In his article, Dishon argues that education has become too standardised and must change towards a more personalised one. He reasons that most industries are being inspired by companies like Amazon and Netflix, using data to personalise their product and thereby comprehend everyone's different consumption patterns. Yet in school environments, he claims that we see diffusing standardisation. Here, children would learn more effectively if they were not obstructed by cumbersome social structures and rather

[5] Post-Doc graduate student from University of Tel Aviv.

offered more personalised learning material matching their personal way of learning. For this he gives an example with a biology student:

> *"Imagine a biology student actively choosing a subject to learn (from a possible pool) according to her personal learning map and is then offered a variety of learning resources (lectures, texts, simulations), which are characterized according to the material they cover, and reviews of previous learners." (Dishon, 2017)*

This way of perceiving education is not at all farfetched. He highlights how Dewey perceives education as being too centred around the teacher, and how this constellation hinders the personal evolvement and lowers the children's learning curve. Dishon draws upon Dewey's notion of how social interaction is the main driver of meaningful learning.

Dishon concludes that big data can play an important role to reform the common ways of teaching (Dishon, 2017). Considering that our thesis is about getting the students out of the classroom and into their daily lives while doing science, there is somewhat a similarity between the two.

Mediational learning through virtual realities

One article found in the literature review offered an interesting case of how to facilitate field trips with pupils, as inspired by the works of Dewey. In Dewey's book *How we think,* he unfolds *place-based education*, which refers to education that takes place outside of the school buildings, commonly known today as a field trip (Dewey, 1910).

In Fitzsimons and Farren's article they argue how virtual reality can be a way of facilitating field trips by mediating a new reality to the students (Fitzsimons and Farren, 2016). Virtual reality is a computer-generated stimulus of the senses where the user is in the perception of being in a different place. By putting on the virtual reality goggles the user enters a virtual world, that can be used for entertainment or educational purposes (ibid: 10-11).

In the educational programme studied in the article, the students visited religious spaces that were not accessible to them under normal circumstances. The authors conclude that the ability to effortlessly shift location in an educational setting, through the use of a virtually constructed reality, has great learning outcomes. Furthermore, the programme made it possible for students to 'travel' without the constrains of religion, geography, and economy of the student, offering a more democratic learning of geographically dependant learnings and reflexive thinking (ibid: 11-12).

The authors call this technology a mediational one, that allows the student to percept their reality in a different way, then without the technology. They use a sci-fi inspired terminology stating the technology to offer 'teleportation' into a new world (ibid: 10). This study is a modern take on Dewey's experience term and how it can be used to describe contemporary educational programmes making use of modern technology and data points.

In this case the technology offers a way into new geographical territory, allowing the students to explore geographical locations. Our prototype differentiates itself by being grounded in the students already explored reality and providing data not else accessible to the them.

Bringing experiences into the classroom

Many of the texts we found for this literature review also make use of Dewey's experience theory. In one of the texts; *Why Everyday Experience? Interpreting Primary Students' Science Discourse from the Perspective of John Dewey* by Jiyeon Na and Jinwoong Song (2014), the authors argue that teachers have to bring the everyday experiences of the students into the science class. This may be both past, present, and future experiences.

> *"We believe that students' scientific discourse talking about their own experiences itself is the field of experience where active interactions among peers are taking place and where the continuity linking the present with the past is to be shown." (Na & Song, 2014: 1047).*

Their argument is that the students' experiences are highly interconnected both now and will be in the future because of social media (Na & Song, 2014).

In another study called *"I see what I see from the theory I have read"* by Nilssen and Solheim, the authors claim that there is, in many cases in the Norwegian educational system, a gap between theory and practice. This is an international problem spanning more than a century and a case of international discussion (Nilssen and Solheim, 2005: 405). They describe how teachers often neglect the transition from theory to practise and assume it happens automatically. They bring forward the notion made by Dewey to bring experiences into the classroom, by experimenting with the theory and doing field observations as an addition to traditional black board teaching (ibid: 406-408). They do this by acknowledging that knowledges are created and not transferred, as takes on a constructivist world view (ibid: 406). A part of this thesis also surrounds how to create engagement and awareness about scientific exploration and research in a 10th grade context. Some of the texts that emerged from this literature review surrounds how to engage students with scientific research as for example; *Empowering First Year (Post-Matric) Students in Basic Research Skills: A Strategy for Education for Social Justice* written by Constance Zulu (2011). She unfolds a research study on how "*under-resourced (historically disadvantaged) black high schools generally encounter difficulties in their academic work at university"* (Zulu, 2011) and how to prepare them better for university level. The author describes how the implementation of an academic skills module, with a Deweyan experienced-based approach, empowered them to work together with other students in group projects and had a positive effect on the students' basic research, writing, reading, and critical thinking skills (ibid).

Aesthetic Experiences

Alongside Dewey's work *Experience and Education* (1938) he also published *Experience and Nature* (1925) and *Art as Experience* (1934). Here, he talks about how *aesthetic experiences* in nature as well as art can evolve the way a human perceives and understands their experiences. Dewey implies that aesthetic experiences in nature are transformative. These types of experiences also include socially negotiated actions and the use of human senses, such as seeing and hearing. It therefore makes the anticipation aesthetic and constitutes an improved quality of learning (Skantz Åberg, 2017). While aesthetic experiences and its purpose is very useful, the way it is used in the texts that we found for this literature review is also well aligned with our research question. Assistant Professor Ewa Skantz Åberg of Göteborg University used the term in her article; *'Horrible or Happy--We'll Have a Little Grey Now": Aesthetic Judgements in Children's Narration with an Interactive Whiteboard'* (2017). The article presents the term *Aesthetic judgements*. This is done by pupils when negotiating the underlying subjective opinion, they have to an object. Skantz Åberg's article circles the topic of how to activate children through technology with the use of an interactive whiteboard as a mediating device. Aesthetic experience does, however, mostly show itself useful if it has to do with artistic or creative contexts where students must negotiate an aesthetic contribution of some kind, like a background colour or a nuance in a painting, where their personal preference may influence the decision (Skantz Åberg, 2017).

Conclusion to the literature review

Through this literature review, we have provided a general overview of what literature has been written relating to our topic of investigation. When going through the literature many different themes have emerged and many of them with similar focal point to what we are investigating, i.e. the relevance of John Dewey and how using experience as a learning objective can improve education. However, none of the texts we found covers the implementation of a technology, grounded in the students own lives, that mediates new understandings.

With this review, we have strived to shed a light upon the amount of research that involves Dewey's theories and a focus on improvement of education with the use of data and technological artefacts. We have been surprised by how little research has been done in the area, and it seems there is a knowledge gap that we might contribute to with this report.

Ethnographic Methods

In this section we will give an overview of which methods we have used to understand and situate us in our field.

PARTICIPATORY OBSERVATION

The art of observation is as intuitive as it is difficult. Only through experience and constant reflection is it possible to thoroughly ground observations from the field into useful conceptions and insights, however there are not one correct way to achieve this. The anthropological work starts way before you enter the field and does not end until you hand-in the finished text (Baarts, 2010: 31). When conducting our observations in the field, we took a double role as both participants and as researchers. As we adhere to a constructionistic epistemology, we describe the gathering of knowledge as a production between the observer and the observed. We do not try to find the 'truth' in the objective sense of the word, but instead look at the nuances and implicit information in the context of our chosen field (ibid: 37). As we are under the belief that you cannot avoid influencing your field, the question is how to influence it in a way that is fair towards the field of study. A way of doing this is through an autoethnographic method, to not only immerse yourself into the field, but to take part in it as you informants are. To walk in their shoes and feel what they feel.

Hammersley and Atkinson (1995) explains some of the drawbacks of complete observation and complete participation. While taking a role as *complete observer* it might be easier to have a detached subjectivity and sympathy and allow the research not to be too attached to the field (Hammersley and Atkinson, 1995: 104). A complete observer keeps their distance to the informants, interacts as little as possible, and try not to be noticed. A *complete participant* is on the contrary very interactive with the field, to the degree where they are almost an informant themselves. This method gives a deeper understanding of the reasoning behind actions and allows the observer to better immerse themselves in the field (ibid). The complete participant is almost undercover, where the informants often does not know the role of the researcher (ibid: 105). The way we situated us in the field was closer to the complete participant, however not quite. During the two sprints in London and Copenhagen, it was clear to the other participants during the sprints that while we were equal participants we were also researching the sprint itself. The same went for our field work at the 10th grade centre in Gentofte, where we both had the role of 'teacher' and 'researcher'. It was also made explicit to the pupils, and their teacher were always present during the field work.

Part of doing participatory observations like this, is to be aware of the influence you might have on the field (Hastrup, Rubow and Tjørnhøj-Thomsen, 2011: 31). This demands constant reflection not only on your own position in the field, but also to that of the informants. We chose to conduct near complete participatory observation because we found that the best way of understanding design processes and design sprints was a 'follow the actor' approach (Marcus, 1995: 96). This is when you follow your subject through several sites, and thus can see their interaction or transformation in different contexts. It's gives a better comparison of the roles an actor has in parallel, related local situations (ibid: 102). In our case the actor is the myAir prototype, which we would follow through multiple sites of development and testing. This allowed us to follow thoughts, ideas, and choice from concepts to actual functionalities and features and see how they would pan out *in situ* so to say. By not only observing, but also participating, in the several phases of design thinking[6], we had the opportunity to get first-hand knowledge into what it means to ideate and test prototypes, as well as first-hand knowledge of how the end-user would interact and utilise the prototype.

Through participatory observations a high degree of immersion in the field is possible (Hammersley and Atkinson, 1995), in our case allowing us to have more equal conversations with the other sprint participants at the sprints, because we were not seen outsiders, but part of the group (Hastrup, Rubow and Tjørnhøj-Thomsen, 2011: 63). However, there were also barriers, like when we had to interview or engage the 10th graders, to whom we had an authoritative role as 'substitute teacher' and were clearly also outsiders in their daily rhythm.

INTERVIEWS

When choosing your interview technique, it is important to consider what kind of information you want to get out the interviewee. Other variables also need to be taking into account, for example when and where you conduct the interview. This can have a huge impact on the results. For our interview methodology, we have followed the *InterView* by Kvale and Brinkmann (2009: chap. 7). According to the InterView, in both structured and semi-structured interviews you start out with an interview guide which provide the frame for the interview. However, for semi-structured interviews you have the possibility to go a bit "off-script" and can insert questions and follow-up comments as needed. This creates more a loose and informal setting and gives the

[6] See 0page 41, Design thinking.

interviewer an advantage when wanting to control the interview in a more natural way. The interview guide is then more a suggestion to topics than a script to follow point-by-point. If you go to much off-script, you risk the chance of the interview getting too messy and seem unprofessional to the interviewee (ibid).

Most of our interviews followed a third method, however, the unstructured interview. We opted for a more improvised and unplanned type of interview. This was an intentional choice used especially during the two sprints, to get out of the 'researcher' role. This gave more 'real' and off-the-cuff reports from the participants. The discussions could for example either be in the order of a brainstorm or a concrete development process. While these types of conversations are very natural in structure, it is still good practice to guide the conversations through thematic topics, like semi-structured interviews. These interviews are harder to document as they are often unplanned. To counter this, we would sometimes record long sessions of conversation. It is not easy to find the specific place in the conversation using this methodology, but it also allows you to discover things that you might have not noticed at the time. If we didn't have the option to record the sessions, we would, as soon as possible, make use of the anthropologist's best friend, the note book.

DOCUMENTATION

When in the field, it is often hard to remember what have been said, who have said it, and what context was it said in. Therefore, it is important to document events and insight as much as possible and in the moment. Though there are many possible digital ways of instantly record and document in the field today, often the simpler ways of documenting are just as good or better. Through the sprints and our testing in Gentofte, we have used a wide arrange of tools for documentations, both digital and analogue. Besides our faithful notebook, post-its, posters, and head-notes were used. Digital recording of audio, video, and photos was done on an audio recorder, Go-Pro camera and mobile phones. Each type of transcription devices has it strengths and weakness, why using diverse set of tools for documentations make for a richer and more in-depth portrayal of the field (Emerson, Fretz and Shaw, 1995: 28). To what degree we can say to have documented the field satisfactory is never easy to answer. As Clifford states:

> *"[...] within this institution, or disciplinary convention, one finds an enormous diversity of experience and opinion regarding what kind of or how much note-taking is appropriate, as well as just how these notes are related to published ethnographies." (Clifford, 1990: 52)*

While conducting research in Gentofte, we had to constantly interact with either the pupils during the lectures and workshops, or with the teacher Niels, getting feedback and insights. It was therefore not easy to make thorough fieldnotes for every situation. We did make use of d*ouble-entry field notes* when the pupils for example did exercises in their groups. Double-entry field notes is when you divide the notebook page into two columns where you on the left side make your direct notes about the culture you are observing and, on the right, describe the feelings and thoughts you, as a researcher, associate with the given situation (Kaplan-Weinger and Ullman, 2014). Furthermore, we took use of a digital recorder for every interview or conversation we had. During our testing of the prototype we also documented with photos. This was both to document the setting and to recall specific situations if we were supposed to refer to a specific one while writing the report. We have found that this is especially a good methodology combined with *head nodes* when not able to take notes (Emerson, Fretz and Shaw, 1995: 144-148). By photographic events and settings, it is easier to recall what happened when. This might seem like a trivial method; however, it is powerful when used in hectic and fast paced situation when notes and recordings are not easy or possible.

CULTURE ANALYSIS

When venturing into a new field, it is necessary to think of how to approach the trivial and mundane situations we might encounter, otherwise it would be easy to miss essential insights and experiences, especially when fully immersed as can happen when conducting participatory observations. Ehn and Löfgren (2006) emphasise the importance of being able to switch between different levels of abstraction, to be able to see the bigger picture. Ehn and Löfgren (2006), describes some different ways to interpret ethnographic material when analysing a culture, and while we have not used their methods to point, we have non the less taken inspiration from them.

According to Ehn and Löfgren, already when entering the field, one starts to interpret and analyse the actions and situations surrounding them. Therefore, it can be hard to abstract from the level of triviality in a situation and it can seem dull and uninteresting for the case you are investigating. Therefore, it is useful to dramatize the situation and by that being able to see the interesting in the uninteresting. They underline the importance of experimenting with the data and thereby let your mind wander, which can create a playfield where new thoughts and creative idea can emerge (Ehn & Löfgren, 2006).

Because we were not alone in designing the myAir prototype, but were also part of the SaveOurAir project, it was important to be aware of this double representation. We took use of the double culture analysis as presented by Tina Damsholt (2011). She emphasises the importance of not only understanding the end-user but also the more distant stakeholder together with those that will have the responsibility of implementing the end-product and ensure its success (Damsholt, 2011). This technique, of making the mundane interesting, has helped catch many of the smaller insights and observations that might else have been lost. When you are part of a process, it is always easy to get lost in the actions in front of you and forget to be aware or reflect on the bigger picture.

A technique that we used was to switch roles during the field work. Sometimes, one of us would step out of the conversations and discussions, and instead observe the interactions between the informants. We would also remind each other to note specific context, interactions, or understandings from the informants. This helped us move between the roles of participants and researcher. Because the layout of a data sprint often involves documentation of ideas and sketches, it was not disturbing to the dynamic in a situation if we suddenly started taking notes or taking pictures of a situation. Again, this was not the case during the testing of the prototype in Gentofte, where the pupils would be much more aware if we took pictures or quietly took notes in a corner.

ETHICAL CONSIDERATIONS

In this section we will unfold our ethical considerations in relation to our field work.

Documentation

During our studies in the field we have documented sessions with photographic material, video recordings, audio recordings, and by taking field notes. We have used these forms of documentation for analysis purpose and we also use the photographic material in the report to emphasise points or to narrate a better story for the reader.

All photos used in this report has been shared with, and approved by, the photographed individuals. In the case of the photos taken during our ethnographic fieldwork in the 10th grade centre in Gentofte, we have shared the photos with both the pupils and their parents, since most of them were not old enough to be legally accountable. None of the pupils nor their parents had any comments with our use of the photos.

Sharing geolocation

The pupils participating in the learning programme have been obliged to use Google Maps and share their geolocation with Google, which entails sharing information with Google. They have furthermore shared snippets of their location with us and their classmates during the programme. The programme was of course voluntary, and the pupils were never forced to share their data. We have actively tried to evoke the pupils to take a stance in relation to sharing their geolocation data. We did this by presenting how geolocation data is used by Google and other companies, to advance marketing and user profiling.

Anonymisation

We have chosen to anonymise all students in this report, by not using their names and not associating their comments with their real identity. This has been done likewise with informants from the data sprints, with one exception of Niels, the teacher from Gentofte. As he was our main informant during and after the testing in Gentofte, we decided to keep him as a recurring entity throughout the report. He has granted us permission to include his name and comments.

NARRATIVISTIC NARRATIVES

Our use of narratives has been inspired from the *thick descriptions* of Geertz (1973) to the *Narrative Configuration in Qualitive Analysis* utilised by Polkinghorne (1995), and the *Narratives in social science research* by Barbara Czarniawska (2004). When trying to explain learnings from in-situ experiences, narratives can be used as a methodology to transfer this knowledge to an unbeknownst reader (Polkinghorne, 1995).

In the thesis, we sharply divide our use of narratives when presenting background knowledge, theory, and our experiences in the field. We use differentiated narratives when writing about our experiences in the data sprints and the testing phase in Gentofte. We do this to reflect the difference between the two fields. While presenting our learnings and observations from the two data sprint, we have chosen to portray the choices and thoughts during the sprint as a collective 'we', to reflect our own deep involvement in the process. It does not make sense to separate our thoughts from the rest of group, because of the type of participatory observations we have conducted in that field. We feel that writing in this way gives a more accurate and fair portrayal of the field, that highlights our subjectivity. We then change the narrative to a much thicker descriptive one, when writing about our experiences in Gentofte, as this part of the design phase was solely developed by us. Because we are no longer part of a larger group, we can account for the reasoning and understandings behind the choices and describe the subjective observations of our experiences at Gentofte without having to account for the myAir group.

Designing the myAir prototype

In this section we will examine the understanding of design and how Design Thinking can be used as a methodology to solve complex user problems. We will furthermore explain what prototypes are and how they can be used in praxis. We will also investigate 'data sprinting' and how we used this format to design the myAir teaching kit.

DESIGNING SOLUTIONS

Design is traditionally understood as a discipline within arts and crafts (Pedersen, 2016. p. 38). It was understood as an extra layer build upon the function of a given product. It gave the product a specific aesthetic or enhanced quality. It was the finishing touch. As an example of this Bruno Latour phrases: *"look* not only *at the function,* but also *at the design"* (Latour, 2009: 1). This sentence emphasizes the understanding of the design and function as two individual entities making up the end-product.

The word *design* has been given a new meaning and the way we think about production has changed as well. Today 'design' is intentionally used and applied in almost everything. It goes further than into the aesthetics of everyday objects and is incorporated into landscapes, cities, genomes, medication, etc. (ibid: 1-2). As design moves into new fields, it has become a political act as well. The way the end-product is designed will eventually favour some and not others (ibid: 1-2). This raises questions as *who you are designing for* and *what problem are we solving through design.*

Design thinking

In the 1950's the term *Design Thinking* found its way into academia. One of the first authors to mention Design Thinking as a method was Bruce Archer in his book *Systematic Method for Designers* (Archer, 1965). Archer was interested in the methodologies utilized by designers to solve problems and how these methodologies could be utilized in other disciplines as well (ibid). This line of thinking was furthered by multiple scholars such as Herbert A. Simon (1969), Nigel Cross (1982), and Peter Rowe (987). As these schoolers took on Design Thinking as a term it spread to architecture, building of landscapes, and public spaces. Eventually the term 'Design Thinking' would evolve to be a method of understanding and how to solve socio-technical problems (The Interaction Design Foundation, 2018).

