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# D2.8 Evaluation report of learning outcomes of high school students after participating in air quality projects

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| **Abstract** | This deliverable evaluates the learning outcomes of high school students participating in ACTION's air quality pilot in Norway and the overall impact of these activities. |
| **Keywords** | Citizen science in high schools; air quality project; Arduino based sensors; learning outcomes; impact assessment |




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# 1. EXECUTIVE SUMMARY

This deliverable contains the evaluation report about the students' learning outcomes after participating in the ACTION air quality pilot together with an analysis of other impacts of the activities. In this pilot, high-school students in Oslo and the greater Oslo area carried out their own air quality science projects, by using an Arduino-based air quality sensor platform the students built themselves. They presented the results on a scientific poster. The aim of the pilot activities was to raise awareness and educate about air quality problems in the greater Oslo area amongst both students and teachers.

In order to assess the learning outcomes and to analyse impacts of the air quality pilot, we applied a framework that has been developed within the ACTION project. It considers five areas of impact: scientific, social, economic, political and environmental, which are articulated in several dimensions each, for a total of 24 dimensions. These include, but are not limited to, impact on scientific knowledge, community empowerment, inclusiveness, impact on learning, behavioural change, impact on policy process, job creation and economic empowerment of local communities. The methodology also considers the transformative potential of the pilot, i.e., the degree to which the pilot can help to change, alter, or replace current systems, the business-as-usual in one or more fields such as science production or environmental protection. The methodology follows a mixed method approach, combining qualitative and quantitative data gathering methods. It is designed to be modular and flexible in order to adapt more easily to the specific characteristics of each citizen science pilot but, at the same time, assuring a cross-pilot and cumulative analysis. Since not all the dimensions are (equally) relevant for all pilots, depending on their nature, their specific focus and the level of citizen engagement, the specific needs of each pilot in terms of impact assessment and the relevance of the various dimensions were collected and presented by help of an impact assessment canvas in advance of the actual impact assessment. For the air quality pilot, focus was put on the impact areas "Social", "Environmental" and "Other" (transformation of educational curricula).

Data for the impact assessment were gathered by help of questionnaires. At the first pilot round in 2019, we distributed only an ex-post questionnaire to the participating teachers and students after the end of the pilot activities. In the second round of activities in 2020, we distributed an ex-ante questionnaire at the beginning and an ex-post questionnaire at the end of the pilot activities to both teachers and students. All questionnaires consisted of closed questions, open questions and Likert Scale-based questions.

In conclusion, we can say that the pilot had positive impacts on the awareness of air quality issues, on the acquisition of news skills and competences (on the topic and on technology) and on the interest for the topic and for science more generally. The impact on behavioural change is not as evident as the impact on learning, only a minority of students thinking of changing their behaviours. The majority of students already show a positive attitude towards the environment at the beginning of the pilot, so the trigger for changing behaviours was less cogent. It could also be mentioned that at least from the teachers' point of view, the pilot did also positively impact the relationships within the engaged classes.

The pilot activities have a scientific impact in terms of innovation in education. They demonstrate an innovative way of implementing the current school curriculum, which states that students should learn how to work scientifically. Rather than assigning the students another paper, the project is an immersive way of teaching scientific skills. Also, the project has been highly appreciated by the teachers because of its interdisciplinary character and the students' independence. The social impact of the activities lies in its ability of community building and community empowerment. All in all, the project scores medium to high on transformative impact, which means the project contributes to changing business-as-usual towards a more sustainable world.

# 2. INTRODUCTION

This deliverable is a result of the EU H2020 funded project ACTION (Participatory science toolkit against pollution). One of the main objectives of the ACTION project is to establish a citizen science accelerator to support hands-on citizen science activities to combat and prevent major forms of pollution in the EU. The accelerator started with a set of five citizen science pilots, one of them being "Air quality measurements in high schools", the pilot that is the basis for this report.

This deliverable is a complementary report of D2.7 "Tutorial for air quality projects in high schools". The previous deliverable described in detail how ACTION partner NILU carried out the citizen science pilot "Air quality measurements in high schools". In this pilot, high-school students in Oslo and the greater Oslo area had the opportunity to carry out their own air quality projects. The students used an Arduino-based air quality sensor platform, equipped with a Nova SDS011 sensor to measure $PM_{2.5}$ and $PM_{10}$ pollution levels. They could add additional components for measuring e.g., relative humidity, temperature, noise or $CO_2$. The results were presented by the students themselves at a joint student conference.

D2.7 described in detail how this project was planned and carried out. It also contained a detailed tutorial that described step-by-step how those that are interested in carrying out a similar project could proceed, how to build a sensor, how to code it and where to find additional (teaching) resources.

This deliverable D2.8 contains the evaluation report about the students' learning outcomes after participating in the ACTION air quality pilot, together with an analysis of other impacts of the pilot. While D2.7 focused only on the activities carried out in 2019, this deliverable describes the learning outcomes and impacts after participating in the activities in 2019 and in another round in 2020. The first round took place in 2019 and engaged 7 school classes; the second round took place in 2020 – however, due to Covid-19 only 3 of the originally 10 school classes completed the activities. The evaluation survey for the first round was carried out at the end of the 2019 activities, while in the second round both teachers and students completed an *ex-ante* questionnaire before the project activities and an *ex-post* questionnaire after the completion of the project activities.

In this report, we describe the methods and we analyse the results obtained from the students' and teachers' questionnaires (chapter 4 and 5). We discuss the outcomes (chapter 6) and conclude by providing a conclusion and lessons learned (chapter 7).

# 3. BACKGROUND

## 3.1 Citizen science activities on air pollution

Citizen science (CS) activities have been ongoing for several centuries, mostly under other labels than CS, exploring nature from a layman's perspective. Over the last hundred years, scientists have been utilising the help of volunteers especially in environmental observations of astronomy, meteorology or ornithology (Schaefer & Kieslinger, 2019).

The rise of advanced ICT technologies, such as mobile internet or smartphone applications, fostered public participation in scientific activities on issues relevant to their local environment and to have easy access to data and information about its state (Liu et al., 2017). This development has opened for new opportunities for environmental monitoring and led to a large number of citizen science and citizen observatories activities.

Another important factor that fostered this development is the rapid development within sensing technology, such as low-cost sensor systems for air quality measurements. Traditional air quality monitoring is carried out with large instruments that are certified by an official regulating body and that are operated by a national, regional or local authority. These monitoring devices form official air quality monitoring networks for regulatory compliance checking. Traditional air quality monitoring is usually connected with high costs, regular on-site maintenance and calibration by trained people. Low-cost sensor systems on the other hand are small, easy to handle and comparably cheap devices that measure air pollutants and deliver data about concentration values to the users (EEA, 2019).

Many citizen science activities have been initiated during the last decade addressing air quality issues by using low-cost sensor systems (e.g., Sensor.Community[1], EU H2020 funded project hackAIR[2], NFR funded iFLINK project[3]). Even though the collected data are not yet of equally good quality as the ones produced by monitoring devices used for official air quality monitoring, they can provide valuable indications about variations in air pollution over time and at places that are not covered by official monitoring stations. Low-cost sensor system networks can therefore be used for complementing measurements taken by official air quality monitoring stations and help to improve air quality models. And last but not least, low-cost sensor systems for air quality can be used for

[1] https://sensor.community/en/
[2] https://www.hackair.eu
[3] https://iflink.nilu.no/en/home/

raising awareness about local air pollution problems or for educational purposes as in the pilot activities at the center of this report.

## 3.2 Application of low-cost sensor systems in high school education

As part of the ACTION project, partner NILU carried out the citizen science pilot “Air quality measurements in high schools”. The Norwegian core curriculum for primary and secondary education claims that “school shall allow the pupils to experience the joy of creating, engagement and the urge to explore, and allow them to experience seeing opportunities and transforming ideas into practical actions” (Utdanningsdirektoratet, 2017, p.7). This matches with the core idea of the citizen science pilot “Air quality measurements in high schools”. By applying low-cost sensor systems in a high school education context, the students were able to actively engage with the topic of air quality with the overall aim to raise awareness about air pollution in Oslo. The pilot activities targeted high schools that offer “Technology and Science Education”. The curriculum for this subject aims at providing basic insight into natural science, technological challenges and issues in society. It shall provide a holistic understanding of technology and natural science being in constant development and the ethical dilemmas connected with this. At the same time, the subject shall provide a basis for assessing and discussing technological products and their consequences for society (Utdanningsdirektoratet, 2006).

ACTION’s citizen science pilot “Air quality measurements in high schools” meets the needs outlined by the Norwegian Directorate for Education. Our activities allowed high school students to design their own research project, building their own air quality sensor measurement devices, carrying out measurements, interpreting and presenting results in a scientific format. These activities should contribute to fostering a holistic view of a scientific and technological topic with relevance for both, themselves and society.

The aim of the pilot activities was to raise awareness about air quality problems in the greater Oslo area amongst both students and teachers. Similar activities have been carried out in the air:bit project[4] of The Arctic University of Norway, where activities have been designed to build air quality low-cost sensors and introduce high school students in Northern Norway to computational thinking and engineering (Fjukstad et al., 2018). They applied a similar approach by introducing the topic to the participating teachers and providing sensor-kits to each class. Students were then supposed to measure air quality with the self-built and programmed sensors and upload their data to a common data portal. These activities were focusing mainly on the technology aspect, whereas the ACTION pilot approached the topic from a pollution aspect, combining technology with science and societal aspects. Furthermore, the air:bit project had not designed an evaluation framework to assess whether the activities were also suitable to increase knowledge and awareness about environmental problems (air pollution in this case). Results from another citizen science initiative on marine litter with high school students indicate that the activities had a positive impact on the students’ pollution perception and the knowledge about marine litter sources, modes of transport and deposition along the coast (Locritani et al., 2019).

[4] http://airbit.uit.no/

In the following, we will describe the study design applied at the ACTION pilot “Air quality measurements in high schools” to evaluate the impact of the citizen science activities on both students' and teachers’ knowledge and awareness level and other related impacts.

# 4. METHODOLOGICAL APPROACH, DATA GATHERING AND ANALYSIS

The following analysis of the pilots’ impact is based on the ACTION impact assessment methodology described in D6.1 (Passani, Janssen and Hoelscher, 2020), which presents a first version of the methodology. Indeed, it has and will be further developed following a co-design approach, engaging the ACTION consortium partners and the other citizen science pilots participating in the ACTION accelerator. Therefore, what is presented in the above mentioned document and hereafter is a work in progress: this framework is going to be constantly improved during the course of the ACTION project[5] by including the lessons learned during the framework application.

