# Teaching Electronics and Programming in Norwegian Schools Using the air:bit Sensor Kit

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# Abstract

We describe lessons learned from using the air:bit project to introduce more than 150 students in the Norwegian upper secondary school to computer programming, engineering and environmental sciences. In the air:bit project, students build and code a portable air quality sensor kits, and use their air:bit to collect data to investigate patterns in air quality in their local environment. When the project ended students had collected more than 400,000 measurements with their air:bit kits, and could describe local patterns in air quality. Students participate in all parts of the project, from soldering components and programming the sensors, to analyzing the air quality measurements. We conducted a survey after the project successfully taught the students fundamental concepts in computer programming, electronics, and the scientific method. In addition, all the participating teachers reported that their students had showed good learning outcomes.

# Introduction

We have developed the air:bit, an Arduino-based air quality sensor kit that students build and program to collect air quality data in their local environment [1]. Together with the air:bit sensor kit, we developed teaching materials that include how to assemble the air:bit and how to program its different sensors, and a cloud based service for students to upload and explore their collected datasets. All of which are openly available online at airbit.uit.no. We used these resources develop an interdisciplinary course for students in Norwegian upper secondary schools, which we offered to different schools across Northern Norway.

From our first deployment of the air:bit project we identified a set of necessary improvements to scale out to even more schools. First, the initial version of the sensor kit did not provide the students with comparable data to official measurement stations. Second, because we wanted to invite more schools we had to improve how we shared resources such as programming guides to the students and teachers. Third, we had to improve the online platform for exploring the datasets to handle data from many geographically distributed locations. Fourth, we needed to develop a survey to investigate the student experiences to further improve the course and their learning outcomes.

In this paper we describe our experiences using the air:bit project in 11 Norwegian upper secondary schools. The participating schools were all in Northern Norway, but spread over a large geographical area. We developed a survey to collect information about the experiences and teaching outcome for both students and teachers. We used this study to investigate the prior knowledge about programming and electronics, the difficulties of the different parts of the project, and to highlight areas of improvement. We describe how we redesigned the sensor kit and its accompanying resources, the online data exploration platform and the student experiences from this second deployment of the air:bit project.

We believe our work provides insight for others that provide similar makerinspired projects to students without any programming experience, and that it answers some questions about the effect of such projects for motivating students to engage in computer science and other STEM subjects.

# The air: bit project

We initiated the air:bit project in 2016 and have since offered it to upper secondary schools at two separate occasions. First, in 2017 to a single school, and then in 2018 to 16 schools from across Northern Norway. In our previous publication, we describe the air:bit project, the first version of our air:bit and our experiences from the first participating class[1]. Here we provide a short background in air pollution, details of the second version of the air:bit sensor kit, and the other necessary improvements needed to offer the course to more schools.

## Motivation

While programming or computational thinking is added to the school curricula in countries such as the UK, Finland or Estonia, Norway is unfortunately falling behind[2]. Initiatives such as Lær Kidsa Koding<sup>1</sup> are working with legislators to introduce these concepts in the Norwegian educational system, but it is a time consuming process. Fortunately, certain science subjects in the upper secondary school allow teachers to add smaller projects that combine programming with the traditional sciences.

Air pollution is the largest single environmental health risk, and it contributes to respiratory disease, cardiovascular disease and certain cancers.[3, 4, 5, 6, 7, 8] Air pollution originates from a wide range of sources, and especially Particulate Matter (PM) from combustion engines and cars driving with studded tires is a major problem in Norway[4, 9].

With cheaper and higher quality sensors, combined with easy-to-use microcontrollers such the Arduino UNO, it is possible to develop small sensor kits with little previous knowledge and experience with electronics. Low-cost air quality moni-

<sup>&</sup>lt;sup>1</sup>kidsakoder.no



Figure 1: The second version of the air:bit sensor kit.

toring kits have already shown their effectiveness in citizen science projects, by reducing the high cost of developing such measurement stations.[10, 11, 12, 13]

## air:bit

The air:bit is a small microcontroller based data logger for measuring dust particles, air temperature, air humidity, GPS-based location, time and date. The kit is enclosed in a laser cut box, equipped with an external battery for portability. Table 1 lists the different components and their respective cost, and Figure 1 shows the assembled kit. We package and ship all components to each school in cardboard boxes.