Design Thinking is a creative process to solving problems. It is an iterative process that can be used to understand users better and solve problems using design. The iteration happens between understanding and empathising with the users to defining problems, ideating solutions, prototyping, and testing the solutions. The phases are not sequential. Instead the process is to naturally jump between these phases as the process advance (ibid). The philosophy of Design Thinking is that the users and the problems are tested to foster new understandings to ideate and produce alternative solutions (ibid). Problems are often more complicated than they seem at first glance which makes the solution harder to predict. Thus, Design Thinking is not only about designing solutions, but also about figuring out what the problems actually are and what barriers the users face (Halse, 2010: 12-13). To identify the problems in a given case, and to solve said problems, a lot of creativity is essential (Plattner, Meinel and Leifer, 2011). Brainstorming and creative measures is essential to a Design Thinking collaboration. The philosophy is to encourage discovery and testing instead of discarding solutions (ibid).

By these definitions, design is not only to apply a finishing touch to a given product. Design as a discipline is to promote well-being in people's lives (Vianna et al., 2012: 15-16). Design do not just emerge. If done properly design comes from a comprehensive studying of the situation in which the problem occurs. Only then it is possible to solve the problem (Ibid: 15). The designer does this by examining the understandings of the user and by acknowledging that problems that affect people well-being are cultural, experience, and context dependant (ibid: 15). The philosophy of Design Thinking shares the same line of thought as John Dewey in relation to how inquiry works. In this case, J. Dewey would argue that only by investigating the situation we are able to understand the problem, and never the other way around (Dewey, 1910: 40-42). This also goes in line with the ethical turn, described by Verbeek. The objects of design are part of our experience of the world and cannot be separated from this. They are embodied in our experiences.

Phases of design thinking processes

Researching literature about Design Thinking offers many illustrations and explanations of the process involved, but they do not all agree on how to phrase them. Some authors divide the process into three, five, or seven stages, even though they contain the same steps in its entirety. We have chosen to base our explanation primarily based on the book *Design Thinking: Business Innovation* (Vianna et al., 2012). Vianna and his associates divide the process into three phases; *Immersion, Ideation,* and *Prototyping*. Even though other literature describes the process somewhat differently, the fundamentals are similar, it is all about diving into the field, ideating solutions, testing the solutions, and iterating the process, as illustrated below in Figure 4.

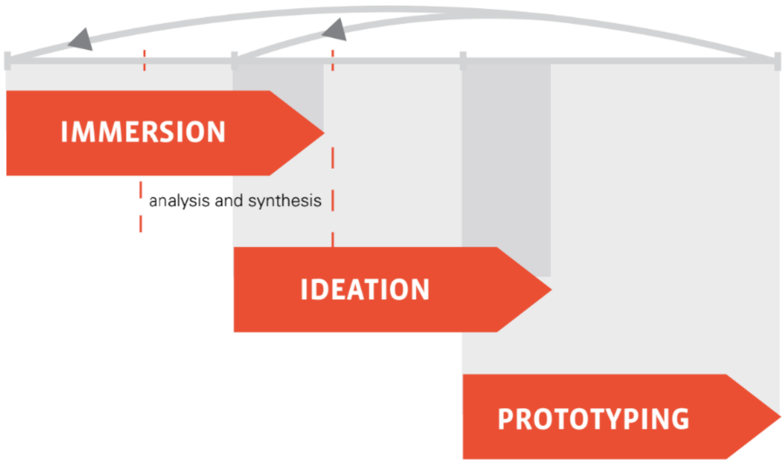

Figure 4 - Illustration of the iteration between phases within design thinking (Vianna et al., 2012).

Immersion

The purpose of the first stage *Immersion* is to dive into the field and view it from a new perspective. Usually knowledge about the field is limited in the beginning of a design project, which is why the first stage is meant for acquiring more knowledge through research (Vianna et al., 2012: 24). In this phase the preliminary strategy of the project is chosen. The scope of the project and the boundaries needs to be defined, after which the research plan is defined. The researchers will have to figure out how to acquire insights about the users. This can be done in a variety of ways including, interviews, focus groups, observation, and cultural probes (ibid).

Relating this to our project, this phase was done during the data sprint at King's Cross University in London in the beginning of the SaveOurAir project. We met with local activists and stakeholders to learn about their relation to air pollution. During the meetings with the activists and stakeholders we would discuss what problems they saw in London and how it could be related to other cities. This was our starting point for the project and from here we would start to strategize how to identify problems and hopefully solutions based on the information received from the stakeholders. We would later iterate this phase both later in the London data sprint and in the Copenhagen data sprint.

Ideation

The *ideation* phase consists of finding alternative solutions to the problem you are solving (ibid: 103). The purpose of this stage is to go beyond the obvious ideas for solving problems and instead look for alternative ways. The team should be a diverse multidisciplinary team, if it is to encompass multiple perspectives to the problem (Platner, 2009). This stage will benefit from inviting the users and other stakeholders to participate in the process (Vianna et al., 2012: 103).

The primary method in this stage is brainstorming. The desired outcome of the brainstorm is to generate as many possible solutions as possible. As a method to generate ideas design games and co-creational methods are often used to spark creativity and space for innovation (ibid: 109)

To foster a great ideation phase in the SaveOurAir data sprints, the facilitators had invited a broad palette of participants during the sprints, among them local activists and stakeholders from the Camden municipality. Politicians and teachers were also invited in the Copenhagen data sprint, which contributed to a diverse team and an efficient ideation phase in the project. A point to critique about the data sprint in London was that the facilitators had struggled and failed to engage teachers in the sprint, which would have been beneficial to the design of the myAir prototype.

Prototype

The *prototype* phase is meant for testing the ideas from the ideation phase. The purpose is to make your ideas tangible and testable. The ideas created is now turned into an object for testing in a feasible and inexpensive way. Often this phase is understood to be the last phase in the whole process of Design Thinking, but this method is preferably applied iteratively through the entire process (ibid: 125-129).

Prototyping

To test the ideated solutions from a perspective of Design Thinking, a prototype is used. The prototype is an initial version of the imagined end-product. A prototype can be made with the intention of testing different aspects of your product or the product in its entirety. The intention of the prototype is then to gain insights about your product that allow you to build a better end-product (Platner, 2009: 33-36).

A universal recipe for the perfect prototype does not exist and is dependent on the context of the testing. It can take many forms and the art of making a prototype can be hard and extensive as the focus of the prototype should answer the most important design questions at that point in the process (Haude and Hill, 1997). Rikke Dam and Teo Siang, from the Interaction Design Foundation (Dam & Siang, 2018), divides prototypes into three levels of fidelity, *low-fidelity, medium-fidelity,* and *high-fidelity*. The low-fidelity prototype is an inexpensive and quickly made version. This version is ideal to keep costs low and to rapidly test your initial assumptions in the beginning of a Design Thinking process. The way to make this prototype might even be as simple as a storyboard or some rough sketches (ibid). The medium-fidelity prototype is a more time demanding version to make and are usually more expensive. This version is closer to the end-product and the things to test with this version is more detailed. The high-fidelity prototype is the version closest to the end-product. This is of course the most time consuming and most expensive version since the prototype is more detailed and closer to a functioning product (ibid). The idea of making different fidelity versions of a prototype is to be able to make a functioning prototype spending the least money and time possible in the early stages of the process, by finding and avoiding the most obvious mistakes in the beginning(ibid). To find the right focus, prototypes should start out as a low fidelity prototype, i.e. an inexpensive quick and dirty solution, that test one or several features. Later in the process, the prototype can be iterated to a higher fidelity prototype to test the same features or new ones (Haude and Hill, 1997).

The prototype is a tangible simulation to test hypothesis and to find problems in the design. Since the design and its potential problems varies from project to project the prototype takes many shapes (Vianna et al., 2012: 122-126). Prototypes can be made as simple as drawings on paper to visually represent an interface or a space. A prototype can also be made volumetric and be more tangible and touchable. This type lets the test-person hold the prototype and makes it easier to imagine the end-product. Prototypes can also be a storyboard to represent the interactions between the people using the product and the product itself. A prototype might not even take a physical form at all, it could be a scenario or concept (ibid: 122-140). A design process will possibly utilise various forms of prototypes, to adequately test hypothesis about the solution. In the end the there is no correct way to create prototypes, but effort is needed to find the right way to test each individual design project.

In the SaveOurAir project and in the myAir group that we were part of, prototyping had a significant role in the process. After a couple of days in London, where we had emerged ourselves in the field, we started to do initial very low-fidelity prototypes. These prototypes consisted of drawings and storyboards that illustrated the use of the end-product, the myAir teaching kit (Figure 5). These prototypes were contested in plenum with the other groups in the data sprint. Later, it was tested on local residents from Camden in London. In the Data sprint Copenhagen, the prototype evolved into a medium fidelity prototype that was tested on a Danish 10th Grade teacher. After the data sprint in Copenhagen we advanced the prototype, in the myAir group into what could be considered a high-fidelity prototype. We created a web platform with most of the ideated features and a teaching guide with material.

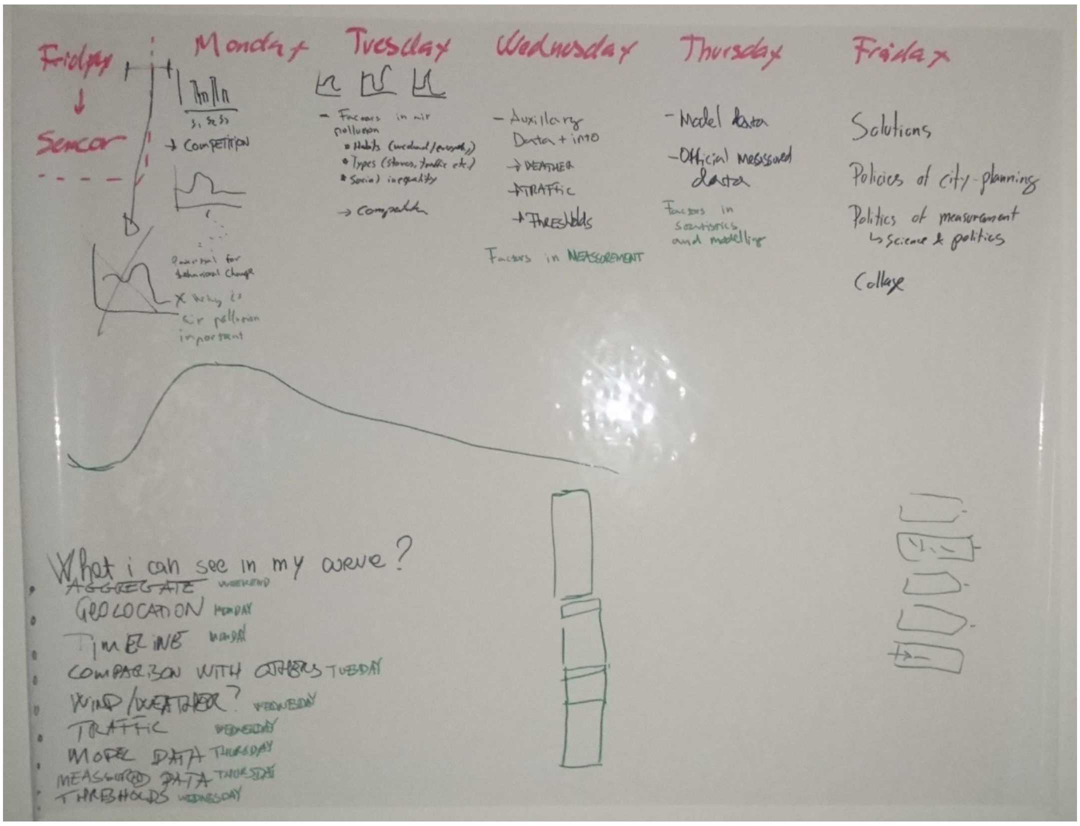

Figure 5 - Early prototype of the myAir teaching kit. A storyboard describing how data would be presented to the pupils (Photo taken during field work)

Data Sprint

Data sprinting is a framework inspired by the philosophy of Design Thinking. It is an intensive research and coding event where participants meet to design new digital solutions. Data sprints has its roots and share similarities with so called "barcamps" and "hackathons", also called hacking marathons, where designers and programmers meet to work on a digital product (Venturini, Munk and Meunier, 2016). The data sprint distinguish itself from barcamps and hackathons by being a longer event lasting more than one day Data sprints are also more structured than the barcamps and hackathons and demand more preparation. Time consuming jobs, like cleaning data and researching the field, is done beforehand to minimise time spent on tedious tasks during the sprint. Data sprints also require more documentation and work after the sprint to make sure the research meet standards of the scientific community (Ibid). This leaves more time for brainstorming and testing solutions during the sprint.

A data sprint is a co-production event and reliant on having the right competencies available. The facilitator of the sprint is responsible for inviting participant that are able to solve the problem, which often means inviting people with a diverse array of disciplinary skills. Heterogeneity of the actors involved is desired and the data sprint is open to a multitude of actors. Designers, programmers, and experts within the field is especially valuable, as their competencies often are required in different phases of the sprint. End-users and stakeholders are also an important set of actors (Ibid).

From this description of what Design Thinking is and how to best implement it, we will now give a review of the two data sprints that together facilitated the concept and development of the myAir prototype. As is often the case, best practice and reality of designing rarely goes hand-in-hand. Many blockades, obstacles, and clashes have to be overcome, before you end with a product worthwhile testing. While there were many learnings about how to facilitate and participate in a data sprint, our focus in the coming sections will be about the outcome of these sprints and what thoughts went into the end-product of the prototype. We will especially put notice to the design choices that aligned with a Deweyan way of teaching and the postphenomenological call to ethical design.

DEVELOPMENT OF THE MYAIR TEACHING KIT

In the following section, we will give account on the development of the myAir teaching kit, both from the perspective of Design Thinking theory and from the perspective of participants of the development. We will begin with an over-all introduction to the prototype and its end-result. We will then explain each of its part and what thoughts and contemplation went into them.

As we were part of developing the myAir teaching kit, and therefore not only privy to the insights and learnings along the data sprints and design process, but also the source of many of the insights, we will refer to the myAir group as 'we' in the following sections. We believe that to distinguish between 'us', the observers of the process, and 'us', the participants of the process would not only be convoluted for the narrative but also hide how deeply we have embedded us in the field. This is also grounded in the fact that near the end of the design process, we took sole ownership of prototyping and development. The insights in this section is derived from notes and documentation made in the field.

The myAir teaching kit were first ideated during the data sprint at the Kings Cross College in London. In the beginning of the sprint, we chose to take part in the 'data and geolocation' group that was later on renamed the myAir group. The initial idea was to find a way to combine data about air pollution and geolocation and was eventually developed to include a guide for teachers to use in an educational setting. The idea spun out from a meeting with some local activists in Camden, London, and an employee from the Camden council that measured air quality. One of the major learnings from these visits was how granularity of data are important for certain inquiries and the said level of granularity are often debated in relation to air pollution. There was a dissatisfaction around how data was collected presently, where it was collected, and the level of details available.

We also learned from the various activists that young people are great to approach with the issue of air pollution. In the activists' opinion, young people are more susceptible to change their habits and are also great at advocating the cause to their parents and peers. These learnings from local actors made the myAir group want to explore the idea of designing a teaching programme for pupils.

The initial problem

The importance of grounding data in a local place to contextualise data about air pollution was also mentioned. To counter the dissatisfaction around air pollution measurements, activists from Camden Air Action had a programme where they conducted their own air pollution monitoring near schools. This was also to be able to make the data narrate a story about the children's exposure to air pollution. This information lead to a discussion in the group about what 'local' actually means and how we could make data tell stories rather than just answering questions. If the current narrations around air pollution did not represent a 'local' version, then what was 'local' then?

From this initial problematisation, acquired during the first day in the London data sprint, the myAir group initiated a series of discussions on whether it was possible to use geolocation as a means to add local context in data. The idea was to somehow combine data about air pollution with data about location or locality. Part of a design process is to figure out if any of the ideated solutions early in the process has already been made. This can both foster ideas on how to improve the current solution, but also prevent spending a lot of time developing some things that already exist. There is a fine line here; just because solution to a problem exists does not necessarily mean it shouldn't be considered or created again. In this case it was quickly found that there were already solutions surrounding geolocation and air pollution, both in a London context (LondonAir) and a Danish context (Luften på din vej). However, several of the participants, us included, had issues with the solution. Even though the air pollution maps included local data, i.e. street level data, they did not reflect the personal idea of pollution in our own local area, when we investigated the maps. Critique from the group was given both to the fact that the data was based on models, i.e. estimates on street level, or they weren't contextual, i.e. didn't represent a dynamic reality.

An example of this critique came from one of the myAir participants. He felt that the maps didn't reflect the many wood burning ovens on his home street. This type of pollution is very seasonal, it was said, so it had been hidden in the yearly average used by the model. The peaks of pollution from wood burning during winter months would be countered by the lower levels of pollution in the summer months when only looking at a yearly average. Another example was the home street of another participant. Though it is a very small street it functions as the delivery point for a larger convenient store. This means daily traffic from heavy diesel lorries every morning, something that was also not shown from the modelled data, as neither traffic nor their pollution was measured in the area.

What is local?

It became clear from the early process in the sprint that 'local' was not only a geographical location. It was as much a personal experience that reflected a reality. So even though solutions had been made to combine air pollution data with local data, i.e. street data, this did not, in the groups opinion, create a solution to the problem of localised narratives. From this came the idea of adding a personal timeline of geolocated air pollution data. If data about air pollution could be combined with location data and a timeframe the result would not only be a dynamic experience of air pollution but also a personal one.

However, it was felt that just presenting 'localised' or personal data about air pollution would not be enough to foster a change in behaviour. There was an agreement in the group that it was notoriously hard to create a change in behaviour from data alone, even if the data was made personal. A comparison to Fitbit watches and other self-tracking devices was made; where the interest in self-monitoring is initially high but quickly fades after a while when there is no new learning from the information, or the information does not create changes in behaviour. The notion was that in order to instil behavioural changes we needed to present a narrative around the exploration of air pollution data to the user. It was not enough to just present or visualise personal data, it had to be narrated.

The 'data betrayal'

An understanding or learning needed to be part of the prototype so to change the experience of not only air pollution, but also of one's own reality in regard to air pollution. This thinking is not unlike Dewey's explanation on reordering data to indirectly suggest a double reflection on the question at hand. If a suggestion, of being interested in the personalised air pollution data, can be designed into the solution the user might be more inclined to reflect not only on what air pollutions means to them, but also what to do about it. This is also akin to Verbeek's explanation on material answers and moral questions. Somehow, the solution needs to mediate and translate the personal air pollution data in a way that gives a certain nudging towards behavioural changes.