The ACTION impact assessment framework considers five areas of impact: scientific, social, economic, political and environmental, which are articulated in several dimensions each, for a total of 24 dimensions. These include, but are not limited to, impact on scientific knowledge, community empowerment, inclusiveness, impact on learning, behavioural change, impact on policy process, job creation and economic empowerment of local communities (Fig. 1).

[5] The ACTION project will be finalised on 31 January 2022.

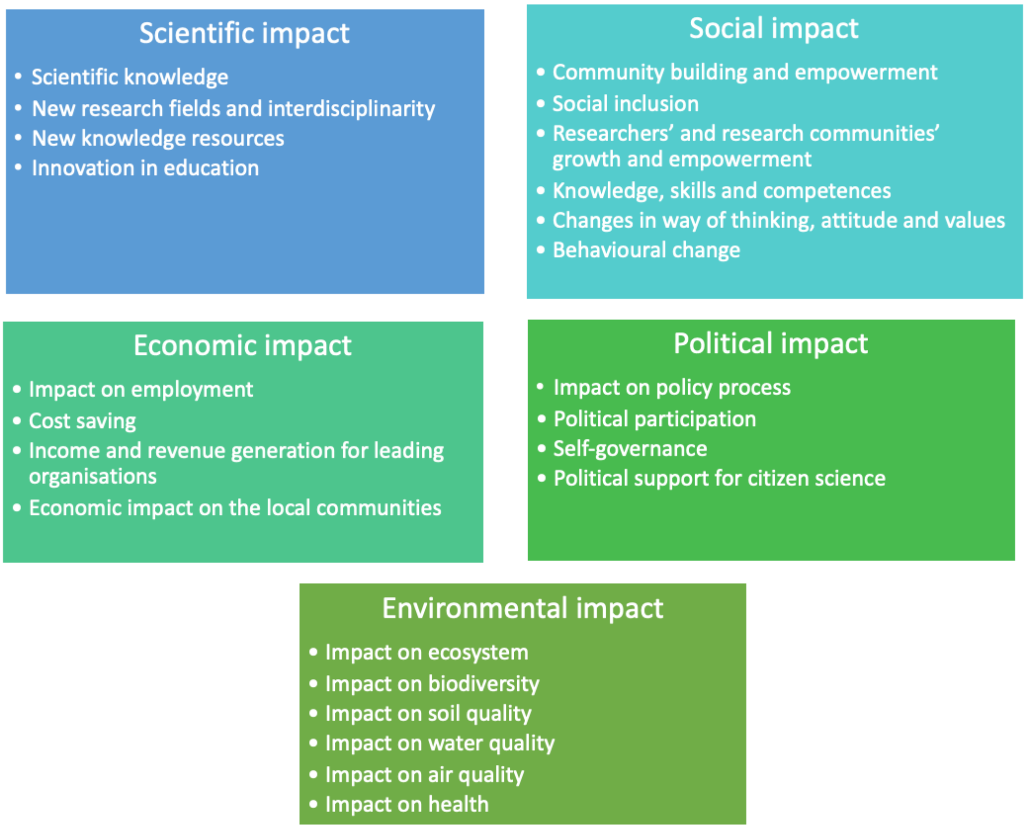


Figure 1: ACTION impact assessment areas and dimensions

Besides these five areas of impact, the methodology also considers the transformative potential of the CS pilots, i.e. the degree to which the pilot can help to change, alter, or replace current systems, the business-as-usual in one or more fields such as science production or environmental protection.

The methodology is quali-quantitative[6] and is designed to be modular and flexible in order to be adaptable to the specific characteristics of each CS pilot but, at the same time, assuring a cross-pilot and cumulative analysis. Indeed, not all the dimensions are (equally) relevant for all CS pilots, depending on their nature, their specific focus and the level of citizen engagement. The specific needs of each pilot in terms of impact assessment and the relevance of the various dimensions were collected and presented by help of an impact assessment canvas (see paragraph 4.1). The impact assessment canvas (Passani, Janssen and Hoelscher, 2020), is a four pages graphic form that supports CS pilots in mapping their stakeholders, their main outputs and the relevance of the impact dimensions. Then, for each pilot, an ad hoc impact assessment process is defined, accompanied by the necessary data gathering instruments (questionnaires, focus group guidelines, data recording matrixes).

[6] The methodology is based on a mixed-methods approach combining qualitative and quantitative methodologies such as descriptive statistics and interpretative analysis.

## 4.1 "Air quality measurements in high schools" canvas

Due to the nature of the "Air quality measurements in high schools" pilot, the most relevant area of impact is the social one which includes one dimension on the acquisition of new knowledge, skills and competences and the impact on way of thinking, attitudes and behaviours. Another important dimension is the one related to the transformation of educational curricula that was indeed suggested by NILU and then added to the overall methodological framework. The environmental impact area was also considered relevant, with reference to the dimension of air quality improvement, however, this impact is considered being long-term, related to the capability of the pilot to have a political impact and improve air quality-related regulation and/or produce a behavioral change in a high number of students and related families able to positive influence the quality of air at local level. Those impacts are, at the time of writing, not observable and will not be considered in the following chapters. The impact assessment team will address this dimension near the end of the ACTION project in order to assess progress that might lead to such positive impacts.

The relevance of the areas of impacts and dimensions for the pilot "Air quality measurements in high schools" is reported in the canvas page below (Fig. 2). The NILU team was asked to attribute a value from 1 to 5 to each area of impact and related dimensions, where 1 is not relevant/no impacts are expected and 5 is very relevant/crucial impact is expected.

| | | |
|---|---|---|
| **Scientific impact 1**<br><br>• Innovation in academia 1<br>• New research fields and interdisciplinarity 1<br>• New knowledge resources 2<br>• Innovation in education 5 | **Social impact 4**<br><br>• Citizens and communities' empowerment 4<br>• Social inclusion 3<br>• Researchers and research community growth and empowerment 3<br>• Changes in way of thinking, attitude and values 5<br>• Behavioural change 5<br>• Knowledge, skills and competences 5 | **Economic impact 1**<br><br>• Job creation 1<br>• Cost saving for project stakeholders 2<br>• Income and revenue generation 1<br>• Economic impact on the local community 1 |
| **Political impact 2**<br><br>• Impact on policy processes 2<br>• Political participation 2<br>• Political support for citizen science 2<br>• Self-governance 2 | **Environmental impact 3-4**<br><br>• Impact on ecosystems 4<br>• Impact on biodiversity 3<br>• Impact on soil quality 2<br>• Impact on water quality 2<br>• Impact on air quality 5 | **Other impacts 5**<br><br>• Impact on schools' curricula (the activities fit very well into the high schools curricula – the ones for Norway are currently under revision, but the current ones have focus on amongst others: interdisciplinarity, scientific thinking, design, execution and assessment of a scientific project, carrying out measurements of e.g., air, noise or water and connection to society) 5 |

Figure 2: "Air quality measurements in high schools" canvas - relevance of areas of impact and dimensions.

## 4.2 Data gathering process and sample

As mentioned in chapter 3 the pilot was executed in two rounds with different teachers and classes and the impact assessment data gathering was executed for both rounds separately. In the first round we only distributed an ex-post questionnaire to the participating teachers and students after the end of the pilot activities that were carried out between April and June 2019. For the second round of the pilot we distributed both an ex-ante questionnaire at the beginning of the pilot activities between February and April 2020 and an ex-post questionnaire to both teachers and students between April and July 2020. All questionnaires consisted of closed questions, open questions and Likert Scale- based questions.

The questionnaire of the first round (2019) and that of the second round (2020) are not identical as the second one[7] was improved based on experience from the first round of assessment and because the ACTION impact assessment methodology was further elaborated and enriched in the time between the first and the second round of assessment.

The ex-post questionnaire for teachers of the first round was structured as follows:

- Information on how the teachers learned about CS in general
- Information related to the activities performed
- Information about the class engaged in terms of demographic composition
- Evaluation of the activities carried out
- Impacts of the activities on teachers' awareness on air quality, impact on skills and behaviours
- Perception of the impacts of the activities on students' skills, behaviours, attitude towards science, motivation and self-esteem and impact on interpersonal relationships within the class

The ex-post questionnaire for students of the first round contained the following elements:

- Students' demographic characteristics
- Evaluation of the activities carried out
- Perceived impact on knowledge and skills
- Perceived impact on motivation and interest towards science and air quality
- Impact on behaviours

The ex-ante questionnaire for teachers of the second round was structured as follows:

- Information on how the teachers learned about CS
- Information related to the activities planned
- Information about the class engaged in terms of demographic and social composition
- Information about the class engaged in terms of:

[7] The questionnaires are part of D6.2 (Passani, A., Janssen, A.L., Hoelscher, K. (2020), Data gathering instruments and guidelines. DOI 10.5281/zenodo.3968459.) and can be foundnd here: https://zenodo.org/record/3968460#.XyQRCB1S-u5

    - Attitudes towards science
    - Scientific competences
    - Interest for scientific-related careers
    - Attitudes towards environmental issues
    - Knowledge about air quality and related issues
    - Motivation and self-esteem
    - Interpersonal relationships within the class
- Teachers' demographic characteristics
- Teachers' psychographic characteristics (way of thinking and behaviours towards science and the environment)

The ex-ante questionnaire for students of the second round was structured as follows:
- Students' demographic characteristics
- Students' psychographic characteristics (way of thinking and behaviours towards science and the environment)

The ex-post questionnaire for teachers of the second round contained the following elements:
- Information related to the activities performed in comparison to what was planned
- Perceived impacts on students:
    - Attitudes towards science
    - Scientific competences
    - Interest for scientific-related careers
    - Attitudes towards environmental issues
    - Knowledge about air quality and related issues
    - Motivation and self-esteem
    - Interpersonal relationships within the class
- Evaluation of the activities
- Perception of students' appreciation of the activities
- Impacts of the activities on teachers' awareness on air quality and impact on skills acquisition
- Teachers' psychographic characteristics (way of thinking and behaviours towards science and the environment)

The ex-post questionnaire for students of the second round was structured as follows:
- Students' demographic characteristics
- Students' psychographic characteristics (way of thinking and behaviours towards science and the environment)
- Evaluation of the activities carried out
- Perceived impact on knowledge and skills
- Perceived impact on motivation and interest towards science and air quality
- Impact on behaviours

The first round questionnaire for teachers was administered via email, while the one for students was handed out as a printed version and filled in during the final event of the pilot. All questionnaires of the second round were administered via Google forms (online) due to the covid situation and the impossibility to distribute them in person. All questionnaires have been presented to respondents in Norwegian.

The table below (Table 1) summarizes the number of questionnaires gathered in the two rounds of the pilot activities.