We designed the kit as simple as possible to facilitate use in an educational setting. To simplify the assembly and soldering of the components to the microcontroller we use a custom PCB circuit board that has pre-defined pins for each sensor, and fits on top of the Arduino UNO board. New in the second version of our air:bit is the Nova SDS011 Dust sensor which allow students to collect data that can be compared to official measurement stations (PM2.5 and PM10). This sensor is more expensive than the previous dust sensor, but provides higher quality data. We also update the temperature and humidity sensor from the DHT11 to the DHT22. This sensor allows students to record temperatures below 0°C, which is frequent in Northern Norway. We also re-designed the box to make it easier for students to carry around.

We continue to use the standard Arduino IDE together with additional libraries to program the air:bit. The libraries provide the low-level functionality to re-

Table 1: A list of the different components in the air:bit along with their cost (as of January 2018).

Component	Cost (USD)
Arduino Uno microcontroller	\$3.00
NEO6MV2 GPS module	\$6.00
Nova SDS011 dust sensor(PM2.5 and PM10).	\$14.50
DHT22 temperature and humidity sensor	\$3.50
SD Card reader and 16GB memory card	\$9.00
Portable power bank	\$15.00
Custom PCB circuit board	\$3.00
Custom enclosure box	\$5.00
USB cable	\$2.00
Zip-lock bag with LEDs, resistors and spare parts	\$5.00
Cardboard box	\$1.50
Total:	\$67.50

trieve data from each sensor, and students use their respective APIs to assemble a program that collects data from all sensors simultaneously and write them to a memory card. We distribute example code to interface and collect data from the individual sensors. These are small examples typically less than 100 lines of code, and students typically end up with a complete solution of around 500 lines of code. The data is recorded to the memory card using a simple CSV file format that make it simple to view and inspect the output datasets.

#### **Improved Online Resources**

To allow more schools to participate in the air:bit project we had to improve the online resources. We developed detailed guides on how to solder the components of the air:bit, how to assemble the box, and how to program each sensor. We also included a resources page with video lectures on air pollution from environmental researchers from the Norwegian Institute for Air Research (NILU) and the The Norwegian Meteorological Institute (MET). All of these are available online at airbit.uit.no. These are open to everyone.

Together with the educational resources we developed the air:bit platform, a system for storing, exploring and visualizing air quality data from air:bit kits and other, external data sources.[14, 15] The system consists of three individual parts, the air:bit web application, a service for retrieving and uploading datasets, and a backed storage service. The air:bit web application provides students with

educational resources such as instructions on how to solder each component and program the sensors, in addition to an interactive visualizations of the air quality datasets. The other two services are responsible for retrieving student data and making them available through the interactive visualizations. We host the backend services on Google Cloud Platform which makes it possible for us to scale out if we get even more participating schools. Together with student data we also retrieve data from NILU and MET through their open APIs. By developing an online service that integrates the different data sources we make it easier for students to explore the heterogeneous data.

#### The 2018 air: bit Project

We have offered our air:bit course twice. The pilot was held in spring 2017 at the University of Tromsø to science students at a local High School (Kongsbakken Vidergående Skole). The second round was in spring 2018 with 11 participating schools, and 164 students from across Northern Norway. In the second round, the participating teachers chose to use the air:bit project in four different subjects, from all three years of upper secondary school. The 164 students built in total 62 air:bit sensor kits.

We invited schools to participate in the project at the beginning of the fall semester of 2017. The participating teachers were invited to a two-day workshop where the goal was to teach them how to assemble and program the air:bit sensor kits. 16 teachers participated and successfully built and programmed 15 air:bit kits. Following the teacher workshops the teachers themselves chose how to incorporate the air:bit project in their classroom.

In the spring of 2018 all participating classes were invited to attend a full day workshop where they got help to finalize the assembly and programming of the air:bit kits. Most classes only had minor programming issues, but some student groups needed help to troubleshoot their soldering and assembly. Following the workshop, each class returned home to start data collection.