From this thinking, in combination with the information about targeting behavioural changes in young people, came the idea of creating a teaching programme that not only presented personalised air pollution data in a local context, but also suggested a reflection on how to investigate the problem and hopefully do something about it.

But before the teaching programme became the main artefact to implement the suggestions, several strategies where ideated and iterated on how to engage the user in air pollution data in a meaningful way. An example of this was the narrative of "Falling in love with your curve". This spoke to the idea of an inherent curiosity a person has, when initially presented with self-produced or self-monitored data. Although this was not stated as a universal trait, and many times during the sprint the question was raised about what to do if this strategy failed, it was non the less a persistent theme that created a foundation for the teaching programme later on. The idea is, that when you are presented with data about yourself, or data that you yourself have produced, there is a higher chance that you are more interested in analysing and inferring on said data. Whether this postulate would hold up in reality would have to be tested, it was thought.

Another narrative was "the data betrayal". This was a strategy to lure the user out of a heretofore established comfort zone in relation to air pollution data, by presenting an extra layer of complexity to the data, or even worse, by contesting the data. The idea was that after the user had been introduced to their personal air pollution timeline and had deducted its relation to their own experience of air pollution, they would be introduced secondary data, e.g. official data of 'local' air pollution. Since this data would not be as dynamic or individual as their own produced data, a discrepancy between 'official' sources and 'personal' sources would hopefully initiate another round of reflection and investigation into this discrepancy. Here, new information and complexity to the question of air pollution should be made available to the user. This goes well with how Dewey describes ambiguity in choices:

> *Thinking begins in what may […] be called a forked-road situation, a situation which is ambiguous, which presents a dilemma, which proposes alternatives. […] In the suspense of uncertainty, we […] try to find some view of the*

situation from which we may survey additional facts and […] decide how the facts stand related to one another (Dewey, 1910: 9)

It is the shock of the unexpected that makes you doubt what you know and seek out more information to better understand what is going on. If we wanted to have the user seek out new information, we somehow had to make the curve betray their new found understanding of reality. *"[…] A state of perplexity, hesitation or doubt [could lead to] an act of search or investigation directed toward bringing to light further facts"* (ibid). This would be done through the addition of new information tailored for a shocking experience.

How the teaching prototype came to life

Although these and several other strategies were iterated several times, it wasn't until the user was tentatively specified that they could be cemented into the prototype. In the very beginning of the project, the combination of air pollution data and geolocation data was only treated on a conceptual level, without a specific user in mind. We soon realised, when we tried to design specific features and views, that we had to be more specific about what context the concept would be used in and by whom. We saw a potential in designing a teaching kit that would include learning scenarios, we were confirmed on the idea by the rest of the SaveOurAir participants. However, we were advised to lock down the age and education level of the end-user, to have more focus in details of the teaching programme. As part of the London data sprint, the facilitators had invited local residents in Camden interested in air pollution to a coffee and a talk about our projects in a local community centre. The set-up was arranged like a speed dating scenario, where each group had a resident for 15 minutes, before they had to move on. The initial response was very positive and the idea of making a teaching programme was especially appreciated. It was suggested the pupils around high-school would have a better understanding of many of the complex aspect around air pollution and we took this advice to heart. This cemented the user and we started to design this into the concept.

During the data sprint in London we did not know which sensor we would use, so instead we developed a set of criteria to what was needed from a sensor in to give the needed experience to the user. One of these criteria were a certain level of fidelity to real world observations. This was defined as how much change in pollutants were needed to incite a response from the sensor, how fast the sensor responded to nearby change in pollution, and the level of change it could measure. The reason for such criteria was to enable a certain experience for the user in to initiate a reflection from the user on their personal pollution timeline. It was thought that in order to do this, the user needed to experience the dynamic changes in their surroundings through the sensor's mediation of pollution. So, if a polluting truck drove past them this should give a reasonable response on the sensor. If the sensor was not able to register the truck it would give a discrepancy between the users experience of pollution and the mediation of the sensor. The sensor needed to not only make real-time measurement, but also 'real-life' measurement that could both confirm and surprise the user. The last part was important. It was fine to show a diesel truck as polluting, which this is often possible to detect with bodily senses. However, it is also necessary to show pollutants that are not visible to human senses, or to surprise the user by showing the amount of pollutants a source might emit compared to another. Thus, the sensor needed a translational mediation, not only a magnifying mediation. To give an example of this, a case that was mentioned by the activist in the London sprint comes to mind. There are more air pollutants inside a car than outside the car, even though this might not be evident. This is because of the build-up of particles in the confined space of the car. It was stated that, because of the build-up, it was healthier to bike next to the car than sitting inside of it. If the sensor was able to mediate this type of reality to the user, this would hopefully lead to a suggested inference from the user about personal exposure and air pollution in general.

From these learnings in London, and the following data sprint in Copenhagen, we found several topics that were used in the development phase. We will in the following give a short description of the parts that was the myAir Teaching Kit.

The Google Timeline

Discussions about how to localize data on air pollution was the starting point for the entire SaveOurAir project. To implement personal geolocation data, we came to use the Google Timeline feature (Figure 6). This feature allows users of Google Maps to go back in time and view their own geolocation at a chosen date and time. The feature, and the possibilities of using it, was one of the first things we discussed in group before even ideating the prototype as a teaching programme. We discussed that by combining the data from the Google Timeline platform with data about air pollution we would be able to put a more personalised 'local' into a data set. The data that was

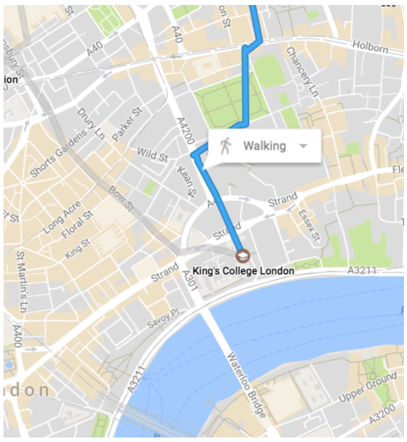

Figure 6 - An example of Google Timeline. The information also has date, time, mode of transportation, and speed.

possible to export from one's personal Google Timeline was the fulcrum for the rest of the myAir group in the data sprints.

The type of data that it is possible to export from the Google Timeline had certain qualities that we had to consider in the development of the myAir prototype. The data offered many advantages to our prototype, but also certain setbacks and boundaries that we had to overcome or design around. Especially the file format and structure of the data had to be taken into account when coding the soon to be web platform that would visualise the data.

In the myAir group, it was discussed how the user of the web platform would experience and see the world through the platform. We discussed how the design of the platform would be able to impact how the user perceived their daily routines, transport, and whereabouts. With the use of Google Timeline, the world is perceived from a two-dimensional perspective, creating a weight on streets and how the user moves around on these streets. Because of the decision of using Google Timeline the focus in the group slowly shifted towards movement in the city, and how the way we move has a big impact on our emission and exposure to air pollutants. Based on this, modes of transport and routes became a focus for the future design of the myAir prototype.

One of the major issues we had around using Google Timeline later in the process, was that if we had to use it in a teaching scenario then the student had to sign up for being tracked. There were ethical issues here, firstly, on whether we could ask this of students in an educational context, and secondly, whether they would be able to understand the consequences if they agreed to this type of tracking. What we would describe as a typical nonchalant attitude at data sprint, these questions were at the same time acknowledged and pushed a side to a later time. One argument was that young people are already sharing their location through a multitude of apps, so chances where they would not be against indulging in a short-term tracking of their location. Another argument where the classical design maxim; 'we will deal with that when we come to it'. Despite this, it did leave a trace in later design decisions. As an active choice when coding the web platform (See 'Interface and visualisations', page 65), it was decided not to rely too heavily on the Google data format, as this would have to be changed at a later point[7]. The other decision was to

[7] At this point in the process, there had been talks about further developing the myAir sensory device to collect geolocation data as well as air pollution data, thus skipping the use of mobile phones completely.

include a chapter about tracking and its unforeseen consequences in the first day of the teaching programme.

The sensory device

To ground air pollution data into the pupils' own everyday lives, we wanted the teaching kit to include sensors that measured their exposure to air pollution. These sensors would, combined with geolocation data from Google Timeline, make it possible to track how much the pupils were exposed to air pollution, and at what time and place it happened during the day. This would allow them to retrace their doings of the day and reflect on the source of pollution exposure. The idea was that this type of reflection would conduct new experiences and hopefully instil a suggestion to avoid such pollution source in the future.

With this in mind, we set out to find a useful sensor. Since air pollution is a generic term for many kinds of pollutants, sensors are made to measure specific types of pollutants. During the London sprint, the group was told that most air pollution monitor stations cost thousands of pounds, are large and immobile, take months to calibrate, and still have problems with real-time measurements of pollutants, often visualising hourly means instead. However, we found a sensor from a company called Airlabs based in London and Copenhagen (**Error! Reference source not found.**) Airlabs create solutions for cleaning air through atmospheric chemistry and engineering airflow. They also develop carbon filters and measuring devices. We established contact to Johan Schmidt a project manager in the company and head of sensors, who found our project interesting enough to lend us three particle measuring devices we could use for our prototype.

Figure 7 - The Airlabs air pollution monitors (Photo taken during field work)

The Airlabs particle measuring device can measure PM_{10} and $PM_{2.5}$ particles, as well as humidity, temperature, and air pressure. It is also able to take measurements at very small intervals[8]. The

[8] We decided to have the sensor measure every 10 seconds, so to have a satisfactory granularity for the visualisation.

device is small and light, which made it possible to carry in a pocket or hold in the hand. The measuring device was itself prototype that Airlabs was testing. This was evident by the lack of a battery, instead having to be charged from a USB-cable. We used a power bank that could power the device for just under two days of constant use before the battery had to be recharged[9]. The body of the device was made from 3D-printed material which made it a bit fragile to the touch. We had to consider how to handle the sensor carefully, especially if young pupils had to carry them around.

Pre-testing the sensory device

Before and during the data sprint in Copenhagen three of us carried a sensor with us everywhere for a week, to test its functionalities and mobility on our own life. This was not only to get an idea of the possibilities and limitations to the device, but also to generate sample data to use in the data sprint. We made sure to test it using various transportation forms and locations, as we had imagined the end-users would. We wanted the prototype to be able to tell personal stories grounded in pupil's lives, which made us think about how to create true to life data samples. We therefore always kept the sensors on us, which gave some funny and interesting interactions[10], as well as surprising facts of about our own exposure to air pollutants. As part of the test, we deliberately chose to visit a pizzeria with an open stone oven with burning wood in it, as we thought we would see a peak in our data when we analysed it afterwards. We tried different pubs, some where it was not allowed to smoke and some where there was a designated smoking room. When we looked at the data afterwards, we saw that the sensors were actually really accurate, and it was easy to see when we changed settings just from the particle measurements. This was to a degree where it was possible to see when a bus had made a stop as the opening and closing of the doors could be seen in the data. In the pizzeria we all had readings well above both WHO and EU's thresholds due to the open fire in the stone oven. When we went to the first bar, which was a non-smoking bar, we had readings that were well within the thresholds, but above average. The next bar we went to was a bar where it was allowed to smoke in a designated smoking area. Immediately when entering, we received high readings on our sensors, which confirmed that it was highly responsive and appropriate to use in our prototype. The average

[9] We acquired two power banks per sensor, so one would be in use while the other was recharging.
[10] At one point, one of the testers was asked by a security guard to hide the sensory device from sight as it had been reported as bombe like object.

reading in the smoking bar was ten times higher than the pizzeria and would often peak over twenty times higher. When calculating our daily exposure, the day after, we had a 24-hour mean three times the EU threshold mostly due to our visit at the bar where smoking was allowed.

Carrying the measuring devices along with us for a week functioned as a preliminary test of parts of the prototype we were creating. By testing on ourselves before designing it to 10^{th} graders it gave us a picture of what data we could expect and it limited mistakes that would not have been obvious if we had not used devices ourselves. During the test period, all three sensors had suffered damages due to its fragile body. Fortunately, the damage was only superficial, and the device were still functioning. Before the test in Gentofte the sensors were repaired and looked as good as new. At this point we could only hope the 10^{th} graders would take good care of them.

The user

We quickly realised, from mid-way in the London sprint, that a lot of decisions we were making in relation to the design were dependent on how old the student was and at what type of learning scenario they were in. Depending on the age of the user, they would have different routines and daily activities which we had to account for in the design of the teaching programme and platform. If we wanted to surpass a conceptual level of designing, we needed to define the end user. In London we then started to develop the prototype to fit in the curriculum and life of a young pupil, but in Copenhagen we changed the prototype to fit into the life of a 10^{th} grade Danish student. This was done because we had been invited to test it on a 10^{th} grade class in Gentofte. Even though the teaching kit so far had been designed a bit flexible around the age of the pupil, now that we had an opportunity to test on a group of 10^{th} graders, the teaching programme became more fixed to this level of education.

The teaching programme

Initially, the prototype was designed as a concept that could be used as a teaching programme at all levels of elementary and high school and could also easily be converted to a bachelor level at the university. The programme was designed as a support for the teacher, to conduct a five-day course about air pollution and the social factors, data handling, politics in measuring, and habits connected to it (See Appendix III – Five-day teaching guide). An essential part of the programme was to have the pupils collect the data and analyse it in the classroom, while creating a sense of ownership in the process, making the curriculum more relatable to their own experiences and thus their reality.

Designing a teaching programme proved to be difficult task for a group mostly consisting of social scientists and programmers, with limited knowledge about the curriculum of Danish pupils. We were highly in doubt of the level of difficulty we could present to 10th graders. We thought it was crucial for the prototypes success that the level was high enough to be challenging and interesting for the pupils, while at the same time we were worried that if the level was too high they would lose interest.

To be sure that we would find a balance, we invited an expert informant to the data sprint in Copenhagen; Niels, a teacher at a 10th grade centre in Copenhagen. Niels helped us adjust the level of teachings to accommodate the skill set of his pupils, by informing us about the curriculum and how challenging we could set the assignments. Niels also explained to us how he and teachers in general prepare their material, which told us that we needed to be very descriptive in our teacher's guide, as there is very limited preparation time for teachers.

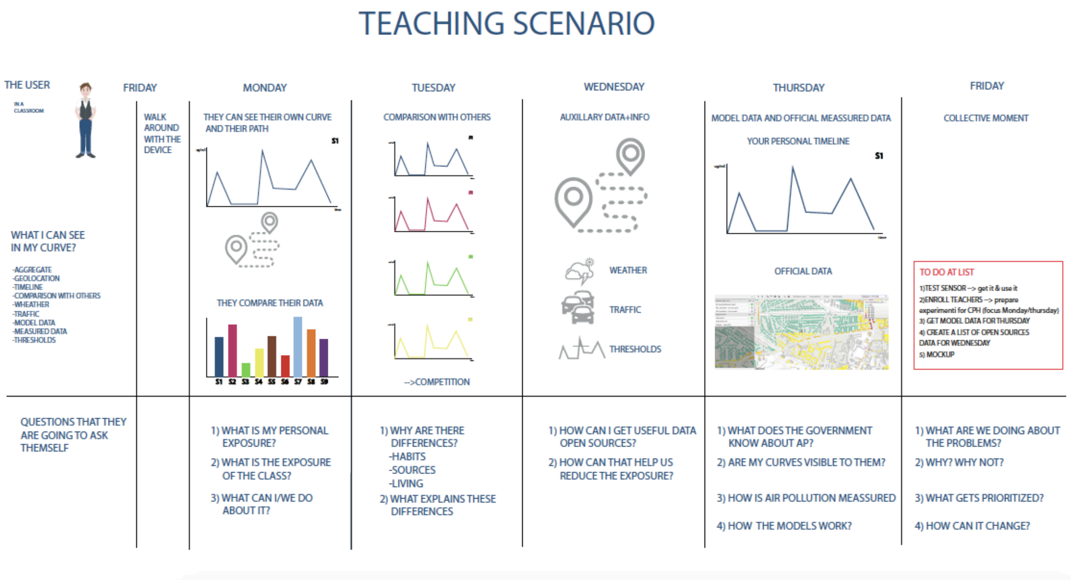

Figure 8 – Storyboard of the five-day programme created in the data sprint in London

In the first days of the programme, the pupils would work with the data that they had gathered during the weekend before the first day. The pupils would learn how to read their personal graph and make sense of it by annotating it with contextual information. This was part of the 'falling in love with your curve' strategy. In the process of contextualising the data, it was hoped that the pupil would see a connection between mundane everyday things, like going to school, and the invisible world of particles. By revealing an unknown part their world, this experience would hopefully change their reality and instil them to do further investigations into the air pollutions in their local surrounding.

The next day, they would work in teams and interpret each other's data and talk about good or bad habits related to air pollution. They should learn from each other and talk about the sources of pollution. The idea was that when faced with the data of your peers you start to do comparisons to your own data and thus your own reality. Why does the other person have less or more pollution than me? What can I do to get less pollution exposure?

This was also to introduce a gamification aspect into the design. Assignments to reduce your pollution exposure from day to day was to further their inductive reasoning to deductive investigation, while also engaging the students in behavioural changes.

On the third day, the focus was designed to be about all the uncertainties and variables that need to be taken into account such as traffic in the streets, weather conditions, and changes in routes. The goal was to present confusion and perplexation to a world they had just started to fathom. Once again, a movement from deduction reasoning to induction reasoning and back again, should inspire them to keep investigating and keep expanding their understanding. The pupils would be informed about thresholds made by the World Health Organisation and the European Union, and so give them a better way of comparing their data to official data.

On the fourth day, the pupils would learn about different techniques and choices related to the measurements. The teacher would bring measurements made by the DCE or King's College in London and show how different ways of measuring and aggregating data would create differing results. This was part of the betrayal of data. The presentation of static or less dynamic data stories, in comparison to their own highly contextual and localised data stories, should give them insight in how models work, but also the politics and social aspects in science and legislation.

On the last day of the programme, the teacher would support the pupils in making a report and presentation of what they had learned from their own data. There were talks, during the sprints, to include an area in the myAir web platform where these presentations could be shared across schools and countries.

In the data sprints in London and Copenhagen, the programme was designed to include five whole days of teachings, but it was not feasible, when testing the prototype on the 10th graders, for the teacher to take a full week off the schedule for an experimental programme. Instead, we redesigned the programme to be three whole days. A shorter period, but with most of the essence from the longer programme (See Appendix II – The Three-day teaching guide and Appendix III – Five-day teaching guide).

In the data sprints, we had great focus on how the measuring of air pollution was a political matter as well as a technical one and had designed this to be a theme throughout the teaching programme. This focus was not kept as an entire day in the three-day programme, but instead taught during the first and last day of the programme with the use of examples from pre-collected data. We also originally designed the five-day programme with the intention of giving each of the pupils a sensor device. But since we only had access to three sensors, the programme we tested with the 10th graders were also revised to accommodate this limitation. This meant that the pupils would have to work in teams with one sensor to share in a group, and that we had to test the prototype on a smaller sample of students rather than a whole class. This again made it easier to facilitate for us, as we were not experienced teachers.

Since we had to shorten the timeframe to test in, the weight on some parts were lessened. We chose to aim our focus on how the pupils were able to tell new stories about daily activities with the use of the myAir teaching kit, and how scientific inquiry could be conducted using data the pupils collected themselves.