Table 1: Questionnaires gathered in the two rounds of impact assessment

| | N. of teachers questionnaires | N. of students questionnaires |
|---|---|---|
| First round (2019) - only ex-post | 4 | 46 |
| Second round (2020) - ex-ante | 3 | 46 |
| Second round (2020) - ex-post | 3 | 38 |

The analysis of the data is descriptive and is done separately for the two rounds of the pilot. Indeed, the differences in activities carried out and in the data gathering instruments (questionnaires) between the first and the second round do not allow comparisons among the two generated datasets.

Additional to the above, the pilot leader from NILU was also interviewed via a dedicated questionnaire in order to investigate areas of impact and dimensions that could not be covered with the survey to students and teachers.

The questionnaires, especially for the part related to impacts, rely on self-assessment, as an example, we ask teachers and students if they feel they have learned something new as a result of the project, or if they are more interested in science and in the air pollution topic due to the project activities. In this sense, what we will present in the following paragraphs is more “the perceived” impact than the “objective impact”. The perceived impact and the objective impact can, of course, be different for many reasons and the path followed for reducing this possible discrepancy is that of asking also to the teachers about the impact on students. Indeed the teachers have more objective instruments for validating the learning outcomes of interventions such as the one under analysis such as exam results, group or individual conversations, analysis of the scientific outputs produced as part of the pilot activities and so forth. Nevertheless, the fact that the research design is not a trial-based one with a control group, represents a limitation that needs to be considered when reading the following chapter.

# 5. RESULTS

This chapter presents the results of the impact assessment questionnaires. It is organised as follows: in the first paragraph we describe the results of the teachers' data analysis, both for the first round and the second round, separating the ex-ante questionnaires results from the ex-post questionnaires results. We also report the description provided by the teachers about the main activities carried on during the pilot in the first and the second round. Finally, we analyse the overall impact the project has had on teachers. In the second paragraph we focused on the impacts the pilot activities have had on students, separating first and second round and ex-ante and ex-post phases. We reported the demographic data, and data on students' opinions and behaviours towards environment and science. Finally, we describe the overall impact the pilot has had on students. In the third paragraph, we describe the general impacts of the pilot activities, focusing on four different perspectives: scientific, social, environmental and transformative.

## 5.1 Teachers' data analysis

### *5.1.1 Teachers' psychographic profile: opinions and behaviours towards environment and science*

Data on teachers' psychographic variables are available only for the second round of the pilot, since this information has not been gathered in the first round of the pilot.

For this second wave of the project, only 3 out of the 4 engaged teachers completed our questionnaire.

To analyse teachers' opinions on environmental issues/concerns we used the NEP (New Ecological Paradigm) scale, which proposes 15 items and asks respondents to agree or disagree using a 5 points Likert Scale. All three teachers show a pro-environmental worldview.

We have also used a shorter version of the 30 items' Roberts ECCB (Environmental Conscious Consumer Behaviour) scale, to measure attitudes towards the environment as consumers. We investigated what type of products the respondents usually buy, and if these are or not environmentally friendly (ex: if they avoid buying products with plastic packages).

Results indicate that two teachers out of three show pro-environmental consumer behaviour. One teacher had a neutral attitude as a consumer towards the environment; it cannot be classified as either pro-environment or anti-environment.

To complete the part that concerns the environmental issue, we used indicators of self-perceived efficacy towards the environment in the interviews. Two teachers show high self-perceived efficacy, while one shows a medium level of self-perceived efficacy.

Besides the environmental aspect, we measured the attitude towards science, through the (M)ATOSS (Modified attitude towards science scale) indicators. Analysing the questionnaires, it shows that the three teachers have a pro-science worldview.

Finally, we asked the teachers if they will be more inclined to behave pro-environmentally once peers/people in their neighbourhood are also engaged in that behaviour to measure their approach to social norms. All the teachers answered affirmatively.

Considering all of the above we can say that the teachers engaged in the pilot activities show interest and concern for environmental issues, behave in an environmentally friendly way (at least from a consumption point of view that is here used as a proxy for the overall behaviours of interviewed persons) and have a pro-science approach.

### *5.1.2 Pilot activities*

In this paragraph we report how the activities in the two rounds of the pilot were organised accordingly to the teachers point of view as reported in their questionnaires.

*First round of pilot activities (2019)*

Activities were arranged in different ways in the four classes engaged:

- One teacher involved the students in the decision of participating in the project. Then, the students had 1-2 weeks to think about their own research questions. For this class, the project lasted 2 months and a half, for a total of 20 hours, including the preparation of the posters presented by the student at the final conference.
- Another teacher divided the class into three groups. In total, the project lasted for three weeks. The students had to work on a task, that consisted in measuring particle concentrations outside of their home/class.
- One teacher organized it as a project, during which the students had five weeks to build a sensor and learn about programming. During this period they became aware of the scientific method of inquiry, and had the opportunity to work with this, including the final report.
- Another teacher dedicated two weeks (for a total of ten hours) to teach programming with Arduino, one week (for a total of five hours) to air quality theory, and five weeks (for a total of twenty five hours) to work with the students on the project. This included developing the sensor, testing it, taking measurements, and writing reports.

We also asked the teachers about their expectations in adopting the citizen science approach as part of their teaching method with the students. Only three of the four teachers answered these questions:

- One teacher reported to have previous experience from similar research with the students, so the project was expected to go smoothly in each phase;
- Another teacher expected that students could learn more about the outdoor climate.

- The third one expected that the project could be exciting for the students.

When we asked the teachers if the activities have met their expectations, all four answered affirmatively.

Finally, we asked them if anything emerged that they were not expecting. Two of them said that nothing unexpected emerged while the others reported problems with the Arduino sensors, especially with the programming part.

*Second round of pilot activities (2020)*

During the implementation of the second round of pilot activities, the outbreak of Covid-19 and the consecutive lock-down led to changes in the project activities. For this reason, we asked the teachers how they organized their activities during this period. We received three answers.

One teacher could distribute the sensors and the students could program them when school was still open, but they did not manage to carry out the measurements in that period.

Another teacher told us that the project had come quite far when schools had been closed. However, some students carried out less measurements than they planned originally. They could bring the sensors home, but not go around freely to take measurements due to the lockdown. For this, and due to the lower support the teachers could provide to their students, the project could not reach the level it could have if the school had been open.

For the third teacher, the project had already proceeded quite far before school had to close. Together with the students they worked on it for five weeks, building the sensors. A NILU scientist also gave a presentation on air quality. After the lock-down, the project continued online, and the NILU scientist joined on Microsoft Teams for the students' presentations. The performance of this project has been part of the students' grades.

We also asked the teachers what had emerged differently from their original expectations. For this question we received only two answers. One teacher answered that students had more time to look at air quality data than expected. The teacher suggested to look at the NASA website and at webpages where Norwegian air quality monitoring data could be downloaded. The students also had the opportunity to collect their own sensor data and to analyse them. The second teacher affirmed that they had to work from home and, for this reason, only two groups could work with the sensors.

Overall, the project was carried out in a fruitful way also in the second round of the pilot and the teachers showed flexibility in adapting to the situation generated by Covid-19. The pilot would have developed differently without the school lockdown but, as we will see in the next paragraphs, students were able to learn more on the topic and on science in general.

### *5.1.3 Analysing impacts*

*First round of the pilot (2019): impacts on teachers*

The project has an overall positive impact on teachers. In particular, we can register positive educational and civic engagement impacts. Figure 3 below visualises the questions used to measure impacts (and the respective answers).

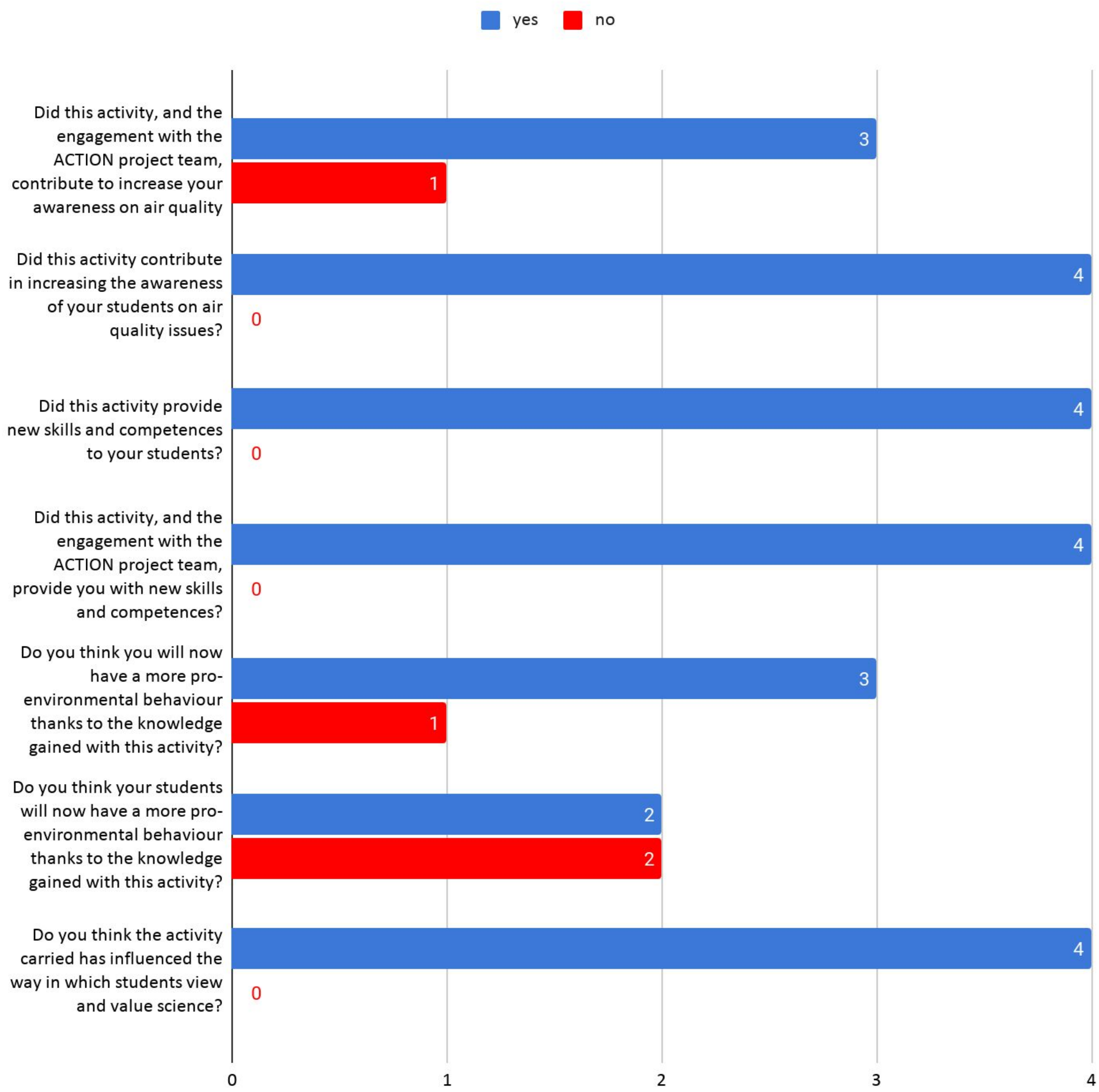


Figure 3: Impact teachers from the first round

As we can see, three out of four teachers in the first round have improved their awareness towards air quality issues thanks to the pilot activities, and so did their students (according to the teachers' opinions). Moreover, all teachers affirm that the ACTION project has provided new skills and competences to them and their students. To the question “Do you think you will now have a more pro-environment behaviour thanks to the knowledge gained with this activity”, three out of four teachers answered “yes” concerning themselves, and two out of four answered “yes” concerning the students.