During the spring of 2018 students uploaded more than 400,000 unique measurements to our online web application. The class with the largest number of data points used their data to investigate and compare air pollution levels on the outside playgrounds of local kindergartens.

## **Evaluation**

We developed two surveys to investigate learning outcomes and experiences from the air:bit course, one for students and another for teachers. Specifically we wanted to investigate: i) the students prior experience with programming and electronics; ii) how much time students spent working on the project; iii) the overall difficulty of the project; and iv) the programming specific learning outcomes, e.g. knowledge about variables and loops.

All questions were written in Norwegian, and we present their English translation in this paper. We have also translated the free-text responses from the students and teachers. We distributed both surveys online using a service similar to Questback.

#### **Student Experiences**

To investigate the student perceived learning outcome and experiences from the course we asked the students to answer a questionnaire consisting of 14 multiple choice questions, and 35 statements answered on a five-level Likert scale. Of the total 164 students, we received 90 individual responses. This gives 55% answer rate. Of the 90 responses 64% were boys and 36% girls.

Table 2 shows the reported number of weeks spent working on the project and Table 3 shows the reported number of hours spent every week working on the project.

Less	4 to 8	9 to 12	13 to 16	More
than 4	weeks	weeks	weeks	than 16
weeks				weeks
4%	20%	45%	27%	4%

Table 2: Reported number of weeks spent working on the air:bit project.

Table 3: Reported hours spent working on the air:bit project every week.

Less than 1	1 to 2	3 to 4	More than
hour	hours	hours	5 hours
10%	23%	50%	17%

We asked the students to evaluate the difficulty of several tasks in the project. Table 4 shows the questions and how the students responded. From the table we clearly see that the students found it easy to get an overview of the components and solder the air:bit together. Further the students fount the LEDs, the temperature and humidity sensor, and the dust sensor relatively easy to program. However programming the GPS and memory card was a more difficult task. The most difficult task of all was to assemble all the individual parts into a single program. More than half the students answered that it was either difficult or very difficult.

Table 4: Survey results from reported difficulty in completing the different tasks of assembling and programming the air:bit.

Statement	Very easy or easy	Nor easy nor difficult	Difficult or very difficult
Get an overview of the components	83%	13%	3%
Solder the components	80%	18%	2%
Program the LEDs	73%	18%	9%
Program the temperature and humidity sensor	50%	39%	11%
Program the dust sensor	46%	41%	13%
Program the GPS	20%	37%	43%
Program the memory card and memory card reader	28%	42%	30%
Assemble the different programs into a single program	15%	32%	53%

Further we asked the students to evaluate seven statements regarding their knowledge prior to starting the project.

94% of the students reported that they used the online materials while they where building and programming the air:bit. From these, 83% reported that these where either to a large degree or to a very large degree helpful. 14% reported that the online materials where to some extent helpful, while 4% reported that the

Table 5: Survey results from the self-ass	essed general knowledge before and af-
ter participating in the air:bit project.	We have combined the top and bottom
categories.	

Statement	Very little or	Neither little	Much or Very
	Little	nor much	much
How electrical	32%  ightarrow 17%	39%  ightarrow 33%	29%  ightarrow 50%
circuits work			
How to solder	23%  ightarrow 8%	22%  ightarrow 14%	55%  ightarrow 78%
electrical			
components			
How to write a	39%  ightarrow 18%	38%  ightarrow 32%	23%  ightarrow 50%
computer			
program			
What an Arduino	46%  ightarrow 13%	28%  ightarrow 28%	26%  ightarrow 59%
is and how to			
program it			
How to plan and	24% ightarrow 8%	29%  ightarrow 30%	47%  ightarrow 62%
execute a			
scientific project			
How to collect	39%  ightarrow 8%	$31\% \rightarrow 30\%$	30%  ightarrow 62%
and analyze			
research data			
How to	36%  ightarrow 12%	41%  ightarrow 38%	24%  ightarrow 40%
determine			
measurement			
uncertainty in			
research data			

Table 6: Survey results from the self-assessed programming knowledge before and after participating in the air:bit project. We have combined the top and bottom categories.