Interface and visualisations

The interface of the web platform should support the learning objectives we had decided for the end-user, thus had to be designed in relation to the different exercises and scenarios we had anticipated before the testing. We had ideated a scenario of a user trying different transport modes to and from school and we thought the interface and the visualisations being outputted should show a comparison between routes (See Figure 9 for an example).

We agreed that the interface and visuals of the platform should support engagement among the pupils, why comparison between the pupils' exposure levels would encourage discussions and reflection among the pupils about who had the lowest or highest exposure to air pollution and why. This amounted to a sort of gamification, designed into the teaching programme. Through the interface, it would be possible to compare the exposure between the pupils or even schools. We thought this might suggest to the pupils to come up with ideas on how they could lower their exposure to air pollution. Ideas at the sprint were tossed around on how to do this, by for example giving points or badges, but several examples were brought forth where people compete for the sake of competing. The reward system could be arbitrary without anything actually being at stake in the 'game'.

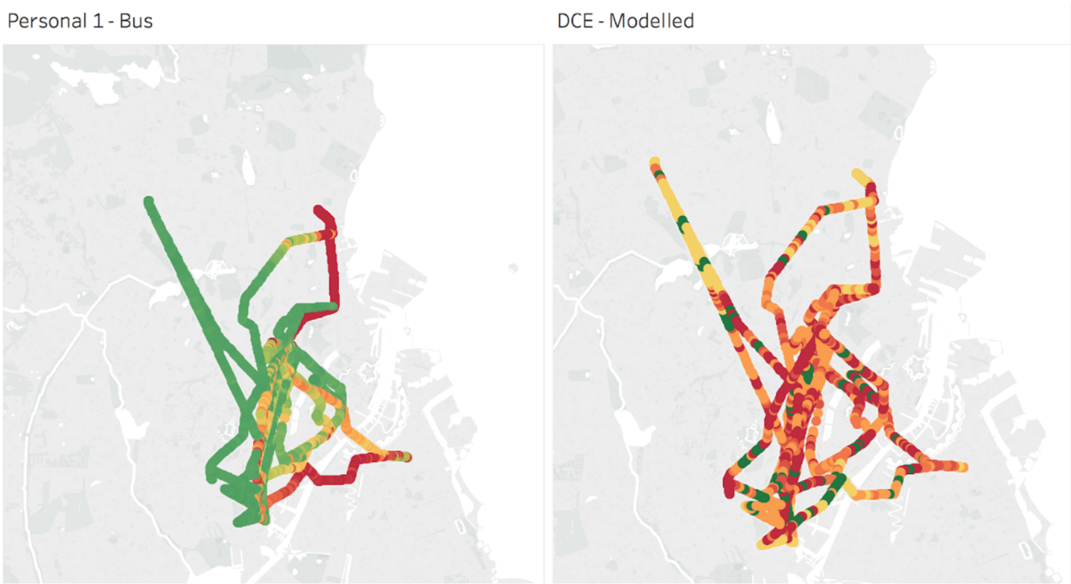

Figure 9 - An early visualisation of routes compared visually. To the left is the data from the sensory device. On the right is the same route, but with information taking for the DCE – "Luften på din vej" map.

An interesting point-of-view came up during the feedback session at the end of the London data sprint, from a local mother in Camden. Knowing how kids often look at things, she would think that they would seek out the highest exposure instead of trying to minimise it. This presented a new challenge to the rules of a gamification feature in the teaching programme. Should they try to create the lowest exposure to pollution, which would entice them to test out new routes and modes of transportation during the programme, or should they try to find the worst sources of pollution, which might teach them about sources and experimentation. Although, both could be implemented, it would make the development that much more complex. For the sake of encouraging reflective thinking both scenarios would be beneficial.

Since we were limited on time in the data sprints neither the comparison interface nor the gamification was built into the actual application we used for the prototype. Instead we made the pupils present and compare their personal air pollution timeline through presentations or in-plenum discussions, and also made them point out the highest and lowest exposures points in their data.

We also encourage the pupils to switch to a new mode of transport or a new route to school, to have them reflect about the sources of pollution and maybe their habits as well.

Figure 10 - A mock-up of the initial interface for the myAir prototype (Photo taken during field work)

How the interface and visualisations should look like, and what features should be included, was iterated multiple times during the data sprints (See Figure 10 for an early example). We had many heated debates about how to visualise the data, what interpretations the visualisation would give, and how we could create the right type of data stories without compromising the integrity of the data. Since visualisation is an interpretation of data, social and political opinions will inherently be designed into the visualisation. The question is then to what purpose should the visualisations serve? Was the base colouration on the graphs depicting air pollution to be the official threshold objectives from the EU or WHO, or should we create a dynamic colour gradient, that changed depending on the measurements inputted to the graph? The last was especially useful if the prototype was used by schools not located in urban environment, which in Denmark would most likely give them measurements well within the thresholds and thus not shock the pupils the way we hoped for. The result was once again temporary. Since we were going to have the first testing of the prototype in an urban environment, i.e. Gentofte, we would set the colours to the EU threshold, so it was easy to see when the pupils would exceed this. Based on the feedback from the test, we would then take a decision later on.

The first representation of the platform was a very low fidelity prototype that made of sketches drawn on a big piece of paper (See Figure 5). Gradually, the prototype evolved into a digital mock-up with features and views that imitated the feeling of using the platform. Lastly, it evolved into a working web platform with many of the functions that was thought of during the ideation phases. The last iteration of the platform, before testing, made it possible for the user to parse the data into the platform and see a graph of the levels of air pollution the sensory device had been exposed to during the day. A correlated map was also drawn that showed the geolocation of where the user was at that given time. In the top of the graph a slider was integrated to make it possible to choose a ranged time period to be showed only.

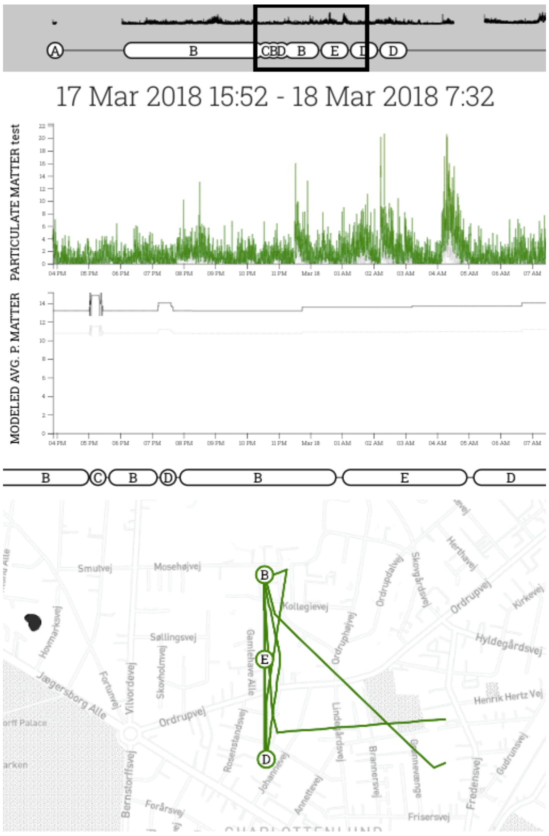

Figure 11 - A sample of the web platform after air pollution data and Google Timeline data had been parsed and merged. In the top is an overview of pollution and time. In the bottom is a visual representation of geolocations. (Madsen et al., 2018a)

Data handling in a prototype

Since our prototype included a web platform, coding was required to make it functional. The data extracted from Google Timeline and the data from the particle sensor had to be programmatically parsed and merged to make it accessible to the user using the platform. The data also needed to be visualised in a way that supported learning objectives, at the same time making it possible for the pupils to recognise their journeys. The coding for the myAir web application happened mostly in the Copenhagen data sprint, whereas the London data sprint were more focused on ideating solutions and concepts. Although the coding was mostly done in Copenhagen, the foreseeing of what was feasible or not dictated many decisions already in the London data sprint as well. Our prototype was very dependent of having granular enough data and merging different data structures to tell new stories with it and therefore the coding had a big influence in many decisions. Data from Google Timeline are formatted as a KML file, a format used to display geocoordinates in digital maps, a format entirely different from that of the air pollution data. This meant that to use these two data sources we would have to create an application that would do this if this data should be available to pupils.

BEFORE THE TEST IN GENTOFTE

As the data sprints were finished so was the development of the prototype for the myAir group in its entirety, but we chose to continue the project and test the prototype in Gentofte where we had been invited by teacher Niels Gorm. Now we were alone and had to make some final adjustments to make the prototype testable. We were still in contact with Niels and used his expertise as a teacher to further develop the teaching programme both to fit his students, their curriculum, and the timeframe we were able to test the prototype in. The teaching programme had to be reconfigured to fit three days instead of five days.

Since the myAir prototype was designed through in an international project the teaching programme and the assignments were written in English, which we had to translate into Danish before the test. Since the programme had to be turned into a three-day programme we had to prioritise what needed to be emphasised and thorough, while some elements had to be downscaled to fit the test. In the previous section we mention the “data betrayal” which we believed would be hard to facilitate under such short intervention. Instead we would teach about the measurement of air pollution and try to dramatize shocks from the data, while teaching.

In the test of the prototype we took on the role of teachers. We taught the pupils through presentations and lecturing and supervised them in the exercises we gave them. The role was new to us. We are not teachers by training and the discipline requires a certain level of pedagogical insights and thoughtfulness that we acknowledge to be lacking. We strived to speak to them in a language that they would understand, while not speaking in a condescending manner. Prior to the test we talked with their teacher Niels, who helped us prepare and structure the lectures and programme in a way that supported their level of understanding. We strived to create a loose atmosphere in the classroom in order for the pupils to get comfortable with our presence, as we found it important to build a safe space, where they felt as they could ask any sort of question.

Along with the role of being teachers our role was also to be active ethnographers. Along with teaching we were also active in taking notes and recording the situation for later analysis. To manage both roles required that we took turns between presenting, supervising, and taking notes.

Prototype in action

In this section, we will analyse how the test of our prototype went when we tested in Gentofte 10th grade centre. We draw our analysis from our own observations and recording in the field, and from a follow up interview with Niels Gorm, who observed the programme. Please note that we will be changing our narrative for the coming section. At this point in the design phase, we are no longer part of a group. From this point on, we are working on our own intuition, phronesis, and expertise. For this reason, we will be utilising a thick descripting narrative to not only make our interpretation of the field subjectively clear, but also to transfer our learnings from the field in a more digestible way.

FIRST DAY OF TESTING

The first day of the test programme was a Friday. We started the day in the teacher's room upstairs, located on the top floor of the building far away from the pupils. We were offered a thick black cup of coffee, which we hence referred to as a 'the teacher's pick-me-up'. As new faces to the room, we tried to blend in with the teachers, who had a laissez faire talk about the risk of a strike breaking out. We were clearly away from our comfort zone, now having to teach instead of being taught. Even though it had been years since we were last in a high-school's teacher room, it's hard to shake the feeling of being in forbidden territory. But we had a class to teach and had come prepared for the activities of the day: A restructured teaching programme, tailored for the testing scenario, a slideshow, and three particle sensors with batteries in our bags. Our gatekeeper Niels soon came to our rescue and led us to the classroom.

As we entered the classroom, we were met by a confident group of 10-12 students that welcomed us to their school. They had been forewarned about our arrival and were ready to test the new 'substitute teachers'. As we had been unsure exactly what level of understanding they had about air pollution, we had prepared an interactional session, where we would ask questions to test their knowledge, and could then adjust the amount and complexity of the teaching material based on their response and activity. However, it became clear they were measuring and testing us as much as we were testing them. We managed to wave off the test by increasing the level of theory and history surrounding air pollution. We noted that this kind of flexibility in the teaching programme was an important feature that need to be extended in the prototype. What was especially efficient was areas that brought the topic of air pollution into their own life. By making them reflect about the air they were breathing, they became more engaged to the topic at hand and less in the subjects in front of them, i.e. us. We asked questions like; what is in the air? How do you know if you are breathing clean air or polluted air? And do you think about air pollution in your daily lives? We were surprised by level some of the students were able to answer the questions in, though their understanding was quite differentiated. Some students were able to provide great explanations to the chemical and physical properties of pollutants, and some were ether quiet or only able to give vague explanations and reflections. We also realised that some of the pupils were holding back and we hoped that we would later engage these pupils to be more active in the classroom

We proceeded to inform the pupils about the sensors functions and how to use and take care of them. We also gave a lecture about self-tracking, sharing tracking data, and the consequences of sharing this data with Google. We stipulated that it was completely voluntary to turn on the Google Timeline feature, but also suggested it might be a good way to see how geolocation data worked and to get a sense of what kind of data other apps are collecting about them, without making it as explicit as Google Timeline does. We ended by giving them instructions on how to delete or change certain geolocation data in case the pupils did not want to share certain legs of journey with the rest of the class.

Figure 12 - An example of a teaching situation. One of us conducted the actual teaching, while the two others observed and documented

(Photo taken during field work)

An interesting insight at this stage was the surprise from the pupil's when seeing their Google Timeline for the first time. As is often the case, in our personal experience, people rarely know if they have the feature turned on, and are shocked when the find the level of detail that have been collected by the feature[11]. While the pupil's surprise about how they are unknowingly sharing data with Google, is in itself interesting. This was our first inkling that the 'fall in love with your curve' strategy had some merit to it. It was clear to see that the pupil's attention had been lost for a spell as they dived into their data. It was also clear that there was a heighten interest from some of them to bring home the sensory devices to see what kind of information about them it would contribute with.

Before ending the day, we presented appropriate methods of conducting science where we stressed the importance of being reflective in what they were doing and documenting their observations for example by writing a journal and possible taking photos to document their inquiry. This was to give them a narrative or understanding that results from their inquiries were expected at the end of the teaching programme. It was joked by their teacher Niels that their graders would be heavily dependent on the end results, joke we were fond of repeating as it did seem to make the concentrate even though they were in on the joke.

At the end of the day, we told them to form groups and decide who from the group would carry the sensor through the weekend. We had purposely planned to end the day early, compared to their normal teaching schedule. This was in order to give them a chance to experiment with their newly acquired sensory device, but also a test of how well we had instilled curiosity in them. Did they stay for a while at the school to try and conduct measurements, or did they take the opportunity to go home early?

The pupils were left with the sensors and all we could do was wait until Monday before we knew if their inquiry with the particle sensors had been successful.

SECOND DAY OF TESTING

Returning to the school Monday, we were excited about how well the pupils individual inquiries with the sensor had been. We hoped the device would have fostered curiosity and made them wonder about how they could use the sensor to learn about their environments.

We started the day by asking the pupils what they had experienced during the weekend in relation to the sensor. We wanted to know if they had experienced anything they did not expect and if it had changed their view on certain things. This was in order to gage their attention to the sensor.

[11] We encourage the reader to test this on their own device.

Had it been a passive object that they had been told to carry with them or was it a mediating device about reality that could give new experiences?

It seemed hard for the three pupils, who had had the sensory device over the weekend, to pinpoint exactly what had been different than what they expected. It seemed like it had been difficult for some of them to read the data from the sensor and also that they had not really expected anything before they started to measure. Beforehand, we had agreed that we would ask the pupils, who did not have a sensor over the weekend, what they had experienced that was relatable with air pollution and if they would have found it interesting to have a measuring device in these instances[12]. This was also an attempt to initiate a group brainstorm about what could be interesting to test with sensor in the coming days. By not only asking the students, who had a sensor, what cases their lives had presented in relation to air pollution, but also engaging in a reflective thinking process about what scenarios could be interesting to seek out, we hoped to activate a deductive reasoning in relation to the device on a class level. The exercise was actually very beneficial to the learning scenario for them, based on their engagement. Many of the pupils had been in situations where they would have found it interesting to have a measuring device. One of the pupils had been in the city centre and wondered about her exposure to air pollution due to more saturated street traffic. Another pupil had been near a truck where black smoke was pouring out of the exhaust and been keen on measuring the effect it had on the air quality in his proximity.

The next part of the programme was arranged as a workshop where the pupils had to work in their assigned groups with the data that had been gathered during the weekend. We asked the pupils to download the data their Google Timeline had collected during the weekend, and to extract the air pollution data from the sensor. When this was done, they had to upload both datasets to the myAir web platform. During this process, we kept a keen eye on how easy the task was for them. Most of the pupils were not accustomed to working with data files and needed more guidance than we had expected. This gave us a good feedback for later development on the myAir prototype. It should have to be easier to handle the data on the platform, and we found that there should be guide included for the teacher on how to supervise the pupils in this process. We also found two bugs with the web platform that unfortunately took a while to figure out. This

[12] See Appendix II – The Three-day teaching guide for the type of questions we asked.

meant that some of the groups where quicker done with the assignment than others. We found that having the groups differentiate too much in what task they were doing gave rise to a frustrating experience for the pupils, a harder time for the teacher to keep track on their progress and a loss or repetition of information, due to the pupils' attention not being in the same state at the same time. While fixing the bugs would have prevented many of these issues from happening, it also made us acutely aware on how quickly a workshop session can derail if not closely monitored. In retrospect, we found that having prepared a more thorough introduction to the initial tasks would have helped, but also having new tasks ready for students completing their assignments ahead of time to keep them occupied while the other students caught up.

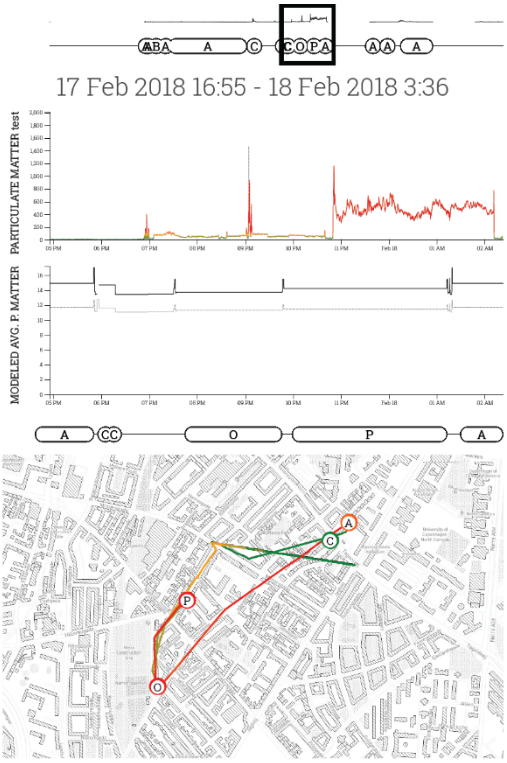

Figure 13 - An example of the myAir web platform. The data is a sample collected before the three-day test at Gentofte (Madsen et al, 2018a)

When the pupils had parsed and merged their data with the myAir web platform they were able to see both where they had been geographically during the weekend and how exposed they were to particulate air pollution in these places (Figure 13). Two of the pupils had been to family birthday parties, one at an inn and another at a family member's apartment. They had both been in proximity of smokers, which clearly showed on the graphs on the web platform. It surprised them how visible it was and made them realise to a greater extend that they had been passive smokers in the situations, even if they had not sensed it at the time. As they had moved around the city they were able to detect which streets had been more polluted than the other at the time.