Final considerations about the project were given; the project was interesting and engaging for the teachers. The only part that was most difficult for students was the Arduino programming and the writing of the final article/poster.

*Second round of the pilot (2020)*

In order to measure the impact that the project had on students from teachers’ perspective, we designed nine questions, using a 5-points Likert scale (1=strongly disagree, 5=strongly agree). The results are shown in Figure 4 below.

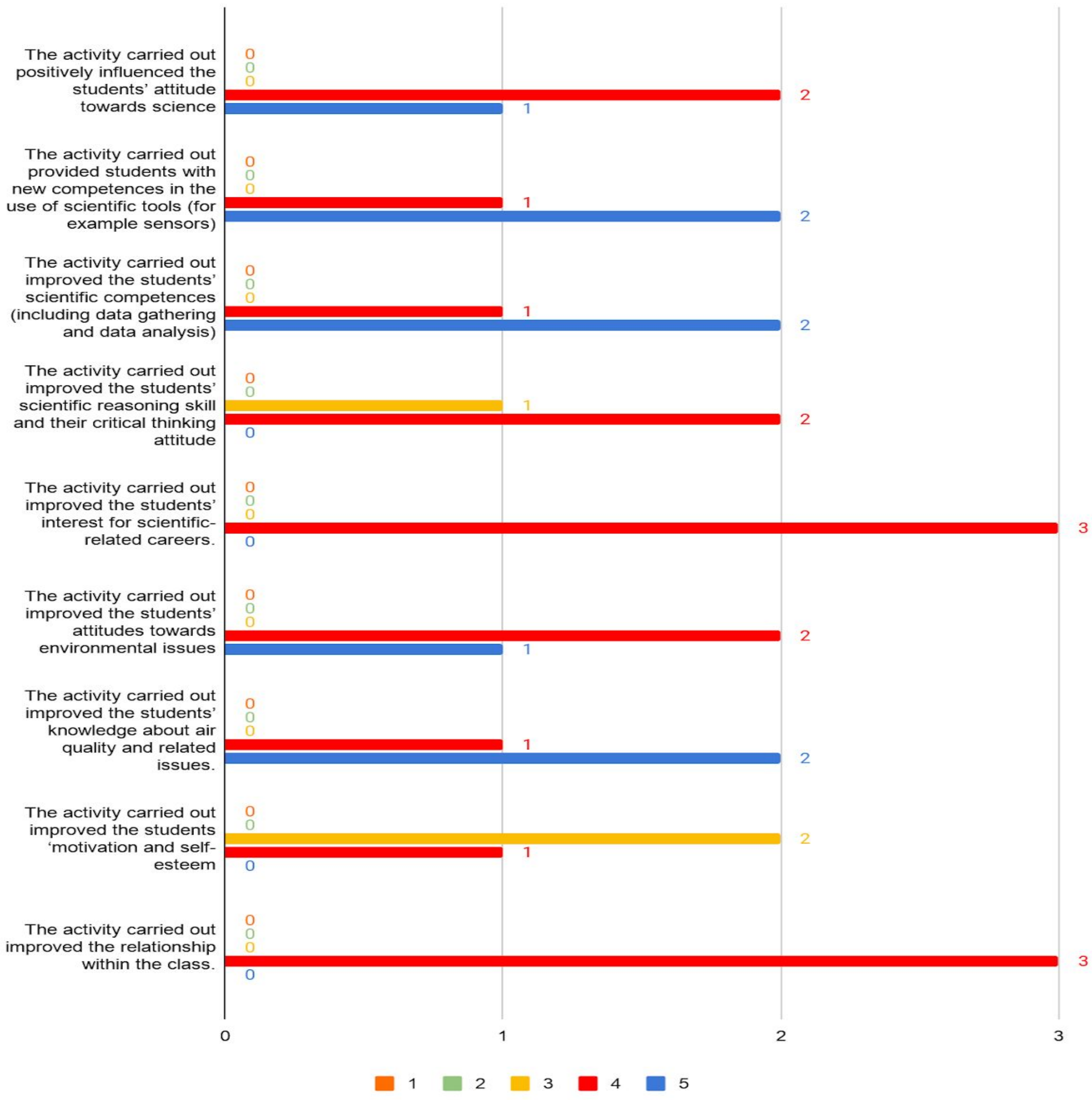


Figure 4: Impact on students from teachers' perspective second round

From the teachers' perspective, the project had a very positive impact on students in terms of scientific and environmental knowledge, self-esteem and relationships within the class groups.

To measure the impact on teachers, we designed two questions where they had to answer "yes" or "no". Results were positive. Firstly, we asked teachers if activity and the engagement with the ACTION project team contribute to increase their awareness on air quality issues. Then, we asked them if the activity and the engagement with the ACTION project team provide them with new skills and competences. All three teachers answered positively to both questions.

## 5.2 Students' data analysis

In this paragraph the results of the questionnaires filled in by the students are reported. We report the results of the first round of the pilot first and then the ones related to the second round.

### *5.2.1 Demographic data*

*First round of the pilot (2019)*

46 students participated in the first round of pilot activities, ranging between 15 and 19 years of age (Fig. 5).

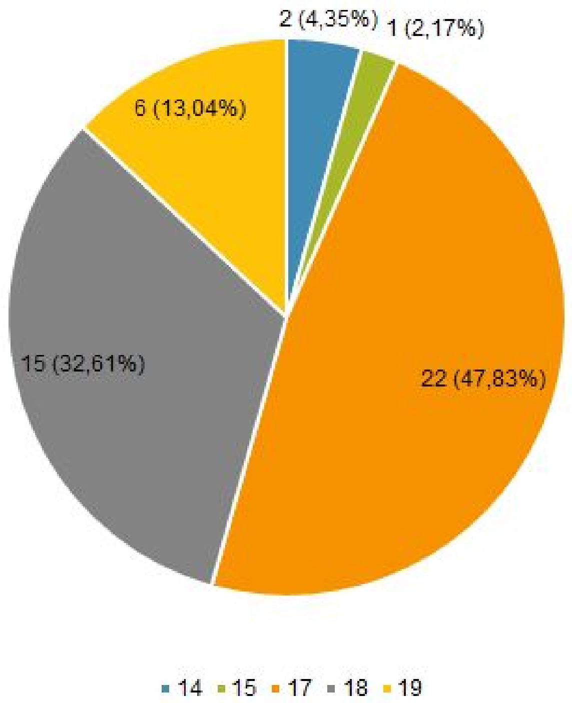


Figure 5: Students' age first round (2019)

The large majority of the students were male (Fig. 6).

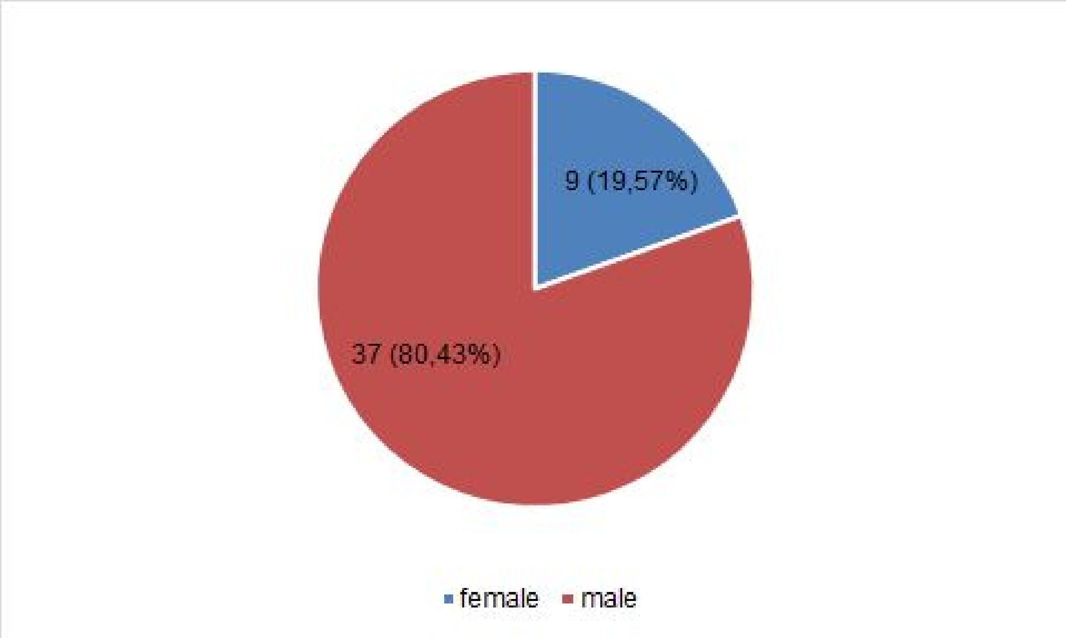


Figure 6: Students' gender first round (2019)

*Second round of the pilot (2020)*

For the second round of the pilot, we have gathered data through questionnaires before and after the project implementation. This is particularly interesting because it corresponds to the periods before and after Covid-19.

<u>Ex-ante data distribution</u>

In the ex-ante phase, 46 students completed the questionnaires. They were between 16 and 19 years of age (Fig. 7).

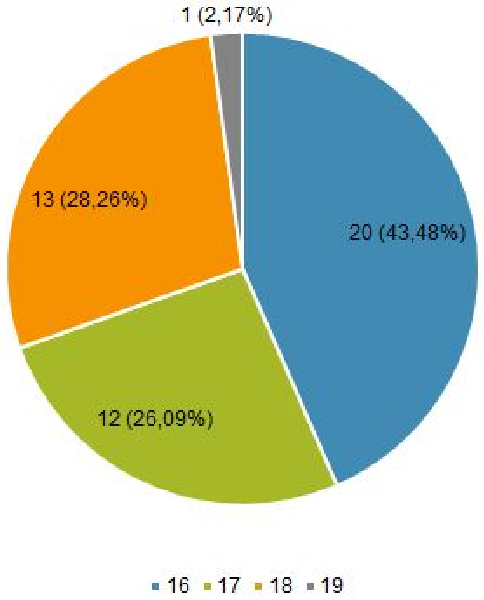


Figure 7: Students' age ex-ante second round (2020)

In this phase, about 61% of participants were male, while 37% were female. One of the students answered “other” (Fig. 8).