Statement	Very little or	Neither little	Much or Very
	Little	nor much	much
What a variable	49%  ightarrow 29%	17%  ightarrow 28%	34%  ightarrow 43%
is and how they are used			
	$50\% \rightarrow 31\%$	$26\% \rightarrow 28\%$	$24\% \rightarrow 41\%$
What a data type	$30\% \rightarrow 31\%$	$20\% \rightarrow 28\%$	$24\% \rightarrow 41\%$
is and how they			
are used (e.g.			
float or int)			
What a loop is	56%  ightarrow 35%	22%  ightarrow 24%	22%  ightarrow 41%
and how they are			
used (e.g. a for			
loop)			
What a logic test	54%  ightarrow 34%	20%  ightarrow 25%	36%  ightarrow 41%
is and how they			
are used (e.g. an			
if test)			
How to debug a	63%  ightarrow 30%	19% ightarrow 29%	18%  ightarrow 41%
computer			
program			

material was not at all or to a small degree helpful.

We asked the students to rate how satisfied or dissatisfied having participated in the air:bit project. 69% of the students reported that they were satisfied or very satisfied, 23% nor satisfied or dissatisfied and 8% reported that they were very dissatisfied or dissatisfied.

We also left a text field where the students could enter free-text comments to the project. In total 17 students used this opportunity to give us comments. From these 17, two students wrote that they were given instructions that the air:bit kits could be used outside, and that the kits had malfunctioned from extensive outside exposure (5 days). Another student noted that the air:bit box was a bit too small for all the components. One student reported "It is a difficult project, but it's fun". Another student wrote "The project was very fun, but much of the work following the data collection it was pretty gruesome to complete. However, I learned a lot of lessons of how complicated such processes are". One student wrote that they did not get the programming guidance they needed when they visited the university. Another student wrote that the programming was too easy, and that it did not challenge the students. One student requested a guide on presenting research data.

## **Teacher Experiences**

We developed a short survey for the teachers that where involved in the project. Of the 11 participating teachers, 8 replied to our survey. From the responses we got an overview of the time spent on the project, their knowledge about programming and microcontrollers prior to the project, and the learning outcomes for their students. The survey consisted of multiple choice questions and a free text field where they could enter their own comments.

Of the 8 replies, all teachers responded that their students had significant or very significant learning outcomes. All teachers also responded that they would recommend other classes to participate in the project. More than half of the teachers reported that they had much, or very much knowledge about electrical circuits, soldering, programming, and how to plan and execute a scientific project. However, there were still teachers who reported that they had very little or little experience in all of these areas.

From the free text responses, one teacher reported that the students became a bit tired towards the end due to the process of writing up their findings. One teacher said that the motivation was highly variable between the students and groups, and that they did not feel any ownership to the programming due to a lot of copy-pasting.

# Discussion

Unfortunately we were unable to distribute the first set of questionnaires before the project started, and another after the project. This meant that we asked the students after completing the project to evaluate their knowledge prior to starting the project. We believe that this could have an impact on the responses.

One of the participating classes ended up not programming the air:bit sensor kits themselves, but sharing a complete solution. We did not make it possible to identify specific classes from individual responses, so we could not exclude the responses from these students. These students will not have completed all the different programming tasks, and we believe that they may influence the results.

# **Conclusions and Future Work**

We have successfully deployed our air:bit project to schools across Northern Norway. Doing so we have introduced more students to computer programming and electronics. The new version of our sensor kit provides higher quality datasets, and together with the online resources the kits are easier to assemble and program. The results from the surveys show that students enjoy the project and have positive learning outcomes. There are still students that report that they are left with little knowledge on programming and fundamental concepts in computer science after participating, and we aim to improve this.

One area of the project we have not discussed yet, is how to analyze the collected air pollution measurements. This has been left out to the teachers, but we are experimenting with interactive Jupyter<sup>2</sup> notebooks that allow students to interactively explore their data with statistical programming languages such as R or Python.

We are currently in the process of organizing a third round of the air:bit project with even more participating schools. We aim to continue improving the course contents and will use the responses from both students and teachers to do so.

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 $<sup>^2</sup>$  jupyter.org

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