The last pupil had been home playing computer games most of the weekend instead of gathering geographically dependant data. As a case for testing the prototype, his data was not very interesting in relation to the data he had collected, but interesting as a critique of the prototype. We found that our test group of 10th graders did not transport themselves a whole lot. Since they were not old enough to drive a car or old enough to go out at night they were mostly dependant on their parents to transport them and arrange activities. To our surprise, they did not move around that much on their own initiative. As our prototype were built to sustain the complexity of geographical data, we anguished that the pupils did not really use this feature much. Although the pupils did not move around a lot during the weekend, when they had travelled the data produced was very granular and made the pupils able to see small changes in exposure to particulate matter.

An interesting learning for us was that the pupil who had stayed in during the weekend had also been the most adamant on having the sensory device before the weekend. He gave many examples on activities he would do, none of which he actually ended up doing. This did not surprise their teacher, Niels, and goes to show that a certain amount of knowledge and phronesis is needed to navigate the teaching kit in a real situation. Knowing what pupils are more likely to live up to the tasks given to them has a big effect on the success of the later learning situation, especially since the rest of the group were dependent on the data collected.

As they went through their data, we would point out interesting parts of the data and ask them what they thought it meant. From our own experience, to look and read a graph, or data in general, takes practise and experience. It cannot be expected from most people that insights and learnings are easily had when they are first greeted by a new type of data. During the Copenhagen sprint, it had also taken us a while to figure out which parts of the pollution graphs was interesting and which parts were mundane. This is not always intuitive to do. For this reason, we guided their attention to parts of their data that we could tell would give them interesting data-stories about their air pollution. We asked questions like: See that spike there, what is that? What were you doing at that time there? Where were you then? Was there a source of pollution nearby? Could it had been other factors? These questions were a way to enhance anomalies or to reduce the static or straightforward.

Building hypothesis

The schedule for the last part of Monday were for the pupils to develop a hypothesis based on what they believed would be an interesting air pollution case to study. Based on this, they had to plan their own small-scale research experiments that could either verify or reject their hypothesis. We were told by the teacher Niels before the programme started that this might be a challenging exercise for the pupils, who had never done any type of scientific research before. We had therefore chosen to do a thorough but simplistic walkthrough of how to develop such a hypothesis, how and why to minimise variables, and asked for the inclusion of a test and control in the research. In plenum, we asked the pupils to brainstorm ideas of what to study and how an experiment could be carried out. This was an attempt to move from the inductive reasoning, the teaching programme had suggested so far, into a more deductive reasoning. By first getting them interested in their collected data about themselves and getting them to reflect on what stories the data told, we now wanted them to try to build their own stories and test these stories out.

The pupils had many thoughts and ideas about what could be studied with the use of the sensory device and web platform. Some wanted to test different railway stations, bus stations, diesel car vs petrol cars, and styles of cooking. One pupil had a very interesting idea of testing how much his family members polluted when they went to the toilet and if levels of pollution could be lowered by putting the lid down or not while flushing. While this sounds puerile or childish, the reasoning behind it was an excellent case of curiosity and deductive reasoning. If air pollution smells and toilet visits smell are there then a connection between the two, and will a change of habit, i.e. having the toilet seat up or down, effect outcome? This was exactly the kind of experiment we had hoped for, from the pupils, even if the topic of investigation did surprise us and the rest of the class. Even though he believed it would have been an interesting study, he eventually decided that it would be too comprehensive due to the many variables, and maybe a bit unethically to study his family going to the toilet. However, we found it important to commend on his originality and pointed out how his reasoning had been sound.

After an in-plenum discussion with the class on hypothesis building, the pupils went back in their groups and started working on writing up a hypothesis and an experiment to test it. The first group decided on cooking eggs in several different ways and measuring the difference in pollution. Group two decided to fry spices on a pan, with and without oil, to measure if there was a significant difference. Group tree took advantage of the ability to record geolocation with the prototype and measured the particulate matter in four stores in their local neighbourhood.

The pupils worked in groups to discuss and plan their research design. When they were done they went out to do their inquiry with their devices. Due to their chosen hypothesis very, little geolocation in was part of their inquiry. We therefore tried to add more information around exposure to air pollution, when travelling, by including examples of our own data during the pre-testing of the sensory device. We realised that including this type of data in the teaching programme to begin with not only gave the teacher a better idea of what kind of projects to suggest to the pupils, but also gave a data set to work with if one of the group lost the data, or the data wasn't that geolocation grounded.

THIRD DAY OF TESTING

Tuesday was the last day of the test programme. We asked the pupils to work in their groups for the first part of the day, to examine the data they had gathered the day before. We then asked them to prepare a presentation with their research design, results, and conclusion to their hypothesis.

We had presumed that a lot of guidance was needed on how to build a good presentation, but our presumptions were disproven. It was clear most of the students were used to building up presentation with slideshows and constructing a narrative. However, understanding data, translating it into a story, and visualising the story proved to be a more challenging assignment than we had expected. How data are aggregated and calculated into averages were a difficult task. It was also hard for the students to understand what were comparable and what were not. We were told by the teacher Niels, that although this was new for them, it fitted very well with the over-all curriculum. As such, it was a good exercise for them at this time, and he felt that the level of challenge was suitable. Mind you, this group of pupils were also selected for their interest in the science and math classes, so it might have been too hard for other students. Because of this, a lot of the time went in learning how do build graphs and present data in numbers. We had not initially thought this would be one of the main learning objects before the day started, but from testing this part of the teaching programme could see that math, statistics, and spreadsheet skills should be a more explicit part of the over-all teaching programme.

It was a pleasure to see how the pupils showed ownership of their data and presentation while working on them. They build neatly made presentation with a thorough walkthrough of their methodologies and results. Many of the pupils even prioritised to work in their lunch break to create a nice presentation, a signal that something was at stake for them. The pupils had all been active in choosing what to study, how to do it, and also carrying out the experiment, which seemed to have a positive effect on the engagement and feeling of ownership. There was a level of proudness to their work. There were also an added, although implicit, competition towards the work they did. It seemed that there was a feeling of not wanting to present shoddy work to their peers.

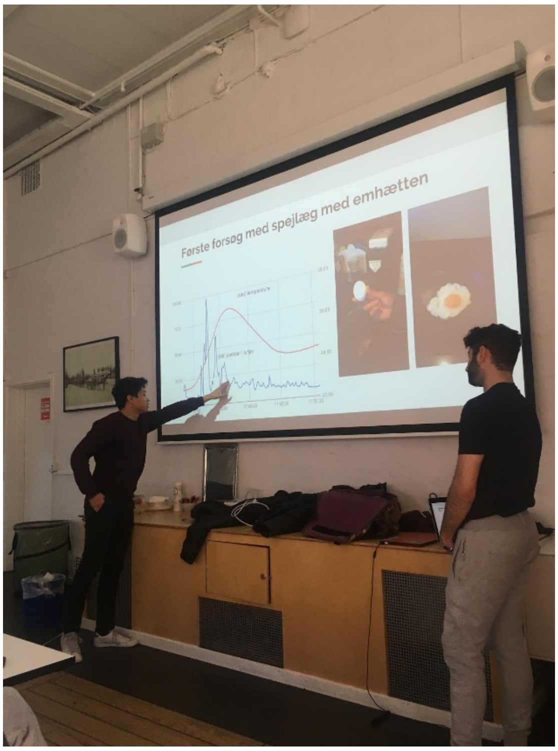

Figure 14 - One of the groups are presenting their experiment and explaining the change in air particles while frying an egg.

(Photo taken during field work)

All three groups had constructed presentations with a well-described narrative that told a story about what they had done and what they had concluded (See Figure 14). They provided a great overview of their methods and results and were either able to confirm or disconfirm their hypothesis. The pupils were in most cases excellent in referring to the theoretical knowledge about air pollution they had been taught the first day of the programme.

During the presentation, we allowed the other students to comment and critique the work of the presented. This is a feature that has often been used in our own study. By presenting your work to your peers for critique, we have found that it can a learning experience both for the one receiving the critique as well as the one giving it. To include this in the programme was thus a natural way of having the groups worked reviewed.

We had hoped the pupils would point out things that were uncertain in the presentation or things that could be improved. However, it was clear, from the tension and few questions from the class, that the students did not feel comfortable with this type of open peer-critique. It was not a type of forum they were used to being evaluated in, while also having to tell your friends problems about their work that they were clearly a social obstacle not easily ignored. Luckily, we did not have this obstacle and so started to praise and critique the presentations and their research. There is an important pointe to be made here, however. These types of social interaction that might but the pupils outside their comfort zone, in a social context, have to be more thought out and facilitated beforehand. How to critique and how do it in a way that doesn't attack the person being critiqued is not an inherent skill. Depending on the class and the dynamic within, this type of scenario could create a split in social dynamics of the class. This doesn't mean that the peer-critique should not be used, but it should have been facilitated. As we later presented out data and interpretation, we suddenly saw a lot of questions and critique being hailed at us in a tongue-in-cheek way, especially as some of the critique was the same we had told the pupils just moments before. For us, this proved that the model of peer-critique has its value, although needs to be guided.

FEEDBACK FROM THE PUPILS – NEW UNDERSTANDINGS AND PERSPECTIVES

As an ending to the programme, we facilitated a small feedback session. We wanted to know how the pupils had experienced our teaching and the programme in general over the last couple of days.

In general, the pupils were positive about the programme and had found it interesting most of the time. But there had been room for improvement in some areas. The pupils all agreed that they had learned something from the programme and that they had been challenged in their understanding of air pollution. One of the students said:

> *"Now I will think about not to be in the same place for too long, if there is a lot of pollution, so I won't be affected by it" (Feedback Session, 20.03.2018: 1h 04m, translated from Danish)*

One of the ways they had been challenged had been where air pollution derives from. In our teaching the first day, the pupils were taught about particles and gases ability to travel vast distances with the winds. This learning was continuously made more robust by the pupil's inquiry with the sensors. When the pupils had been places exposed to winds from ferry routes or near constructions sites, the pupils were able to detect changes in their data to support this learning. This example shows how theoretical knowledge and individual inquiry support each other and strengthens the learning.

We were curious about the balance between group work in the classroom, group work outside the classroom, and lecturing. We asked the pupils about how they had found the balance and got deviating answers. Some pupils had found the balance to be appropriate, some had found that they would have wanted more time to experiment with the sensors, but one pupil also expressed that the experiments with the sensors had been cumbersome and would rather have had more theoretical lecturing. To this, they also mentioned that the learnings around global air pollution impact on their local environment, as well as stories about the history of fighting pollution, was a welcomed addition to the theoretical lecturing and could have filled more in the programme.

We asked the pupils what they would have preferred if we had a day more in the programme. The pupils mostly agreed that it would be great with teachings away from their normal surroundings in the school, where they tested the sensory device. They had ideas of going to a power plant or an incineration facility to measure the effects of being in proximity. One student explained how he found it much more interesting to be taught while moving around than being stationary in a classroom:

> *"I think it is most exiting to walk around with the sensor. Then you are active instead of sitting and watching the blackboard." (Feedback Session, 20.03.2018: 1h 12m, translated from Danish)*

On the second day of the programme, the pupils had to handle their data and use the myAir web platform to merge it. There were some problems with loading the data and we had to do technical support during exercise. In the feedback session on the last day, the pupils expressed this situation as a bit confusing and frustrating. If the prototype is to be iterated, the coding of the platform would have to be altered to make it easier for the pupils to merge the data. In the ideation phases in the design of the prototype, we imagined that the web platform would be able to analyse the data input and output aggregates and calculations based on the user's preferences. Since the web platform were almost entirely coded during the five-day sprint in Copenhagen, this was not feasible to implement in such a short amount of time. Instead, the pupils used Google Sheets as a tool to analyse their data on the third day of the programme. This worked as a concept, but the pupils struggled with how to use Google Sheets.

> *"It was not really understandable in the beginning before you explained it" (Feedback Session, 20.03.2018: 1h 13m translated from Danish)*

The pupils had found it interesting to be able to calculate their data and were eager to build a good presentation about their measurements and how they had calculated them. As we are testing a prototype and not a final product, the prototype does not have to be perfectly designed and ready to use. In this case, we actually found that once the pupils had learned how to calculate their results using Google Sheets, they were really proud of the result and how they had been able to calculate the results themselves. If the prototype had calculated these results for them, they might not have had the same learnings and feeling of accomplishment. This goes hand-in-hand with the previous finding that math and spreadsheets are suitable teaching topics that might be a permanent fixture in the five-day teaching programme.

The pupils thought the idea of having to hold something in their hands was a great way of making things more interesting in a learning situation. One pupil said, in relation to the sensory device:

"Always, what interests me and what I have noted other people think is interesting, is when you are able to hold something physical in your hands." (Feedback Session, 20.03.2018: 1h 9m, translated from Danish)

The prototype was built on the principle of taking active part in the data gathering in a way that supports the teaching. By using the sensory device, the pupils take action and are familiarised with the process, and ownership of the data is enforced. By being an active part of it and holding the sensor, the subject becomes more familiar and personal.

The pupil further explained how to take the personal experience even further:

"If you could bring a gram of pollution, to show us how much it was. Or if you could bring a box with sod or something." (Feedback Session, 20.03.2018: 1h 11m, translated from Danish)

Seeing and touching what is normally not visible or tangible was something this pupil were very susceptible to, so that it made a memorable impact. Bringing something forward that is not accessible under normal circumstances is the mediating role of the prototype and what we had strived to design.

INTERVIEW WITH NIELS

Early in the morning on the busy streets of Copenhagen, on National Labour Day, we are excited about seeing Niels again, the teacher who allowed us to test our prototype in his class. While *we* were *preparing the last couple of things* and *having some bagels from the buffet,* through *the door comes Niels and presents himself with a; "Hey guys! Long time, no see!".*

After some catch-up and small talk, we turned on the audio recorder and started to interview Niels about how he thought the programme had gone. When asked about the overall programme of the teaching kit,

Niels told us that we had done a very good job creating and taxonomy, structure and progressions, and it seemed like we had been using Bloom as inspiration. He points out that we came to a very high level of taxonomy:

"The progression of the programme was very good. You guys pulled it to a high level, where you fed [the pupils] with knowledge, and made them use that knowledge afterwards. Very didactical – a bit Bloom'esque [Benjamin

Bloom's taxonomy]." (Interview w/ Niels, 01.05.2018: 02m 47s, translated from Danish)

A question that we had been asking ourselves after the fieldwork were if the educational level was high enough, or maybe too low. When we asked Niels about this, he pointed out that there was some technical stuff that not even he would have been capable of solving. It is not obligatory to use spreadsheets in the Danish school system, so, he explains, that many teachers would probably feel challenged with even the simplest Excel task;

"Just a simple thing like 'text-to-columns' could be a major challenge. I am not an Excel specialist, and I think that many teachers feel the same way. Those small things could probably make many teachers run their head against the wall. (…) The Pupils' know-how is also very limited." (Interview w/ Niels, 01.05.2018: 05m 03s, translated from Danish)

This notion of the technical part is something that we found very interesting, because it is a big part of our teaching kit. Therefore, we felt like exploring this a bit further. A bit contradictory Niels actually wanted more Excel, because he also saw this as an important part of the learning process. He felt that this was one of the more challenging parts, but also a suitable to have more focus on how to calculate and analyse data in spreadsheets. Just a simple task like making a graph would be something that the pupils could learn a lot from. He points out that it is an important skill, but that it may be more suitable for a math teacher to teach it. He uses another software that is a bit more intuitive in his lectures.

"[graphs in excel] I think that was really cool. (…) There is a lot of physics teachers and math teachers that could learn the children some useful stuff. I think it was very good that you included it, and you could maybe have done some more out of it – it's an important skill. Personally, I don't use it during class, I use another program which is a bit more intuitive." (Interview w/ Niels, 01.05.2018: 08m 01s, translated from Danish)

The quote above paved the way to a discussion about one of our main focal points of this thesis; what was the concrete learning yield for the pupils? Niels told us that one of the cool things about the programme was that we encouraged the students to make research themselves. When they are investigating their own behaviour and do the research themselves, the outcome is also very individual. While someone might learn a lot about air pollution, some might find it more interesting to make a nice-looking graph that show their exposure. This way there is something for everyone. He emphasises that it is good to encourage curiosity and create a knowledge platform that gives room for reflection.

> *"This is one of the cool things about this project, because it encourages the pupils to investigate the things themselves. (…) I think it is important to open up the possibilities from the beginning. It is great that you make room for reflection, that encourage to learn something new." (Interview w/ Niels, 01.05.2018: 10m 22s, translated from Danish)*

Exactly this way of reflection was something that we really strived to achieve. Firstly, by letting the pupils make up their own hypothesis', which Niels also points out can be a bit dangerous because they have not done it before, so they do not know how to make a good one, and therefore make the hypothesis too easy. It takes background knowledge to know the difference between good research and fun research.

> *"It is always great to make pupils work with hypothesis' (…). But you need to find the right balance about how much you should control it. (…) It is new to them, and it requires some knowledge to distinguish between exiting and fun." (Interview w/ Niels, 01.05.2018: 12m 33s, translated from Danish)*

The teaching kit was also created in the hopes of seeing a change in the student's behaviour within the classroom and maybe also their position to certain topics. Niels told us that it was clear to him that they had learned a lot during the programme, and that we created a whole new way of thinking for the students. All the students in the classroom were non-smokers, but he had seen that their opinion had been even more critical when they found out that you actually could track the particles from tobacco in their clothes after being to a party and such. He pointed out one of the pupils especially, whose character had changed radically. Where she normally is a quiet and shy girl she took a lot of responsibility for her group during the programme.

> *"They had a wonderful experience! I think it was very clear to see that they learned a lot. It has also really made their head spin in regard to certain topics and made them reflect upon things like smoking. (…) They were in*

general much more engaged. (…) Anna[13], for example, was super cool. She really surprised me. She is very introvert but really brought something to the table during the programme." (Interview w/ Niels, 01.05.2018: 16m 46s, translated from Danish)

During the interview, we were very curious about the different types of pupils you meet as a school teacher. It was not a secret that Niels had specially selected the kids for us and thereby taken some of the "better" pupils, which made us reflect about how it would have been to have tested the teaching kit on another more diverse class. He points out that the reason for some of the other pupils in the 10th grade in Gentofte are in the 10th grade is because they are 'inbetweeners', understood as pupils who have not made a decision about which way type of education they want continue with. He points out that some of the other type of pupils at the school would probably have given up and left the classroom if they had encountered any technical issues, or maybe even would have lost the sensory device.

"You wouldn't have been able to teach the same way. The sensor would probably not have been returned as well." (Interview w/ Niels, 01.05.2018: 22m 01s, translated from Danish)

He does, however, point out that it would have been a good thing to try out the prototype on the other types as well. There would probably had been some difficult situations, but they would also have gained a lot from it and would maybe have been more creative in their approach. But on the other hand, with the technical issues that we experienced, they would probably not have been as persistent.

"It would, however, have been really cool to have tested on the other group as well. There would probably have been some chaotic situations, but I think they would gain a lot from it. They would maybe have been a bit more 'out of the box', been a bit more creative, and brought some more abstract hypothesis' to the table. (…) On the other hand, if any technical issues had

[13] The name of the participant has been changed due to ethical considerations (see chapter about Ethical Considerations). The true name of the participant is known to writers of this thesis.

happened they might've left." (Interview w/ Niels, 01.05.2018: 23m 19s, translated from Danish)

In the end of the interview we wanted to investigate if Niels thought the whole reasoning about doing academic research is too early for pupils in their age. Niels explicated that he did not think that, but that it may had been great to include more in our presentation about famous academic research. That we could have given them a bit more theory and background knowledge in the beginning.