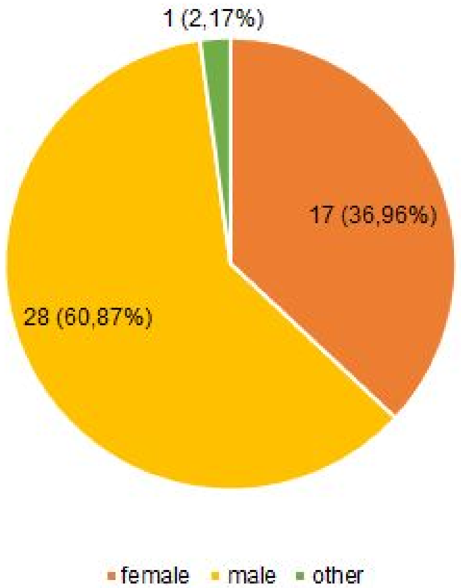


Figure 8: Students' gender ex-ante second round (2020)

In order to understand the cultural background of students without asking about their nationality and without mentioning (for ethical purposes) the status of migrant/refugees they might belong to, we asked - as a proxy for nationality - the language used at home. The obtained data show that

80% of the students speak Norwegian at home, while 13% come from families whose cultural background is different from Norwegian (two of them are from extra-european countries and other two of them are from european countries) (Fig. 9).

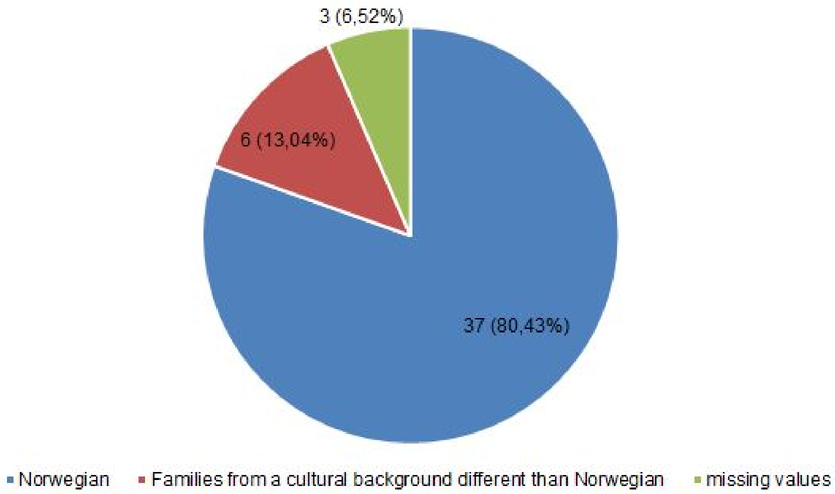


Figure 9: Students' language ex-ante second round (2020)

Ex-post data distribution

In the ex-post phase, we register a smaller number of students compared with the ex-ante assessment. In this phase, 38 students completed the questionnaire, aged between 16 and 18 years (Fig. 10).

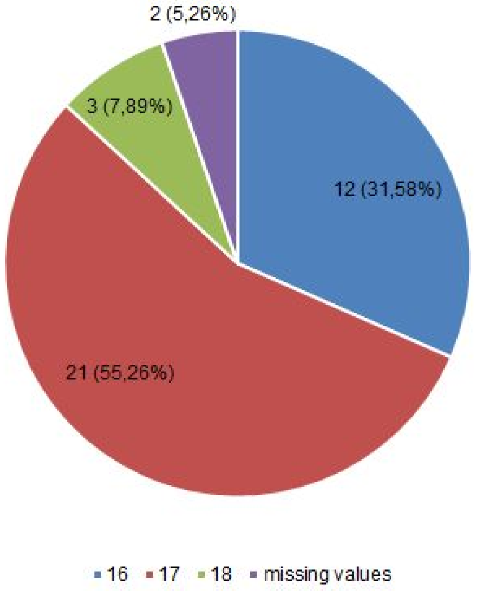


Figure 10: Students' age ex-post second round (2020)

The gender distribution is shown in Figure 11 below.

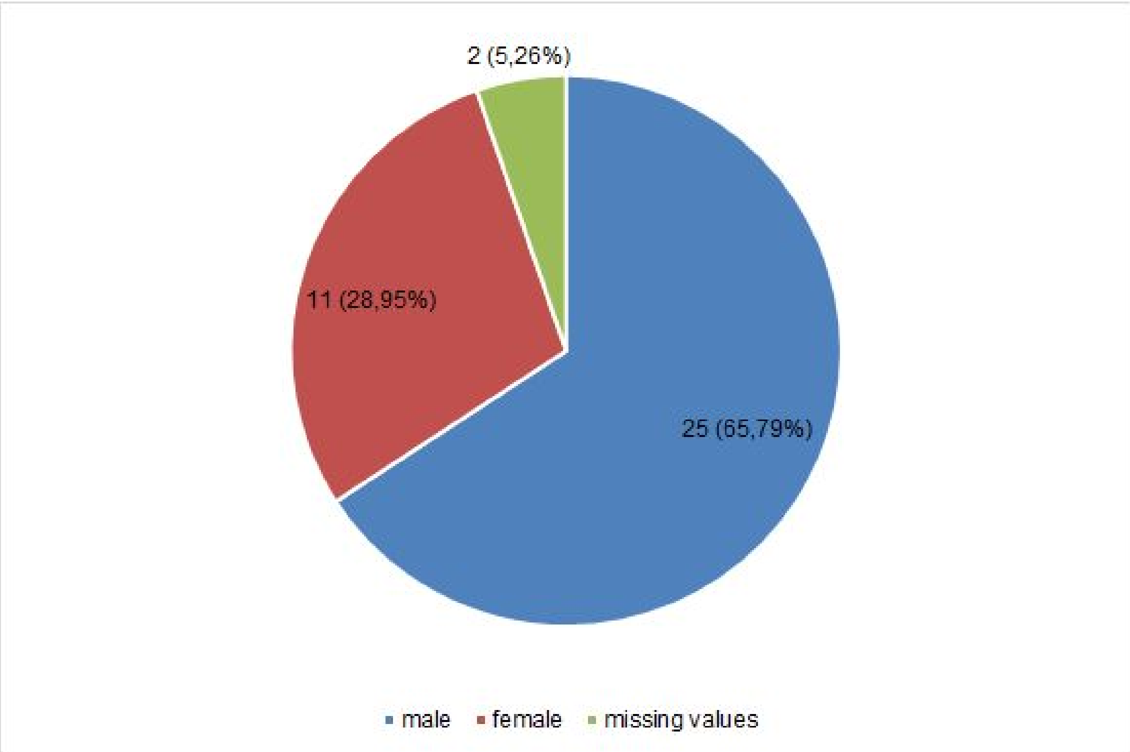


Figure 11: Students' gender ex-post second round (2020)

As seen in the ex-ante assessment the majority of the students come from a Norwegian cultural background and speak Norwegian at home (Fig. 12).

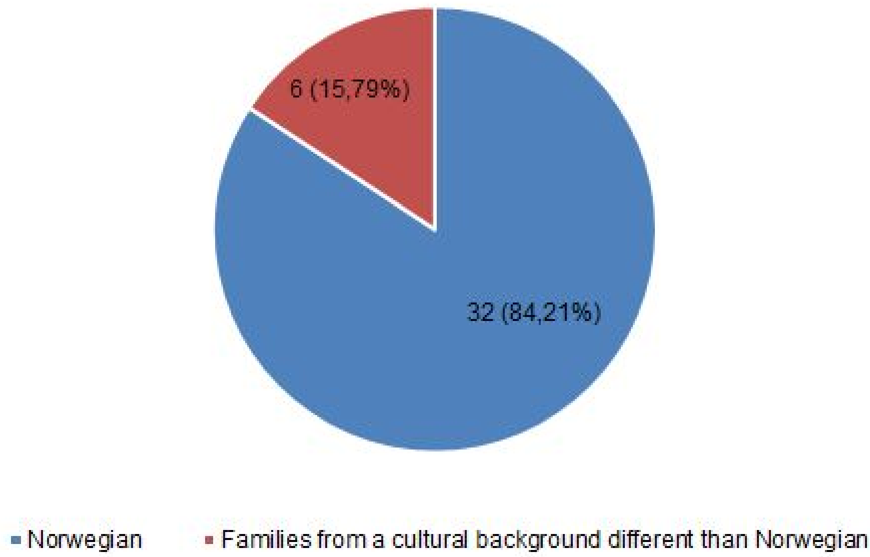


Figure 12: Students' language ex-post second round (2020)

***5.2.2 Students' opinions and behaviours towards environment and science***

*Second round of the pilot (2020)*

In the second round of the pilot activities, we measured the way of thinking, attitude and value of the students in the same way we have done with the teachers. The second round of assessment was organised in two rounds of data gathering: the ex-ante and the ex-post. In the following paragraphs we report the results of both. For the description of the methodology and scales used in this part of the analysis, please refer to Passani, Janssen, Hoelscher, 2020.

<u>Ex-ante assessment</u>

As mentioned in the previous paragraphs, to measure the way of thinking on environmental issues/concerns we used the NEP (New Ecological Paradigm) scale, which proposes 15 items and asks respondents to agree or disagree on them using a 5 points Likert Scale. In Figure 13 below we can see the results.