> ***"[Is it too early to teach pupils at this level about academia?]*** *No. I don't think so. (…) It is always fun for them to hear about. You could actually have given them a bit more, during the first session.*
>
> *I generally think that it worked out VERY well!" (Interview w/ Niels, 01.05.2018: 39m 29s, translated from Danish)*

As a last question, we asked him if he could be interested in doing something like this again, he said:

> *"Hell yeah! Of course, I would!" (Interview w/ Niels, 01.05.2018: 47m 32s, translated from Danish)*

After we had ended the interview, we turned off the recorder and talked a bit about the place we were sitting. Apparently, it was one of Niels' favourite places, and he used to work there when he had just moved to Copenhagen. He told us that if we wanted to test the teaching kit again in one of his classes, when it was further developed, we should not hesitate to ask.

We finished our cup of coffee, went outside, where we, with air pollution deep embedded in our minds, ironically enough smoked a cigarette and agreed to grab a beer after our hand-in.

Discussion

In this section we will discuss how John Dewey's ideas about learning relates to the learning scenarios and experiences observed during our fieldwork in Gentofte 10th grade centre. We will also discuss if the prototype mediated a new reality for the pupils and if the programme in its entirety were able to encourage reflective thinking.

EXPERIENCE BASED LEARNING IN GENTOFTE

To answer questions about air pollution, the pupils who participating in our three-day programme had to gather data about themselves to obtain a certain kind of new knowledge. On the second day of the programme, the pupils build hypothesis' and later answered them through data gathering and experiments. They also had to handle and analyse the data to be able to prove or disprove their hypothesis. This is one example of the Deweyan approach *learning through experience.* In this case the pupils learn about scientific inquiry through their own observations and through the challenges they meet along the way.

Dewey distinguish between direct and indirect experiences. The difference lies in how data is acquired. Dewey explains this through an example of war. By going to war and experiencing the agony, pain, smell, etc, you are confronted by direct experience. By reading about war in a text book or hearing stories from a person who have experienced war, you are acquiring indirect experiences of war. Relating Dewey's example about experiencing war to our case, the pupils are directly experiencing what it means to gather data and do scientific inquiry. We guide the pupils to create hypothesis' and test them, and they thereby experience the complexity of the task of doing something that can be called scientific method.

We made sure to provide the pupils with just enough knowledge about what a hypothesis is and how to test them in a scientific way, while not telling them what to test. The pupils had to reflect on their experience and understandings and find their own problems to investigate. This also gave them the opportunity to build the experiment around a personal context, e.g. to test things in their own homes or local environment. We saw, as we had intended, that they all engaged inquiries that was grounded in their own lives.

The notion of direct and indirect experiences is also relevant in regard to the theory of mediation offered by postphenomenology. There are several things in our programme that mediate and translates reality. The sensory device is most obvious, a technological artefact that translates air pollutants into numbers. The web platform also mediates a certain kind of view around the data collected by the device, as it translates the numbers into graphs, colours, and locations. Lastly, the teaching programme is also a mediation device, as it suggests certain answers to the moral questions of air pollution and how to understand them. While it is not the most obvious mediator, think of the strategies build into it. The 'betrayal of the data' or 'the falling in love with your curve' are both suggestions on how to understand data in a context. The combination of all the elements of the myAir teaching kit is in its totality an artefact with an inherent morality designed into it. Its objective is to move a student from a certain view of reality, where air pollutants are abstract entities, to a new reality, where pollutants are concrete elements in their local environment that should be avoided. The mission is to instil behavioural changes in the pupils and hopefully advocate these changes to their parents and friends.

We would argue that if this happens, an embodiment between the pupil and air pollution has happened. While Ihde and Verbeek describes embodiment as when a technological artefact extends the capabilities of the user through mediation, we would here argue that the teaching kit extending the understanding and reasoning skill of the pupil through its mediation of reality. It is the specific kind of thinking that is being extended and thus embodied. In our chapter about postphenomenology, we quote Ihde paraphrasing Galileo as saying to experience his new-found reality through his telescope, a hermeneutic skillset is needed. We would say our teaching kit implements the skillset needed to understand air pollution, while at the same time mediates the new phenomenon as an embodied experience for the pupil. The combination of a Deweyan pragmatic learning style and a postphenomenological understanding of inherently designed morality mediates a new way of interpreting reality.

Knowledge is iteratively constructed, happens every day and in various settings. To do their data gathering and test their hypothesis, the pupils had to physically move away from their classroom to do experiments. One of the groups went to several stores in their local community, one group utilised a kitchen in the school, and the last group experimented in one of the pupils' homes. By changing settings, the pupils were able to meet new stimuli, which fosters creativity. The teacher Niels also valued this feature of the programme and liked how the pupils were challenged when they had to change setting.

THE MEDIATING ROLE OF MYAIR

The purpose of the prototype was to mediate new understandings of air pollution by enabling the pupils to access data about their surroundings. Through this mediation, it should enable the pupils to tell local stories about air pollution based on their own personal and contextual data. As mediation theory is understood by Verbeek, artefacts are able to provide material answers to moral questions. This notion should deliberately be sought to be incorporated into the design of the prototype. The way our myAir prototype was developed should allow the pupils to visualise their exposure to air pollution, and thereby be able to embody a new understanding of the air they breathe.

In the test, one of the pupils unwittingly measured how he had been exposed to passive smoking when he had been at a birthday party. The pupil had already an initial understanding of the lowered quality of the air, but by using the prototype his understanding was challenged. With the use of the prototype he was able to detect a change in the air quality that was much higher than what he had expected it to be. This encounter with the technology, in this case the sensory device and the myAir web platform, made him able to see the world in a different way. Particles in the air were not visible to him before, but he now had a reading on his computer that gave him a whole new understanding about his reality.

Another example of the mediating role was how one of the groups used the sensory device to study different stores in their local community. With the use of the sensory device they could measure how much particulate matter was in the air in five stores located in their neighbourhood. The data they produced in their small case study might not be robust enough to offer a conclusion worthy of academic significance, but it sets the foundation for further reflective thinking about their exposure to air pollution. It leads them to be aware of what factors and variables are relevant in this complex issue. In this case, the pupils became reflective about why the readings had been high or low in the different stores and came to the conclusion that it most have smoke from kitchens in the canteen or dust particles in the stores. However, when they compared the measurements in the stores to the measurements outside they saw that all the shops had comparable low amounts of air pollution. This led to a new type of understanding of what sources air pollution came from. It was no longer kitchens that was speculated to be the culprit, but the opening of the doors to outside pollution.

The prototype is a political artefact with an intertwined morality. The morality is that air pollution is bad and should be avoided. Higher readings of particulate matter are visualised red in colour in the visualisation and lower readings are visualised in green. This visualisation supports the pupils in taking moral decisions related to air pollution, by the underlying premise of wanting to be in the "green zone". Through this design process, there has been an intentionality towards the political aspect of the artefact, along the same mentality as Verbeek's 'ethical turn'. As technological artefacts are already morally inclined, intentional or not, it would be better to be aware and active in the ethical design of the technology, but also be transparent about it. We would claim that the myAir teaching kit has lived up to this.

INDUCTIVE AND DEDUCTIVE THINKING

One of Dewey's arguments was that learners should be moved between being inductive and deductive in their approach. The programme in the prototype was designed in such a way that students had to do observations, in order to see patterns, and do inductive reasoning to ground these patterns in context to their own life. The pupils were also asked to work with a deductive approach, by testing hypothesis'. In this way the pupils were encouraged to do both.

To critique our approach, the shift between working with an inductive and a deductive could have been more fluid throughout the entire three-day programme. If we had repeated this shift more and made it more obvious to the pupils, we could maybe have been able to evoke more reflective thoughts. This is of course a gambit and focusing on this shift would sacrifice other parts of the programme, which already spanned over limited duration of time.

We would here add that a certain insight knowledge about the pupils is an important factor to knowing when to push one way and when to push another. As we discovered in the field in Gentofte, each pupil as very different, not only in know-how but also in temperament. This demands a lot from the teaching kit, as it must be flexible enough for the teacher to accommodate the difference in pupils, while being easy to understand and straightforward at the same time. It demands a lot from the teacher. She needs know her class well enough to implement and adapt the teaching kit in the best suitable manner, while taken individual needs into account.

LOCAL AND LOCALITY

During the design of the myAir teaching kit, we had long discussions about what it means for something to be local and how to build the feeling of locality into the prototype. We ended up taking advantage of geolocation data from pupil's smartphones to contextualise data about air pollution.

While locality is what is geographically in your nearby surroundings, local is what you personally associate with in your locality. This was why we found locality relevant in relation to what local is. But local is more than locality, it is also about being a part of something. It is a relation to something more personal than locality. *Local data stories* were a term discussed in the data sprints in the London and Copenhagen. The notion of making data local can be about localising it with geolocation, but also about creating personal data by mirroring the individual, that gathers the data, in the data.

John Dewey do not speak about local data stories, but instead he speaks of direct and indirect experiences, which can be interpreted as local or not local. Direct experiences that the pupil senses are a local experience, while an indirect experience which we would interpret to be non-local experience. This speaks to the importance of grounding the pupils' experiences locally in their world. The associations between their local connections and the knowledge they create through direct experiences is the purpose of the teaching kit.

The teaching programme was designed to support local inquiry grounded in the pupils' lives to make for a personalised learning programme. By generating data about the pupils' lives and adding information or stories that are able to give the pupil a disturbing shock or a feeling of confusion, it should evoke reflective thought according to Dewey. We encountered this on our own bodies while testing the sensory devices in a bar where it was allowed to smoke. We were all shocked about how much pollution was in the air, which made for many thoughts and discussions afterwards. The pupils in our programme had similar experiences. One of the pupils had experienced how big an impact passive smoking at a birthday party had affected his daily average of exposure, which made him think about his father's smoking habits and how it affected him in his home. This is a hyperlocal experience that modelled data from the official sources would never be able to give him.

During our ethnographic field work in the 10th grade centre, we realised that two of the groups had not taken advantages of the geolocation feature of the prototype, when building hypothesis and testing them. They had instead been interested in testing particulate matter while cooking food in different ways. We realised that their type of experiments was not grounded in geolocation. This was a big mistake in our part, but it made us realise that geolocation had to be much more prominent in the teacher's guide and in the teaching programme. This grounding is an important aspect of the myAir teaching kit, as it allows the pupil to translate stories that involves movement around their locality into experiences about their locality thus turning it into local experiences. By using the sensory device coupled with the geolocating phone as mediators between air pollutants and the pupil's journeys, the experience of air pollution can be embodied into the habits of the pupil.

By this, we draw on the postphenomenological explanation that when your understanding is changed due to the mediation of the technological artefact, your future experiences would also be affected. In our case, this means that the new experiences around air pollution and its sources would affect future actions, e.g. travelling or visiting bars with smoking rooms, and thus our new reality and experiences, created by the prototype, has been embodied in us.

This change, on how you see reality; now filled with sources of air pollution that was hitherto unknown, could be the means to which habits would also change. In other words, the strength of the myAir teaching kit is to personalise the exposure of air pollutants into their understanding of local and their experience. Even though measuring indoor air quality when cooking, which two of the groups did, would give valuable insight for the pupils to the hidden world air pollutants, it would neglect many of the moral questions the teaching kit was supposed to help them answer.

This gives critique to our execution of prototype, specifically the freedom of developing their own hypothesis. While Dewey advocates for the students to learn from mistakes, it is the job of the prototype to guide them in to the 'right' kinds of mistakes, so they will also encounter the 'right' kind of solutions. It is an important insight about how personal data about air pollution is not always bound around location, but also around interest and what happens in those locations.

HOW DID THE PROTOTYPE MANAGE?

Since the inception of the teaching kit, it has undergone many changes; starting out as a thought and ending out as a high-fidelity prototype. Part of the criteria for success was how well it was received by its users.

As we were introduced to Niels Gorm, during the second data sprint in Copenhagen, we went with the immediate choice of testing the prototype in his class. When testing the prototype in Gentofte, we had a vision of encouraging an educational setting for the pupils and to do this by experimental based learning. One of our goals was that the pupils would be able to gain new experiences that would expand their view upon air pollution. After interviewing their teacher, Niels, it seemed that it did just that. He did, however, point out that it would have been interesting to test it on different types of pupils. It is important to point out that our testing group were a bit homogenous. Niels had many types of students he could have selected for the test group but had picked pupils with who were mathematical skilled and had an interest in physics and chemistry. It would have been interesting to see how the prototype would have managed in a different class, with pupils that might have had a harder time figuring out how to navigate the assignments and the sensory device. Niels pointed out in the interview that many disturbances might have occurred with such a class, but also that there might have been more creative solutions and experiments.

We saw how the teaching kit encouraged curiosity of the pupils and even made them change their characters. By a change of their normal setting, the pupils were able to experience new data and new ways of solving problems. We would argue that with the use of a Deweyan approach and a mediating technology it is possible to mediate new learnings.

As a final note, we would like to point out that even though the teaching kit was set in a context of air pollution, nothing limits it to a certain topic. The idea of using a Deweyan pragmatic approach, coupled with a postphemenological design principle, could be used in a number of themes. Developing a generic teaching kit on this basis would be a template for future teaching endeavours

Conclusion

We will now conclude on the following research question: "How can a technological artefact be designed to mediate local data stories to evoke reflective thoughts, in a learning situation?"

Through active participation, we have observed how a creative design process can be facilitated in data sprints to design a technological artefact with premeditated suggestions. In the design process the technology is ideated, prototyped, and tested iteratively to continuously further the development and design of the technology. By carefully designing a teaching program grounded in the pupils' own life and data about it, it is possible to add data points that mediate new understandings and that evoke reflective thought in learning situations.

We conclude that the pupils were susceptible to the educational programme and the concept of the prototype. From observations in the field and interviews with informants, we document how the pupils were able to achieve new understandings from the programmes mediation. The prototype offered the pupils a way of gathering empirical data about their own daily lives and challenged their understanding. The data gathered by the pupils were not always enough to draw conclusions, but in return forced them into reflective thinking and experimentation. Even when their experiment was inconclusive, they were still able to create stories from the data about their local, personal reality.

Perspective

Although the myAir teaching kit showed promise, we cannot yet state that it would change behavior, as was the original idea behind it, or that it installed the material answered into the pupils that we had designed it for. Even though we saw it live up to some of the pragmatic ways that Dewey suggest, there are still much to be done before we can say the prototype is a success. While it is a running joke in academia to end a report with "more research is needed", we will however claim that it was never our goal to run the design process to its end, and so the design process is not yet done for the myAir teaching kit. To continue the process, we would suggest three more iterations of the development of the myAir teaching kit.

The first would be to test the prototype on a teacher. In this report, we have named the pupils the end-users of the product, since they are the ones being targeted by the teaching kit. However, the true end-user are the teachers, as they will be the ones implementing the product. If they can't use the product, or if they disagree on the premise of the product, it would not be implemented no matter how well it functions on the pupils. As such, this product needs to be designed as much for the teacher as for the students, and thus must be fully tested to their criteria.

The second iteration would be to test on a 'real' class. By this we mean a random selected class that resembles a homogenous sample of a typical Danish class. This would test a more diverse type of pupils and reveal more common flaws that could be expected in the Danish school system. A control group could also be used, where the problems of air pollution at taught in a more common way, to see if myAir teaching kit is better tool for engaging student in a learning situation.

The third iteration would be to move the testing of the prototype to a London setting or other EU city. The SaveOurAir project was part of an EU project on how to use data to tell stories about air pollution on a multi-national scale. For the myAir to live up to this, it needs to be shown that the design can work in different cultural contexts.

DO WE PROVIDE NOVEL RESEARCH?

In the literature review we sought to find relevant cases of studies about personal data being used in teaching situations. We concluded in our literature review that little research has been made in relation to how personal data is used together with the learning principles of John Dewey in modern literature.

The novelty of the myAir teaching kit, and this study as well, is that we unfold how data about an issue can be transformed to include personal data and offer new understanding of reality through designed mediation. This way of using data, in the context of John Dewey, is not something there has been done much research about. It is, however, interesting to think about how Dewey have become such a big personality within academia, but still is not used combined of postphenomenology, as the two theories how much in common and are well suited together. We see this thesis as novel research in academia and hope it will inspire others to continue on this path.

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Appendix I – myAir teaching slides

Due to copyright restrictions, it is unfortunately not possible to include the teaching slides used during the three-day testing of the teaching kit, as it is not allowed to include copyright material in a publication outside the universities domain. The slides can be shared in specific non-commercial, educational only context in the EU. Please contact the authors for further details.

Appendix II – The Three-day teaching guide

Mischa Szpirt, Nikolaj Frøsig and Mads Retoft, 2018

"myAir" undervisnings pakke

myAir er en pakke med undervisningsmaterialer, der giver eleven mulighed for at udforske, forstå og diskutere luftforurening som et komplekst fænomen, der spænder over flere fag. Undervisningen tager udgangspunkt i elevens egen eksponering af luftforurening ved at inddrage flere forskellige datakilder:

- Niveau af PM 2.5 og PM 10 (partikelstørrelse), målt fra mobile Airlabs monitor. Eleven skal bære denne monitor i løbet af undervisningsforløbet.
- Geolocation fra Google Timeline. Eleven skal måle dette med sin smartphone.
- Data fra DCE. Årligt gennemsnit af luftforurening ved alle adresser i Danmark baseret på en modellering.

Dette dokument beskriver et udvalg af øvelser og læringssituationer, som kan bruges i undervisning.

Indholdsfortegnelse

Overordnet tidsplan
Undervisningsplan
Fredag
Mandag
    Opgave 1: Udforsk din personlige "Luftvej"
    Opgave 2: Sammenlign jeres personlige "Luftveje"
    Opgave 3: Afprøve hypoteser
    Læringsmål
Tirsdag
    Opgave 4: Konsolidering af hypoteser
    Opgave 5: Hvad har vi lært

Overordnet tidsplan

Fredag:
Eleverne for en introduktion til hvad luftforurening er.
Præsentation
Video
Artikler
Udlevering af sensor
De får tid til at teste og skal ud og måle
Introduktion til videnskabs metoder
God skik for indsamling og dokumentation af data.
Lørdag-søndag:
Eleverne har sensorerne med hjem og foretagere målinger

Mandag:
Eleverne lærer at arbejde med data og konsolidere det.
De arbejder med deres egen data og skal læse og annotere grafer.
De kommer også til at blive introduceret til hvordan man opstiller hypoteser og afprøver disse.
De tager ud i felten for at indsamle ny data

Tirsdag:
De analyserer deres data, og finder ud af om deres hypoteser passede.
De bliver introduceret til de officielle målinger, og ser hvorfor disse måske ikke stemmer overens med deres egen data

Skema (estimeret)

	Fredag	Weekend	Mandag	Tirsdag
09.00-10.30	Præsentation af forløbet + Undervisning i luftforurening.	Målinger	Snak om weekenden. Behandling, annotering og analyse af data	Behandling, annotering og analyse af data
10:30-10:45	Pause		Pause	Pause
10:45-11:30	Introduktion til Sensor, Google timeline Og dokumentation		Opgave 1+2	Opgave 4
11:30-12:45	frokost		frokost	frokost
12.45-14			Planlæg forsøg Udføre forsøg Opgave 3	Opsamling af forløbet. feedback

Undervisningsplan

FREDAG

Undervisning omkring partikelforurening og instruering om brug af sensor og indsamling af data.

Vi starter med at spørge ind til deres viden og bekymringer ift. luftforurening.

1. Dagen starter med undervisning i hvad luftforurening er. Der undervises i forskellige typer af luftforurening, kilder til forureninger og måder at måle på.
2. Eleverne får udleveret en Airlabs monitor. (hvis der ikke er nok til hver elev, må de være 2-3 elever pr monitor)
3. Eleverne bliver informeret om brug af monitor.
   a. De skal have monitoren med dem i løbet af weekenden.
   b. Monitoren må ikke ligge i en lukket lomme eller taske, da den skal kunne suge frisk luft ind.
   c. De skal huske at lade batteriet op. Batteriet holder i lidt mere end en dag.
   d. Monitoren er dyr og skrøbelig. De skal passe på dem!
4. Eleverne bliver instrueret i brug af Google Timeline.
   a. Ved at tænde for geo-tracking på deres telefon giver de appen mulighed for at vide hvor de er.
   b. De skal have denne funktion tændt i løbet af undervisningsforløbet.
   c. Eleverne bør slå denne funktion fra, hvis der er tidspunkter, hvor de ikke vil dele deres geolocation med google.
5. Eleverne bliver instrueret i dokumentation i løbet af projektet.
   a. Eleverne får udleveret en notesblok, som de skal tage noter i løbet af forløbet. Eksempelvis skal de notere, når deres omgivelser vil påvirke sensoren, f.eks. når der laves mad, nogle ryger i nærheden, om der er stearinlys tændte i huset, transportmiddel, mv.
6. Underviser giver nu eleverne lektier for. De skal se en video om luftforurening fra National Geographic og læse en artikel omkring luftforurening. (Her)

MANDAG

Eleverne har nu indsamlet data ved hjælp af sensorer og geotracking hen over weekenden. Undervisningen kommer til at behandle den data de har indsamlet.

I. Dagen starter med et fælles øjeblik, hvor underviseren spørger eleverne, om de har oplevet nogle spændende/mærkværdigt udslag på sensoren eller hvilke erfaringer de har fået i løbet af weekenden.
   a. Hvordan gik det med at have sensorerne med rundt?
   b. Var der nogen steder/situationer, hvor sensorerne målte høje målinger?
   c. Var der nogen steder/situationer, hvor der skete noget, der ikke var forventet.

II. Eleverne skal nu lære at arbejde med den data, de har indsamlet.

a. De skal gå ind på google timeline[14] og downloade deres data fra de relevante dage.
    i. Vælg dag
    ii. Ret data, så den stemmer overens med ens bevægelser, og evt. ubetydelig stedet ikker indgår data.
    iii. Tryk på tandhjulet i højre hjørne -- eksporter dagen til KLM filer
    iv. Gentag for hver enkelt dag de har foretaget målinger
b. De skal tilslutte SD-kortet fra sensoren til computeren, og gemme data i en mappe.
c. De skal nu uploade både deres data fra sensoren og deres timeline til myAir appen: https://medialab.github.io/personal-air-timeline/app/#!/upload
d. Underviser sikre at alle elever har forstået og klaret opgaverne.
e. I print sektionen er det nu muligt at se og manipulere med sin data.

III. Eleverne kan se deres data og skal finde ud af hvad den fortæller dem.
a. Opgave 1
b. Opgave 2

[14] https://www.google.com/maps/timeline

Opgave 1: **Udforsk din personlige "Luftvej"**

Eleverne i har løbet af weekenden indsamlet data, som de nu skal bruge til at analysere deres egen adfærd, og hvordan denne har indvirkning på den mængde luftforurening, de er udsat for.

Tidligere har eleverne lært hvordan man henter data ned og parser den i myAir hjemmesiden. Nu skal eleverne bruge denne data, til at lære om luftforurening gennem deres egen data. Gennem myAir hjemmesiden er det muligt at se niveauet af PM10 og PM2,5 partikler, de har været udsat for, og samtidigt se hvor deres målinger er blevet målt på et kortet.

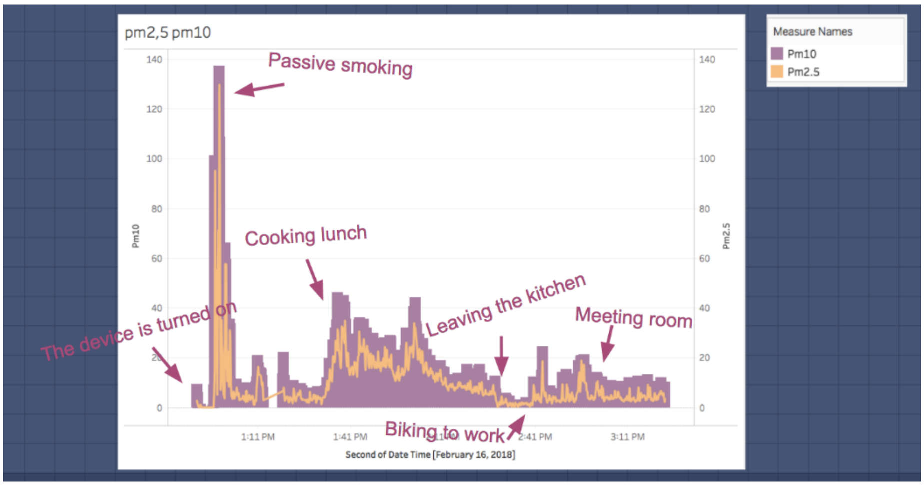
Ved at kigge på graferne skal eleverne, sammen med informationerne fra deres logbog og de billeder de har taget, svare på følgende spørgsmål.

- Eleverne skal vælge et udsnit af deres data, som de printer ud og annotere.
- Hvornår var min eksponering høj og hvornår var den lav?
- Hvad kan forklare hvorfor målingerne variere?
- Har de taget billeder, når der var høj eksponering af luftforurening?

Evt. opgaver kunne være:

- at finde sit daglige gennemsnit af forurenende partikler
- Udregne hvor mange partikler man har fået i lungerne (aktivitet->liter luft/min-> ug/m3)
- Sammenligne ens egne udsættelse af forurening vs. EU og WHO grænseværdier

Ex:



figur 1 - eksempel på annotering

Målet med denne opgave er, at alle elever får annoteret deres egen personlige "luftvej", og gennem dette forstår deres grafer bedre. Eleverne bør også opnå en forståelse for hvornår og hvorfor de måler høje eller lave målinger. Og danne sig nogle hypoteser omkring luftforurening generelt.

Opgave 2: Sammenlign jeres personlige "Luftveje"

Denne opgave lægger op til at eleverne, i deres grupper, nu har forenet deres hhv. Sensor og 'timeline' data. Hertil skal de kigge på sine "luftveje" ud fra disse målinger. Der skal nu dykkes dybere ned i data og annoteres forskellige cases fra deres målinger.

- Hvor var de på de forskellige tidspunkter?
- Hvor ses der udsving?
- Kan der dannes nogle generelle hypoteser omkring netop disse målinger?
- Kan det forklares hvorfor sensoren har lavet høje målinger et sted og lave målinger et andet?

Det er vigtigt for undervisningens udbytte, at læreren foretager en forholdsvis stram facilitering, og dermed guider eleverne til at tage ejerskab over deres data. Det kan være svært og relativt tungt, at dykke ned i så meget data, så der er en fordel, at læreren kommer rundt til grupperne og stiller spørgsmål til deres data, som dermed kan sætte dem i gang med de relevante diskussioner.

Eleverne har nu mulighed for at diskutere og hjælpe hinanden, til bedre at forstå hvorfor de havde høj eller lav eksponering af partikelforurening, i givne situationer.

Undervisningen starter ud med at være guidet forholdsvis stramt af læreren og udvikler sig forhåbentligt til, at eleverne kan diskutere med hinanden selvstændigt.

Til dette kan læreren stille følgende spørgsmål ud i klassen:

I. Ræk hånden i vejret hvis du er overrasket over noget på din "luftvej".
    - Eleverne rækker hånden i vejret og fortæller om deres scenarie, hvorefter læreren fremviser elevens resultater på lærredet, og dermed gennemgå elevens scenarie.

II. Ræk hånden i vejret hvis du tror du er i blandt de mest udsatte 30 procent.
    - Læreren finder to af de mest udsatte elevers timelines og sammenligner disse. Her skal de i fællesskab kigge nærmere på hvorfor de er blevet særligt udsat i disse situationer.

III. Ræk hånden i vejret hvis du er udsat for mindre end disse eksempler.
    - Læreren fremviser to af disse eksempler og lægger op til en diskussion af hvorfor nogle er mere udsatte end andre.

Underviseren beder efterfølgende eleverne om, at printe nogle udsnit af deres målinger fra myAir webapp'en. Eleverne kan inde i browseren bruge musemarkøren til at markere enkelte sektioner som de mener er interessante cases.

Eleverne bedes derefter om at præsentere deres udprint for hinanden og diskutere hvorfor deres målinger var som de var.

Eleverne kan eventuelt parres så der er diversitet i forhold til transportmiddel, rygning, distance fra skole, mm.

Formålet er at bruge den indsamlede data, til at åbne op for diskussioner omkring forskellige levevaner og hvorfor de resulterer i forskellige former for luftforurening.

Ting, der skal udpeges, er:

- Forskellige typer af transport midler (bus vs tog vs bil vs cykel/ben)

- Forskellen på indendørs og udendørs luft
- Handlinger, der har indvirkning på resultatet: madlavning, rygning etc.
- Eksterne faktorer, der har indflydelse på resultatet: Vind, temp., luftfugtighed
- Sensor artefakter: fejl i data, fejl i målinger, manglende data, forkert brug af sensoren etc.

Læringsmål
Eleverne har efterfølgende:

- Dannet sig et bedre sprog om luftforurening
- Lært at diskutere med hinanden om emnet
- Lært at præsentere en "finding" (forskningsresultat) og formidle det til udenforstående.

Eleverne har efterfølgende en bedre forståelse for:

- Udefrakommende faktorer
- Data artefakter
- Formidling af forskningsresultater
- Tracking
- Adfærd
- Vaner
- Transport
- Sociale faktorer
- Konsekvenser ift. Luftforurening i forskellige scenarier

Opgave 3: Afprøve hypoteser

Nu hvor eleverne har haft mulighed for at forstå deres data, handler det om at translatere deres personlige målinger til generaliserbare og kausale sammenhæng omkring luftforurening. Hvor deres nuværende fund højst sandsynlig kun har enkelte observationer, kræver videnskabelige målinger en mere grundig eksperimentel tilgang.

Opgaven her handler om at opstille hypoteser for hvordan luftforurening hænger sammen. Efterfølgende skal eleverne så bevise eller modbevise disse hypoteser med eksperimenter.

Baseret på deres hypotese, skal de beskrive en eksperimentel opstilling, der skal teste kilder eller årsager til forureningen. Undervisning skal her støtte op omkring hvordan man bedst indsamler og dokumenterer data og opbygger et forsøg. Journal, foto-dagbog, opstilling, fejlkilder, kontrolgruppe, etc., skal alt sammen være planlagt inden de går i gang med at teste.

De skal have:

- En hypotese, der skal afprøves
- En forsøgsbeskrivelse: Lokation, opstilling af måleapparat og test objekt (bl.a. afstand mellem testobjekt og sensor), beskrivelse af interne og eksterne faktorer/påvirkninger, kontrolforsøg, etc.
- En plan for dokumentation; Journal, Billeder, uddelegering af roller/opgaver

Resten af dagen går således med at lave forsøget. Eksempler på forsøg kunne være:

- Tage en rute med bus og tog, sammenlign resultatet.
- Cykel langs forskellige ruter (grønne mod grå ruter) og se forskellen.
- Mål forskellige indendørs situationer, madlavning, pejs, rygning. F.eks. hvad er mest forurenende: koge et æg, stege en fisk, bage en kage. Man kunne også undersøge forskellen på gaskomfur og keramiske/induktionskomfur.
- Måle forskellige steder: Kantine, restaurant, s-tog station, kontor, rygerum

- Sammenlign officielle tal med deres egen sensor (besøge en målestation, og sammenlign resultaterne).

Læringsmål
Den studerende vil have lært om:
- Hvordan tester man en hypotese
- Forsøgsopstilling
- Dokumentation af forsøg
- Hvilken indvirkninger/fejlkilder skal man være opmærksom på
- Hvordan man minimering af variabler og hvorfor det er vigtigt
- Aggregering af data, gennemsnit, og statistisk signifikans
- Præcision af målingsinstrumenter

TIRSDAG

Om tirsdagen skal de igen samle deres data på via webplatformen[15], og undersøge de forskellige scenarier/eksperimenter de har lavet.

Første del af dagen går på analyse og deling af resultater. Hvis der er tid, vil de kunne blive introduceret til flere variabler, der spiller ind i deres data. f.eks. offentlige data fra Københavns målere, "Luften på din vej" hjemmesiden fra DCE instituttet[16], trafikdata og vejr kunne også komme i spil. (Vores umiddelbare fornemmelse er, at der ikke bliver meget tid til dette. Men dette kunne være næste skridt i deres analyse, hvis de når så langt)

Anden del af dagen vil gå på at skrive deres fund op. En sides tekst, eller 5-10 min præsentation omkring deres eksperiment; hvad der gik godt, hvad der gik mindre godt.

Til sidst vil vi facilitere en feedback session, hvor eleverne kan give os kritik og viden om hele forløbet.

Opgave 4: Konsolidering af hypoteser

Nu hvor eleverne har udført eksperimenterne, og skabt sig en idé, om hvorledes deres målinger lever op til deres forventning, er deres opgave at konsolidere disse forventninger ud fra data. Dette gøres bl.a. ved at sammenligne kurverne mellem de forskellige målinger, overvejer fejlkilder - og hvilken indflydelse de har på deres målinger, samt alternative fortolkninger/forklaringer til det data viser og hvorvidt fortolkninger/forklaringer er mere sandsynlige end deres egen hypotese.

Eleverne parser deres data i webplatformen[17], og analysere deres fund. De forbereder herefter nogle resultater til fremvisning for resten af klassen senere. Under denne forberedelse for de støtte af underviser.

Lærings mål:
- Eleverne lærer omkring vindens indflydelse på luftforurening.
- Eleverne lærer hvad aggregeret data er.

[15] https://medialab.github.io/personal-air-timeline/app/#!/upload
[16] http://lpdv.spatialsuite.dk/spatialmap
[17] https://medialab.github.io/personal-air-timeline/app/#!/upload

- Hvad er statistisk signifikans.
- Hvordan man kan minimere variabler i et forsøg, og hvorfor er det nødvendigt.
- Præcisionen af måleren.

Opgave 5: Hvad har vi lært

Eleverne får nu mulighed for at præsentere hinanden for deres eksperimenter, og hvad de har fået ud af det. Det forventes at eleverne forbereder en 5-10 min præsentation af deres data, samt hvordan det har indflydelse på deres egen hverdag. F.eks. forskellige transportruter til skolen, madlavning i hjemmet, osv.

En del af præsentationen skal bestå af anbefalinger til at forbedre ens påvirkning af luftforurening baseret på deres indsigt fra opgave 1-4.

Et forslag til præsentation kan være:

1. Problematikken bag forsøget: Hvorfor dette forsøg?
2. Hypotesen: Hvad vil vi undersøge?
3. Eksperimentet: Hvordan vil vi undersøge det?
4. Indsamling af data: Hvad skete der?
5. Konklusion: Hvad har vi lært?
6. Perspektivering: Hvad betyder dette for os?

Appendix III – Five-day teaching guide

Feb. 2018

MyAir
An air pollution teaching kit

Anders K. Madsen, Anders K. Munk, Mischa Szpirt, Nikolaj Frøsig and Mads Retoft

MyAir is a teaching kit that enables students to explore, understand and discuss the phenomenon of air pollution with departure in their own 'personal air journey'. This journey shows where the students have been and how exposed to pollution he or she has been in different times and places. The local air journeys are constructed combining three data sources:

a) Levels of PM 2.5 and PM 10 from mobile AirLabs monitors that the students carry around with them on them.
b) Geo-tracking from Google Timelines that the student must have turned on in order to leave traces of where he/she was at a given point in time.
c) Data from DCE about a yearly averaged pollution level for every address in Denmark. This data is based on models.

This document described a selection of teaching exercises that can be done on the basis of these local air journeys as well as the needed preparation in order to make these exercises happen.

PREPARATION

Here is a list of preparations in order to prepare the teaching that starts Monday morning.

I. On Friday afternoon, monitors are handed out to students. We imagine that students split in groups of three and each group decides who gets to take the monitor home. This person agrees to three things:
    a. To carry the monitor with him/her for the whole weekend
    b. To turn on Google Timelines on his or her phone.
    c. To take pictures in places where he or she thinks that the exposure is high

II. In relation to the monitor the students are told about the way it functions. The most important information is the following:
    a. The monitor needs power, which means that the students must carry a charger as well
    b. The monitor needs to be in the open air when the student is moving around. This means that it cannot be in a jacket or in a bag.
    c. The monitor is fragile. The student needs to be careful not to damage it.

III. In relation to Google Timelines the student needs to know the following:
    a. Once the student turns on Google Timelines it will track where he or she is. This means that his or her personal journey through the weekend will become data that the class will look at in the coming week.
    b. Google Timelines will track the geo-location until its turned off. This needs to be done by the end of the project.

IV. As homework the students are given readings on the two types of particles that the monitor measures. These are PM 2,5 and PM 10. The students read these in order to get a basic understanding of the different types of particles and the sources that emits them.

V. Monday morning the students export the following two data-files that are needed to create their 'personal air journey'
   a. The first file is a KML-file from Google timelines. This is the geo-data that shows where he or she have been during the weekend.
   b. The second is the file from the SD-card of the monitor. This is the file showing the level of pollution the student have been exposed to during the weekend.
   c. These files are put in a folder and uploaded to a shared Dropbox.

VI. The teacher drags these files into the dedicated spaces in the 'reconciler' in order to create the kind of merged file that is needed for the exercises below.

EXERCISES

Here is a list of exercises that can be done with the students once the preparatory steps have been taken.

Exercise 1: Explore your personal journey

For this exercise the student-groups use a browser/device to explore the personal air journey of the student who have been carrying the monitor during the weekend. The view in the browser displays a timeline that shows the level of pollution that the student have been exposed to (aggregated - PM2,5+PM10) as well as a map that shows his or her movements during the time of measurement. The view is interactive in the sense that the students can click on a peak in the timeline and be guided to the place where he or she was when the measure was taken.

-

[fig 1. Insert picture of a personal journey view]

-

By looking at this timeline in combination with the photos that the student took during the weekend the group discuss the following simple questions:

- *When was the exposure high and when was it low?*
- *What can explain the variances in exposure?*
- *Were the photos actually taken at times where the exposure was high?*

The answers to these questions are used to annotate the timeline like in the example below. This is done on a printed version of the timeline. The outcome of this exercise will be that each student have a description of a 'personal air journey' and some hypotheses about the reasons for their exposure. These hypotheses can then be shared and discussed in class.