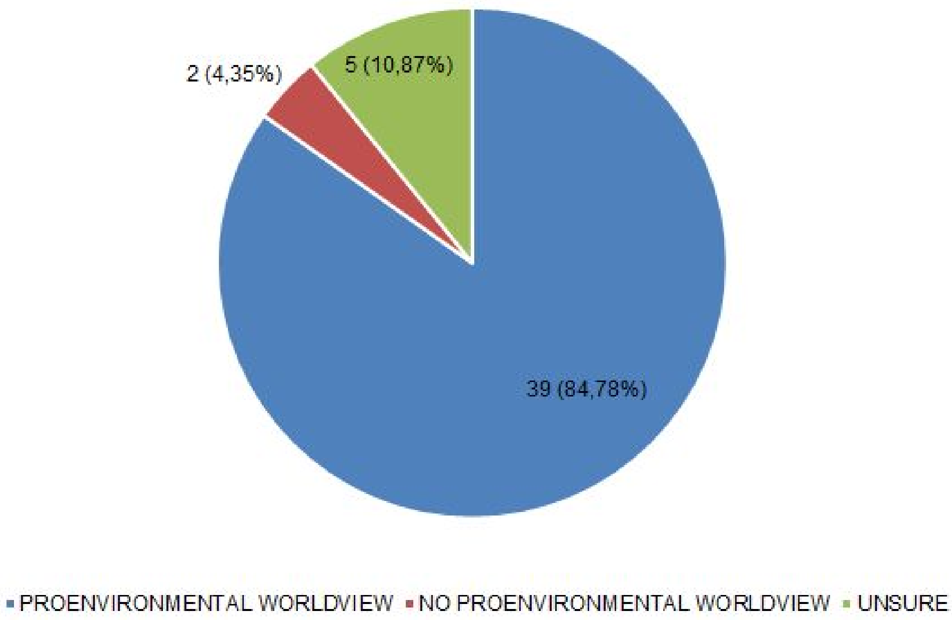


Figure 13: NEP scale students ex-ante second round (2020)

To measure the attitudes towards the environment as consumers, we have used a shorter version of the 30 items Roberts ECCB (Environmental Conscious Consumer Behaviour) scale, calibrated on the students' perspective. The scale measures what kind of products a person buys as a consumer; for example, if he/she prefers to buy products with less plastic packages that are more sustainable for the environment. The results are reported in Figure 14 below.

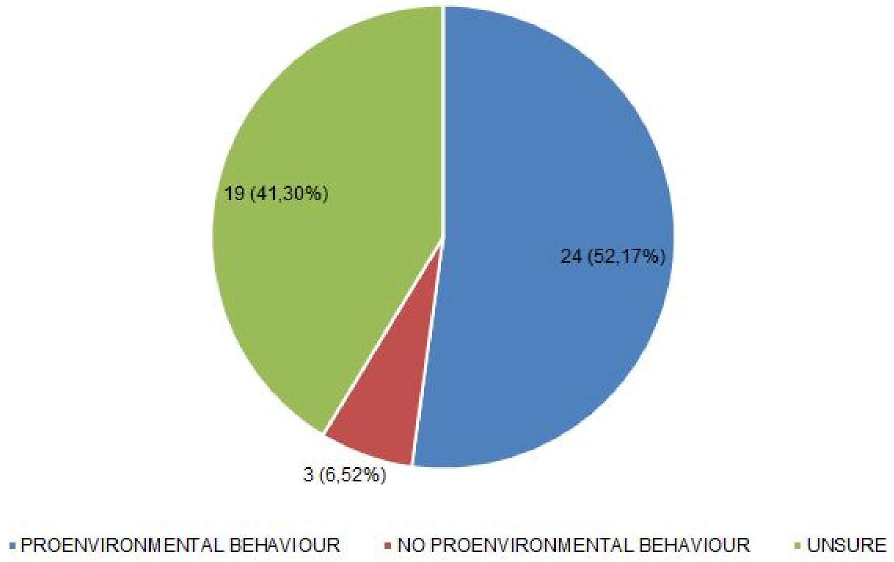


Figure 14: ECCB scale students' ex-ante second round (2020)

The students' "green" attitude is visible for more than half of the students (52.2%), 41,3% of the students are classified as "unsure" and 6,5% show behaviours patterns that could be considered as "non green".

Figure 15 shows the results about the students' self-perceived efficacy.

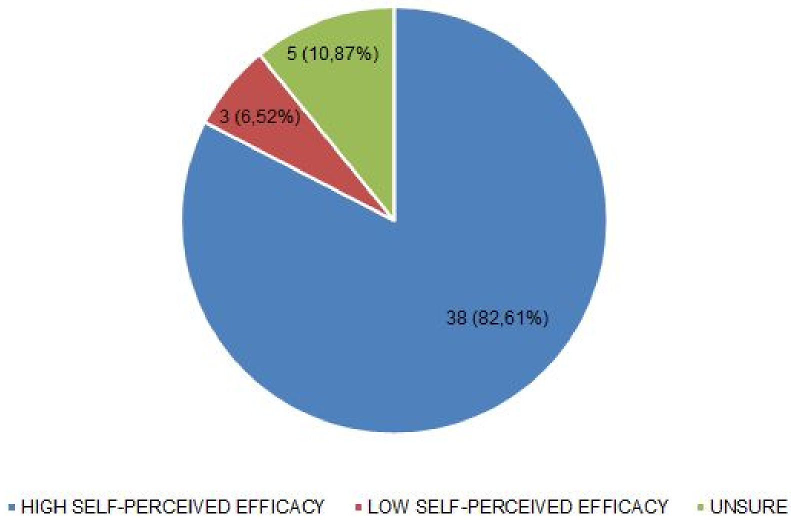


Figure 15: Self-perceived efficacy students ex-ante second round (2020)

The results showed that, generally, students have a positive self-perceived efficacy, i.e. that they are convinced that their action can have an impact on the “world” and that their actions count.

Then, we asked the students to express their agreement or disagreement with the following sentence: “I will behave environmentally-friendly when my friends and family also behave environmentally-friendly”. This can help in understanding to what degree the students are prone to social norms and group pressure or can act as innovators and initiators of new behaviour. As we can see below in Figure 16, 76% declared that they are ready to act in a pro-environmental way even if their family and friends are not doing so, in this sense showing an attitude of independence.

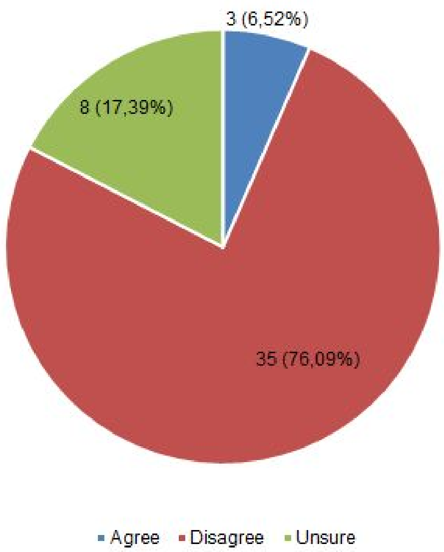


Figure 16: Willingness to behave in a pro-environmental way independently from parents/friends choices in the second round (2020)

Finally, for what concerns the (M)ATOSS indicators, we can see in Figure 17 that there is a general pro-science attitude among students already before their participation in the pilot activities.

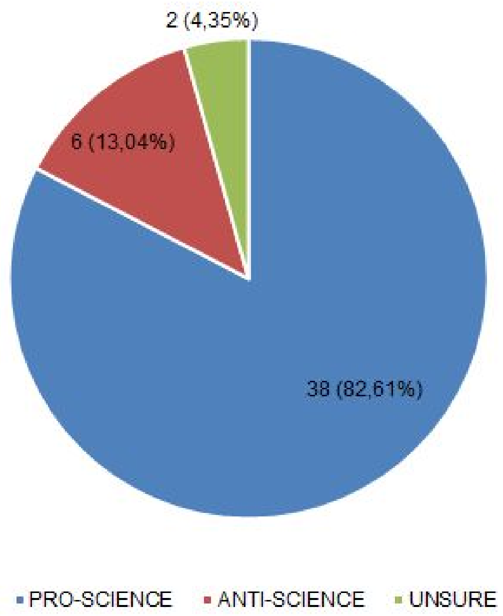


Figure 17: (M)ATOSS students ex-ante second round (2020)

<u>Ex-post</u>

In the ex-post stage, we included in the questionnaire the same questions on psychographic dimensions. In the ex-post phase only 38 participants completed the questionnaires compared to 46 in the ex-ante phase.

Below we can see the results for the NEP scale (Fig. 18).

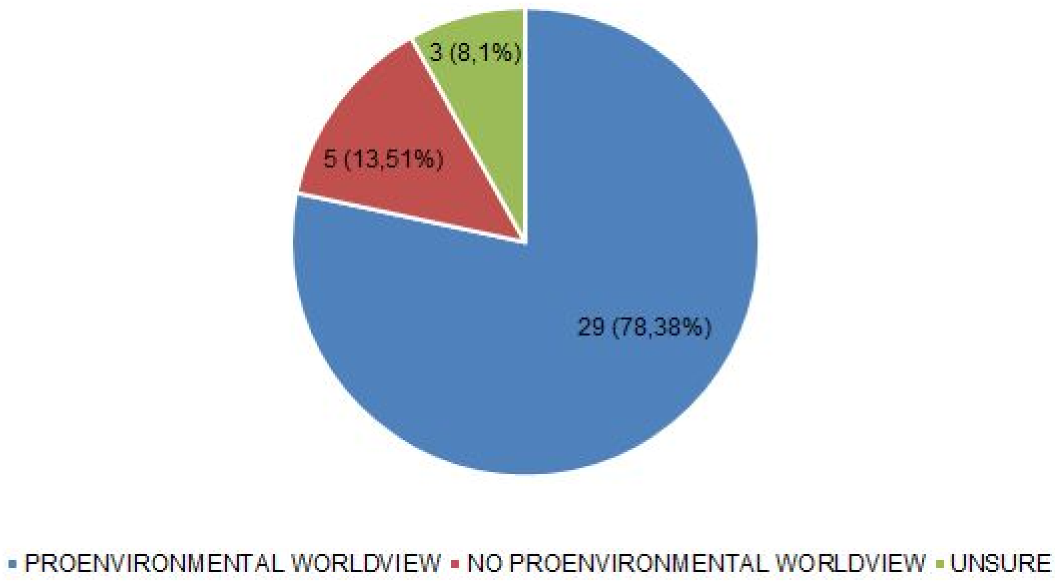


Figure 18: NEP scale students ex-post second round (2020)[8]

We can register a polarisation among students compared to the ex-ante situation. The percentage of students that show pro-environmental attitudes decreases (from 84.78% to 78.38%), the percentage of "unsure" also decreases (from 10.87% to 8.1%) and the percentage of non pro-environmental worldviews increases (from 4,35% to 13,51%). It is difficult to explain this change because the results are not aligned/coherent with the others: so further analysis should be carried out, especially in considering the possible difficulties in answering this specific question. Indeed in this question students are asked to provide a value from 1 to 5 to a set of 15 items and the "meaning" of the values changes across items so that, for example, "5" labels a pro-environmental worldview on some items but not on others. Lack of attention or difficulties in understanding the wording of some items might have influenced the results. It has to be considered that the ex-post questionnaires have been filled in by students from home, without the help of teachers and schoolmates as in the first round due to the covid lock-down and this could have increased the difficulties related to this question.

In the Figure 19 below we can see the ex-post results for the ECCB scale.

[8] It should be mentioned that one student's values are missing, so Figure 18 represents only 37 participants.

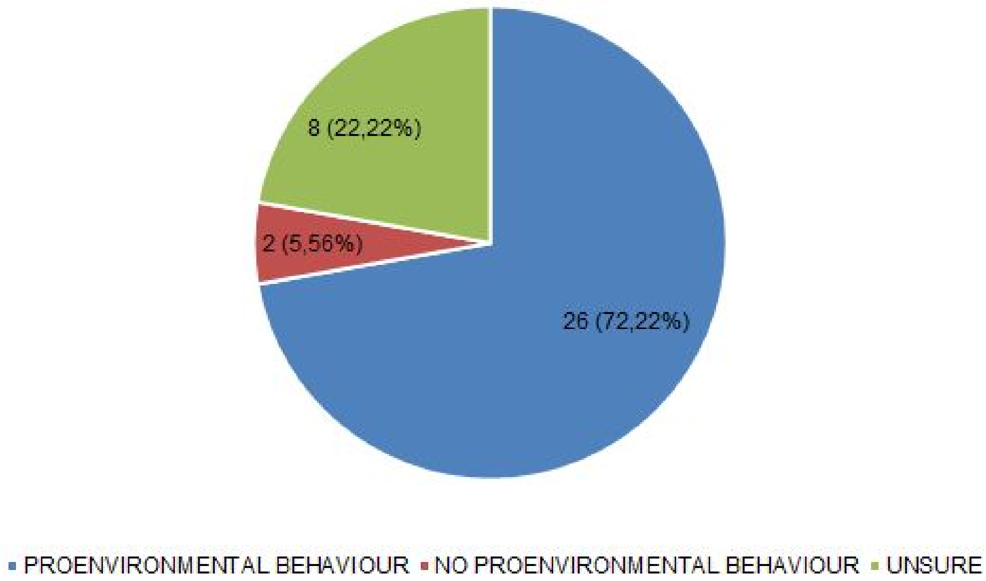


Figure 19: ECCB scale students ex-post second round (2020)

The students' attitude towards the environment experienced a noticeable improvement compared to the results from the ex-ante questionnaire. In fact, from 52.2% of students pro-environment in the ex-ante questionnaires, now we have 72.2% of students pro-environment in the ex-post questionnaires (see Figure 19); two students did not answer the questionnaire.

In the Figure 20 below we can see how the students perceived their own self-efficacy towards environmental protection.

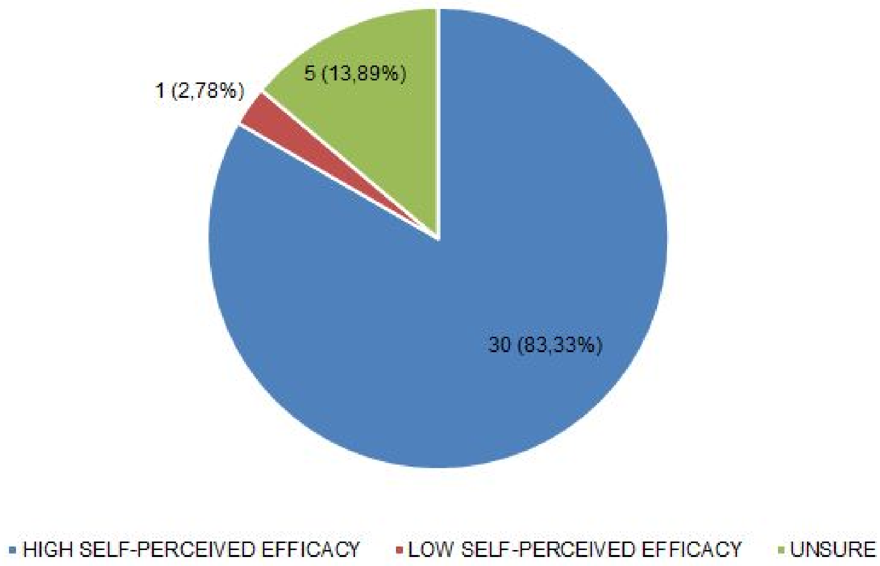


Figure 20: Self-perceived efficacy students ex-post second round (2020)

As we can see, their own self-perception increased a little from the ex-ante questionnaire. We miss the replies of two students.

Finally, we asked students to express their agreement or disagreement with the following sentence: “I will behave environmentally-friendly when my friends and family also behave environmentally-friendly”. As mentioned in the previous paragraph, this can help in understanding to what degree the students are prone to social norms and group pressure or can act as innovators and initiators of a new behaviour. As we can see below in Figure 21, 83.3% declared that they are ready to act in a pro-environmental way even if their family and friends are not doing so (disagree), in this sense showing an attitude of independence. This number increased compared to the ex-ante analysis when 76% showed the same attitude. The students seem more motivated to act in a pro-environmental way independently from their family and friends, but the increment (7%) is not particularly high so that further analysis would have been needed to better investigate this aspect.

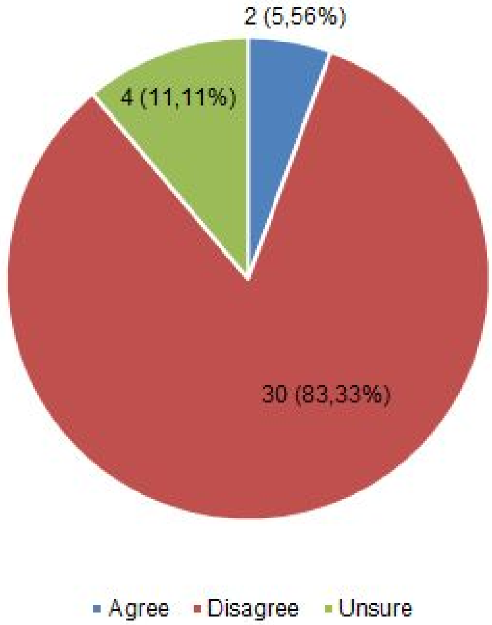


Figure 21: Willingness to behave in a pro-environmental way independently from parents/friends choices (2020)

Finally, speaking about students' attitude towards science in the ex-post questionnaire, Figure 22 shows the results of (M)ATOSS indicators.

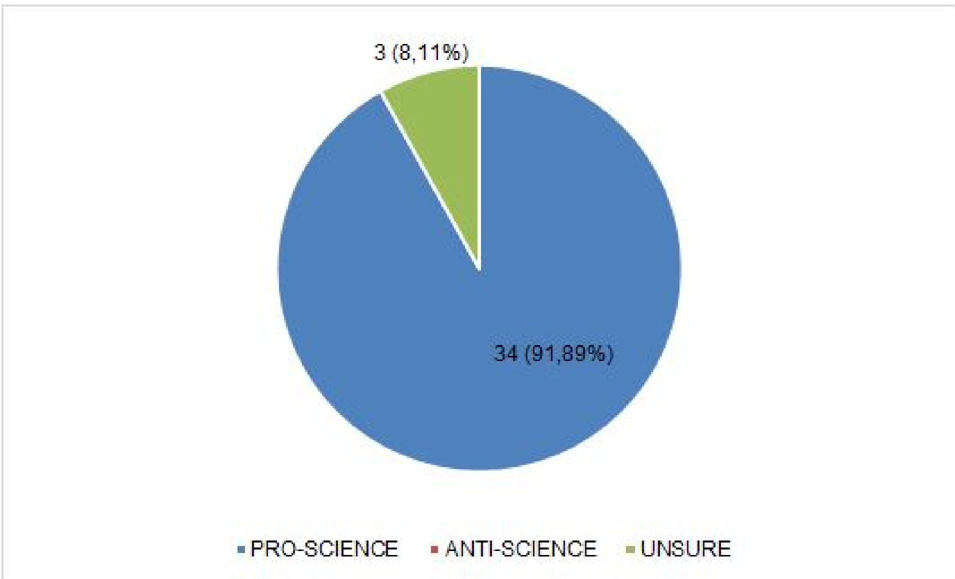


Figure 22: (M)ATOSS students ex-post second round (2020)

As we can see, the attitude towards science improved slightly among the students compared to the ex-ante results. In fact, in the ex-ante phase 82.6% of students had a pro-science attitude, while in the ex-post stage 91.9% of the students showed pro-science attitudes. We miss values of one student for the (M)ATOSS scale.

### *5.2.3 Impact data analysis*

*First round of the project (2019)*

We have measured the impact that the pilot activities had on students through specific questions. Figure 23 below shows both questions and answers. We used the 5-point Likert scale.

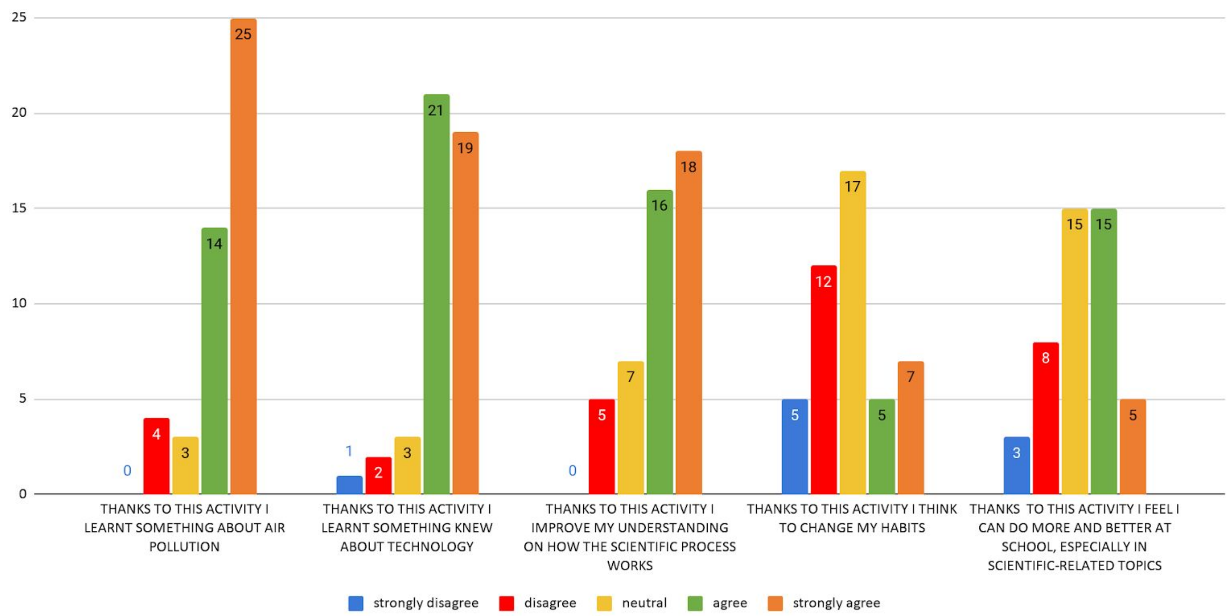


Figure 23: Impact on students first round (2019)

As we can see, the strongest impact that we have registered is on the learning aspect. Less strong is the impact on behaviours. 39 out of 47 respondents declare that they learned something about air pollution, 39 that they learned about technology, 43 that they improved their understanding of scientific processes. Only 12 said that they are thinking of changing their behaviours and 20 declared to see a positive impact on how they can do at school in general and especially in scientific topics.