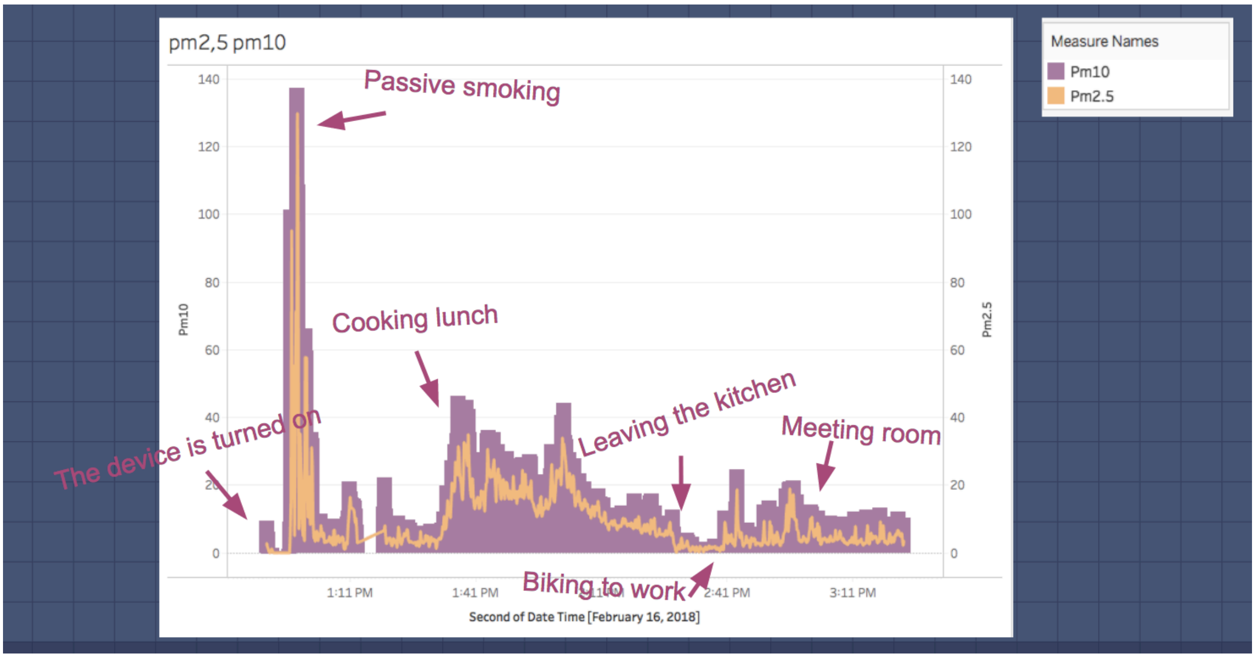


Fig 2: Mock-up of a tagged timeline

Based on this initial encounter with the timeline, the group use a slider in the browser to choose three specific situations that they want to explore further on a map. A 'situation' is a specific time slot on the timeline that catches their interest for one reason or another. Suggestions for how to choose the three situations could be: points where the curve changes, intervals where the curve does not change at all, points where the students decided to take a photo or points where the shape of the curve seem surprising given the students own knowledge of his or her movements during the weekend.

-

[Insert screen-dump of the slider and the choice of a situation]

-

When the groups have selected a situation for further exploration they set the slider on the chosen timeslot and print a physical copy of the view they see in the browser. They put this printout on the wall and discuss the following:

- *What is the link between the chosen situations and the geographical places in which they occured?*
- *What can these printouts tell us about the link between air pollution and cityscapes?*

After having discussed these questions the group visits another group to compare situations and thoughts. These are finally used as the basis for a shared reflection in class based on the following questions:

- *How is time, space and pollution linked in a personal air journey?*
- *What kind of practical changes should the students with the monitor try make to their journeys before tomorrow to try to lower their exposure to pollution?*

Answering this latter question will hopefully motivate the students with the monitors to take specific actions (such as changing their road to school) before they meet in school the next day.

Exercise 2: *Compare journeys in the class*

For this exercise the teacher gets access to compare the different local journeys of the class in a browser-view dedicated to that. Since the teacher is the only person who have access to compare data this exercise is performed collectively in the class. The teacher has access to filters of the different students and can thereby control the comparisons. Useful filters could include: students with the highest or lowest overall exposure; students with peaks at certain moments in the day, e.g. on their way to school; the two students with the most different timelines in terms of when they peak and/or in terms of overall exposure; filter by student name.

[Insert screen-dump of the comparison of timelines]

The teaching scenario is that the teacher asks the students to do the following:

> *Raise your hand if you were surprised by something on your personal timeline.*
> → A student shares a story/surprise and the teacher brings his/her data up on screen in order for the class to discuss the case.
>
> *Raise your hand if you think you belong to the most exposed 30% of the class.*
> → The teacher brings the data of two of these students up on the screen to discuss what high exposure looks like and also why the students think that this is higher than the rest.
>
> *Raise your hand if your exposure is lower than these examples.*
> → The teacher brings the data of two of these students up on the screen together with the two cases of high exposure just discussed. This leads into a discussion of why some students are highly exposed while others are not.

The aim of this is to leverage the data to open discussions about different habits/conditions of living and why they result in different forms of exposure. For instance, if two pupils who go to school through different roads have very different exposure levels, it would be relevant to discuss why this is so.

If we introduce the filtering right filtering options (see my comments above) we will also give the teacher the ability to point to surprising patterns or contrasts between the students, if they are not themselves immediately able to imagine how they could be different.

Exercise 3: Compare journeys to official data-models

For this exercise the groups go back to working with the local journey of the student who has the monitor. However, this time they get to see this journey in contrast to the official statistics and data-models that currently tracks pollution levels in the parts of town where they have lived. For instance, in Denmark this web-site provide a yearly average of PM2,5 and PM10 for each street level address: http://lpdv.spatialsuite.dk/spatialmap. The map draws on a model that is to a large extent based on the assumption that car traffic is one of the most important sources of air pollution.

During this exercise the student will be confronted with a view in the browser that illustrates how their personal journey would look if it had been measured with official data. The tool computes a graph based on the geo-track of the student's route and the official air pollution data. The view shows the actual graph as measured by the student's portable devices compared to the manufactured graph based on the official data. This allows the student's to explore where their own measurements disagree with the models.

[Insert screen-dump of the comparison of own measures vs official models]

The teaching scenario is that students focus on situations in their journey where the two types of measurements tell different stories. Focusing on these situations will be enable the group to discuss the following questions:

- *The official data knows your address, but does it get match your local measurements? Why/why not?*
- *Which of your exposure is NOT visible in the official models and what could be done to make these concerns visible?*

This teaching scenario can cover three related topics, for instance in a cross-disciplinary thematic block. Namely:

1. How does simulation modelling work? (Mathematics?)
2. How do sensors work? (Physics/chemistry?)
3. How do different ways of measuring and modelling air pollution support political decision making? (Social Science)

Exercise 4: From descriptive measures to experimental set-ups

In this exercise the aim is to get the students to think about what it would take to translate their personal measurements into generalizable and causal claims about air pollution. Whereas their own measurements are just single observations, science usually make its claims based on experiments where a test-group that receive a specific manipulation is compared to a control-group that does not.

This exercise takes departure in the hypotheses the the groups derived from the personal timelines in exercise 1 and the task of the class is to formulate a simple experimental setup that could confirm or disconfirm these hypotheses. These experiments can both take place outside or in the laboratory of the school. The important point is that in this exercise the monitors are used in an experimental way (e.g. half being the test-group and half being the control-group of the experiment.

Below we have tried to formulate some examples of hypotheses can could be derived from the personal journeys

1. Testing how wind influences the measurements.
<u>Hypothesis: The wind has an influence on the measured values.</u>

This hypothesis could be derived from exercise two. For instance, one student may have walked next to a smoker and found that it made a huge impact on the measure whereas another may not. They hypothesize that it may be the wind direction that is the cause of this difference. Or, all students may experience a higher exposure-level on a certain time of the day and realize that this was when the wind came from south and thereby carries particles up north,

Experiment description
In school hours, the teacher takes the student to the nearest street that cuts the direction of the wind (e.g if the witd comes from south the street has to be east-west). Half of the group stand on one side whereas the other half stands on the other side. The students measure particle levels for half an hour and come back and each of the groups upload

their measurements to a browser-view that aggregates the measurements and computes a chi-square test to know whether there is a significant difference.

[Insert a picture of tthis view]

The data is then uploaded and visualised in a part of the browser. The result will show whether the hypothesis is right or wrong.

How do you hold variable constant?

Learning goals

The students will learn about

- The effects of wind condition in relation to air pollution.
- What aggregated data is.
- What is statistically significant?
- How to minimise variables and why
- The precision of the measurement device

<u>Phase two:</u> **Laboratory setting**

The students will discuss how to minimise variables.

<u>Ex</u>. The students light a candle light, and generate wind with a fan. Particle levels are then measured in the direction of the wind and in the opposite direction.

2. Gas or ceramic stove in the kitchen

<u>Hypothesis: Cooking with a gas stove emits more particles than a ceramic stove.</u>

The students do this as part of their homework.

Experiment description

As part of the students homework, the students are asked to measure the particle levels in their kitchen as their family is preparing dinner. Some of the students will have a gas stove in their home and some will have ceramic stoves. The students place the measurement device at a given distance from the stove while dinner is being prepared.

The next day in the school, the students upload their data, and is able to compare with each other. The data should be converted to an average of the entire cooking period, and then to an average of all the students grouped by what stove they have.

(maybe they should be asked to cook without ventilation?)

Learning goals

- Statistically significant
- Averages and aggregates
- How behavior affects air quality
- Scientific lineup and documentation

3. Field trip to a measurement station.

<u>Hypothesis: The measurement device is 95% precise.</u>

This a field trip with the teacher(s)

This could possible be the first experiment, where the devices are tested and calibrate afterwards.

Experiment description

The teacher(s) and students all bring their device with them on a field trip. They are powered on at all times. The field trip takes place at the nearest measuring station in copenhagen. On the way the pupils and the teacher(s) make use of public transport and will be exposed to the same relative air. The data generated is then later able to be used to analyse the air quality in public transport, and the accuracy of the sensors.
When students and the teacher(s) arrive at the measuring station they stay there for 2 hours, and measure the particle levels. Since they will stay for two hours, they should have a lecture here or maybe use the time to count modes of transport (how many cars, bicycles, trucks etc.).
The data generated can be used to later calibrate the sensors and to calculate the accuracy and precision of the devices.

Learning goals

- Calibration
- Accuracy and precision
- Different ways of measuring
- Particles produced by vehicles

Exercise 5: From descriptive measures to games

For this exercise the groups get challenges that builds on the insights from exercise 1-4. These challenges can be solved using the monitors and the groups compete with each other to solve these challenges. An example of a challenge could be that the groups are told to take a one-hour walk in a 500m radius from the school with the aim of having as high exposure to air pollution as possible. The groups should - based on what they have learned in exercise 1-4 - decide on a route. When the groups return they each upload their data to the system and there is a dedicated browser window that compares their results.

[Insert screen-dump of the view that compares measurements]

Alternative exercises

Exercise ??: Make policy *recommendations Summarize & compare to other schools*

For this exercise we assume that when a school has previously worked with this teaching kit, they will upload a summary of their findings some sort of aggregated data and summary of their findings that other schools can compare to. This means that classes working with the kit have a collective task of:

a) Making a top 5 list of the most problematic situations of exposure that the class have encountered during their week of measurements (could be the final outcome of exercise 1 and 2)
b) Making a top 5 list of the situations of exposure where the class measures and the officiel models were most in disagreement (could be the final outcome of exercise 1 and 2)
c) Uploading an aggregate of the exposure-levels of the class during the week they worked with the kit

The teacher have access to retrieve these lists and aggregates in the browser from the schools who have previously worked with the kit:

[Insert picture of an interface for retrieving and comparing these lists and aggregates]

The teaching scenario is that the teacher has access to these lists and aggregates from other schools and retrieve these in order to discuss the following questions with the class:

This data can be accessed by the teacher at the end of the project. By comparing the data of the class with other classes who have use this.

- *What is the difference between our local problems and the problems of school [insert name]? What explains the differences in the lists and aggregates?*
- *How can we use that knowledge to make policy recommendations? How should be balance different concerns against each other? What weight should we attribute to different kinds of evidence?*

Appendix IV – Literature Review Articles

Articles selected in the literature review

1. Big Data's Call to Philosophers of Education
    - (Blanken-Webb, Jane, 2017)
2. Why Everyday Experience? Interpreting Primary Students' Science Discourse from the Perspective of John Dewey
    - (Na, Jiyeon; Song, Jinwoong – Science & Education, 2014) (Na & Song, 2014)
3. New Data, Old Tensions: Big Data, Personalized Learning, and the Challenges of Progressive Education
    - (Manni, Annika; Ottander, Christina; Sporre, Karin, 2017)
4. Students' Aesthetic Experiences of Playing Exergames: A Practical Epistemology Analysis of Learning
    - (Na, Jiyeon; Song, Jinwoong, 2014)
5. "Horrible or Happy--We'll Have a Little Grey Now": Aesthetic Judgements in Children's Narration with an Interactive Whiteboard
    - (Skantz Åberg, Ewa, 2017)
6. A Brave New World: Considering the Pedagogic Potential of Virtual World Field Trips (VWFTs) in Initial Teacher Education (Mediation)
    - (Fitzsimons, Sabrina; Farren, Margaret, 2016)
7. Empowering First Year (Post-Matric) Students in Basic Research Skills: A Strategy for Education for Social Justice
    - (Zulu, Constance, 2011)
8. "I See What I See from the Theory I Have Read." Student Teachers Learning through Theory in Practice
    - (Nilssen, Vivi; Solheim, Randi, 2015)

Articles not included in the literature review

1. Young Students' Aesthetic Experiences and Meaning-Making Processes in an Outdoor Environmental School Practice

- (Manni, Annika; Ottander, Christina; Sporre, Karin, 2017)

2. Learner-Centered Mentoring: Building from Student Teachers' Individual Needs and Experiences as Novice Practitioners

    - (Kolman, Joni S.; Roegman, Rachel; Goodwin, A. Lin, 2017)

3. The Level of History Teachers' Use Active Learning Methods and Technics

    - (Yildirm, Sefa; Akman, Özkan; Alagoz, Bülent, 2017)

4. Living in an Age of Assessment: The Quality Component

    - (Spaid, Robin L.; Parsons, Michael H., 2014)

5. The "Body Pedagogics" of an Elite Footballer's Career Path--Analysing Zlatan Ibrahimovic's Biography

    - (Andersson, Joacim; Maivorsdotter, Ninitha 2017)

6. Mapping the Entangled Ontology of Science Teachers' Lived Experience

    - (Daugbjerg, Peer S.; de Freitas, Elizabeth; Valero, Paola 2015)

7. Effective Learning Strategies in the History of Dress

    - (Marcketti, Sara B., 2011)

8. Building a Web in Science Instruction: Using Multiple Resources in a Swedish Multilingual Middle School Class

    - (Jakobson, Britt; Axelsson, Monica, 2017)

9. Trends in Research on Project-Based Science and Technology Teaching and Learning at K-12 Levels: A Systematic Review

    - (Hasni, Abdelkrim; Bousadra, Fatima; Belletête, Vincent; Benabdallah, Ahmed; Nicole, Marie-Claude; Dumais, Nancy, 2016)

10. Arabic and English during Study Abroad in Cairo, Egypt: Issues of Access and Use

    - (Trentman, Emma, 2013)

11. Educational Technology and Student Voice: Examining Teacher Candidates' Perceptions

    - (Byker, Erik Jon; Putman, S. Michael; Handler, Laura; Polly, Drew, 2017)

12. Elementary Teacher's Conceptions of Inquiry Teaching: Messages for Teacher Development

    - (Ireland, Joseph E.; Watters, James J.; Brownlee, Jo; Lupton, Mandy, 2012)

13. Voices of Pre-Service English Teachers: Reflecting Motivations during Practicum Learning

    - (Kuswandono, Paulus, 2014)

14. Aesthetic Experience as an Aspect of Embodied Learning: Stories from Physical Education Student Teachers

    - (Maivorsdotter, Ninitha; Lundvall, Suzanne, 2009)

15. Did the Preservice Teacher-Generated Studies Constitute Actual Instances of Teacher-Researcher Studies, and Were They Consistent with Notions of Dewey?

    - (Kretschmer, Robert E.; Wang, Ye; Hartman, Maria C., 2010)

16. Critical Participatory Looping: Dialogic Member Checking with Whole Classes

    - (Murphey, Tim; Falout, Joseph, 2010)

17. Using Media as Subject Matter to Teach Thinking

    - (Van Kannel-Ray, Nancy; Newlin-Haus, Esther, 2009)

18. Constructing a Doubt-Free Teaching Self: Self-Efficacy, Teacher Identity, and Science Instruction within Diverse Settings

    - (Settlage, John; Southerland, Sherry A.; Smith, Leigh K.; Ceglie, Robert, 2009)

19. Transactions in Primary Physical Education in the UK: A Smorgasbord of Looks-Like-Sport

    - (Ward, Gavin; Quennerstedt, Mikael, 2016)

20. Media Arts: Arts Education for a Digital Age

    - (Peppler, Kylie A., 2010)

21. Negotiating Authority in an Undergraduate Teacher Education Course: A Qualitative Investigation

    - (Brubaker, Nathan D., 2009)

22. Assessing the Validity of Can-Do Statements in Retrospective (Then-Now) Self-Assessment

    - (Brown, N. Anthony; Dewey, Dan P.; Cox, Troy L., 2014)

23. Foreign Language Houses: Identities in Transition

    - (Bown, Jennifer; Dewey, Dan P.; Martinsen, Rob A.; Baker, Wendy, 2011)

24. Does Measuring L2 Utterance Fluency Equal Measuring Overall L2 Proficiency? Evidence from Five Languages

- (Baker-Smemoe, Wendy; Dewey, Dan P.; Bown, Jennifer; Martinsen, Rob A., 2012)

25. Relationship between Reported Out-of-Class English Use and Proficiency Gains in English

    - Baker-Smemoe, Wendy; Cundick, Denisa K.; Evans, Norman; Henrichsen, Lynn; Dewey, Dan P. 2012)

Appendix V – Air Pollution Threshold Levels

TABLES OF THRESHOLD SET BY EU AND WHO

European Union

Guideline levels for each pollutant (µg/m3):		
PM2.5	1 year	25
	24 h	n/a
PM10	1 year	40
	24 h	50
Ozone, (O3)	8 h, daily maximum	120
Nitogen Dioxide, (NO2)	1 year	40
	1 h	200
Sulfur dioxide, (SO2)	24 h	125
	1 hour	350
Lead (Pb)	1 year	0.5
Benzene	1 year	5
Arsenic	1 year	000.6
Cadmium	1 year	000.5
Nickel	1 year	00.2

Table of guideline levels from data from the European Union (Ec.europa.eu, 2018).

World Health Organisation

Guideline levels for each pollutant (µg/m3):		
PM2.5	1 year	10
	24 h	25
PM10	1 year	20
	24 h	50
Ozone, (O3)	8 h, daily maximum	100
Nitogen Dioxide, (NO2)	1 year	40
	1 h	200
Sulfur dioxide, (SO2)	24 h	200
	10 min	500

Table of guideline levels from data from the World Health Organisation (WHO, 2005).