*Second round of the project (2020)*

Ex-post data distribution

To measure the impact that the pilot activities had on students in the second round we used simple questions, to which we applied a dichotomic type of answers (“yes” and “no”). In Figure 24 below we can see the results.

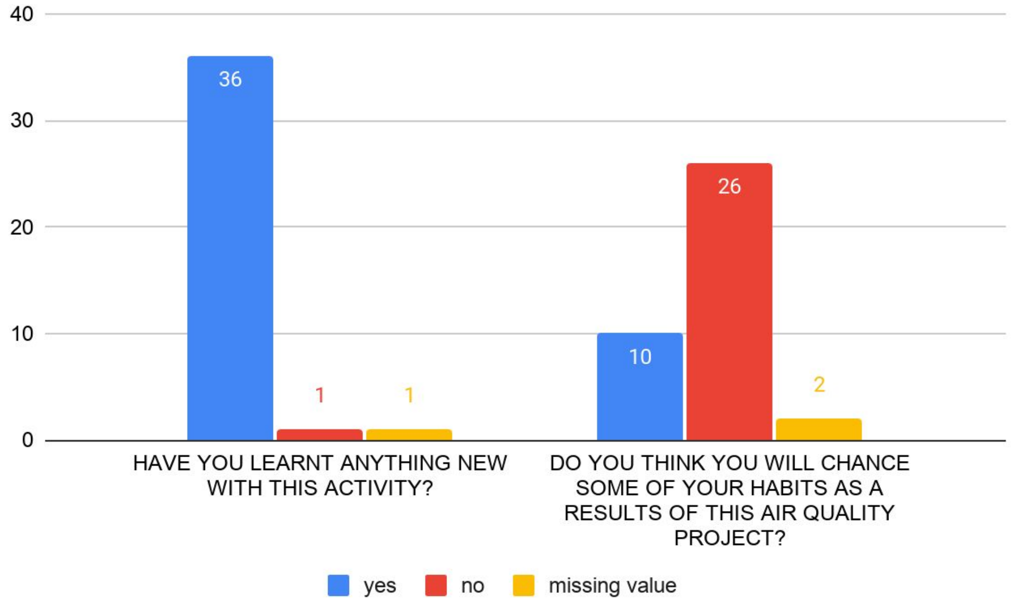


Figure 24: Impact on students ex-post second round (2020)

Results in the second round of the pilot activities are very similar to those registered during the first round. We can see a positive impact with regard to the learning aspect, but a less positive impact regarding behavioral changes.

To better understand the impact with regard to the learning aspect of the project, we proposed to students two sentences that they had to complete with the options we have provided them. One of those was “Do you think that through the air quality project…” and the two possible answers were “...my interest for this topic has not changed”, or “...I am more interested in learning about air quality and ways of improving it”. The other sentence was “After completing the air quality project…”, and the possible answers were “...my interest for science-related topics and activities has not changed” or “...I am more interested in science-related topics and activities”. Figure 25 and 26 show the results.

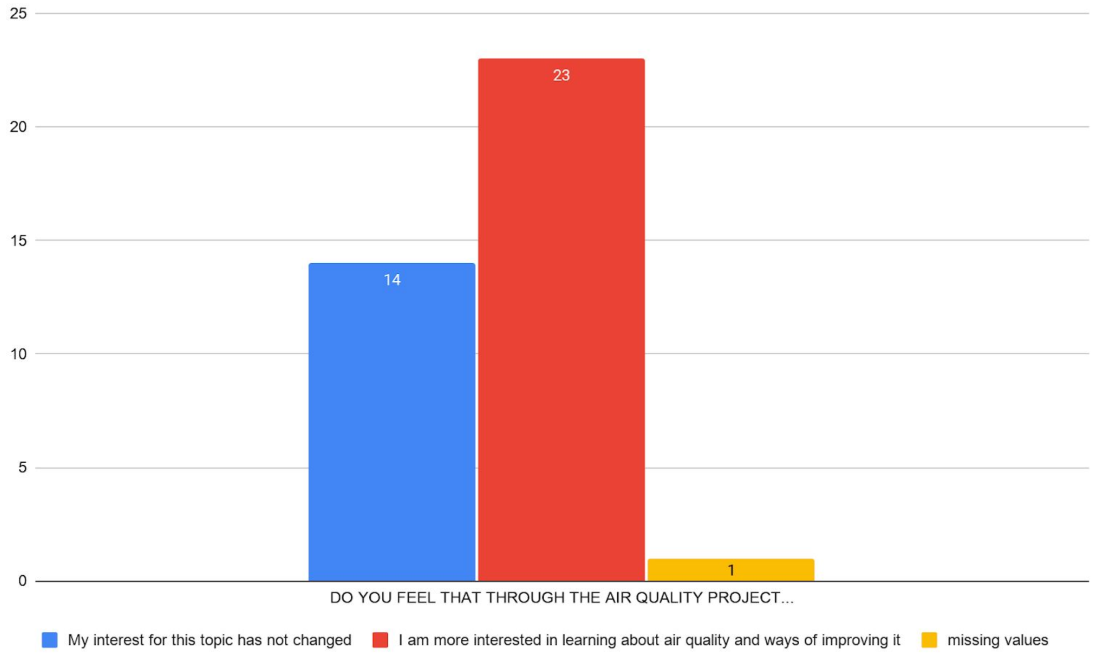


Figure 25: Impacts on students ex-post second round (2020)

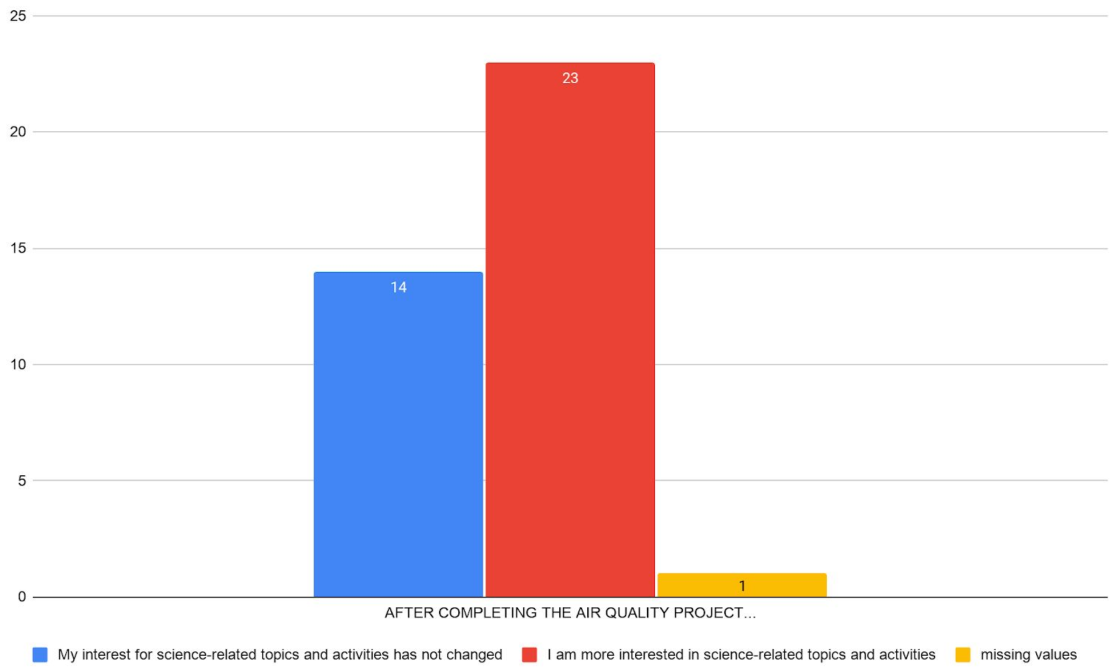


Figure 26: Impacts on students ex-post second round (2020)

As we can see, after the pilot activities, most of the students are more interested in learning about air quality and ways of improving it, and in science-related topics and activities.

# 6 General impact of the pilot activities

This section describes the general impact of the Air Quality Pilot activities from the perspective of the citizen science project manager.

## *6.1 Scientific impact*

Most of the scientific impact of the Air Quality Pilot has been in terms of innovation in education. The project is an innovative way of implementing the current school curriculum, which states that students should learn how to work scientifically. Rather than assigning the students another paper, the project is an immersive way of teaching scientific skills. Also, the project has been highly appreciated by the teachers because of its interdisciplinary character and the students' independence.

The project will also have a wider impact on school curricula, because a national organisation that provides high school teachers with material for their STEM classes will make the project's tutorial and other materials developed available for download - to be shared with other high school teachers.

Producing project output in terms of datasets or publications has not been the aim of this pilot. This means that impact on the other subdimensions of scientific impact - knowledge in academia, new research fields and interdisciplinarity, and new knowledge resources - is minimal.

## *6.2 Social impact*

While the social impact can be described best from the assessment done in the questionnaires for students and teachers, we can give some additional information from the perspective of the citizen science project manager.

In terms of community building and community empowerment, this project has had a substantial impact. As we have seen in the previous paragraphs, the pilot managed to reach quite a large number of students, despite the Covid-19 limitations in 2020. Across the two rounds, between 120 and 150 students were engaged in the project.The student conference in which the results were presented in 2019 was attended by ~90 people. In 2020 no such event was possible. Furthermore, two students made a video about the project that was included in the Ars Electronica festival in 2020. The online event presenting the video was attended by ~10 people.

## *6.3 Environmental impact*

Environmental impact is not visible at the time of writing - being mainly a long term impact that can be achieved with a large amount of persons changing their behaviour or by influencing the related policies. The behavioural change observed so far is not strong enough and the project does not engage enough people to see a significant improvement of air quality. However, the project manager is active in supporting policy change at the local level, which might lead to environmental impact. We will assess this dimension again by the end of ACTION.

## 6.4 Transformative impact

We asked the citizen science project manager to assess the pilot activities with regard to their transformative impact based on five categories: Radical, Iconic, Catalysing, Timely and Learning. For each category, the citizen science project manager could give up to five scores (max). As shown in Figure 27 the Air Quality Pilot scores 4 on Radical, 3 on Iconing, 3 on Catalysing, 3 on Timely, and 5 on Learning.

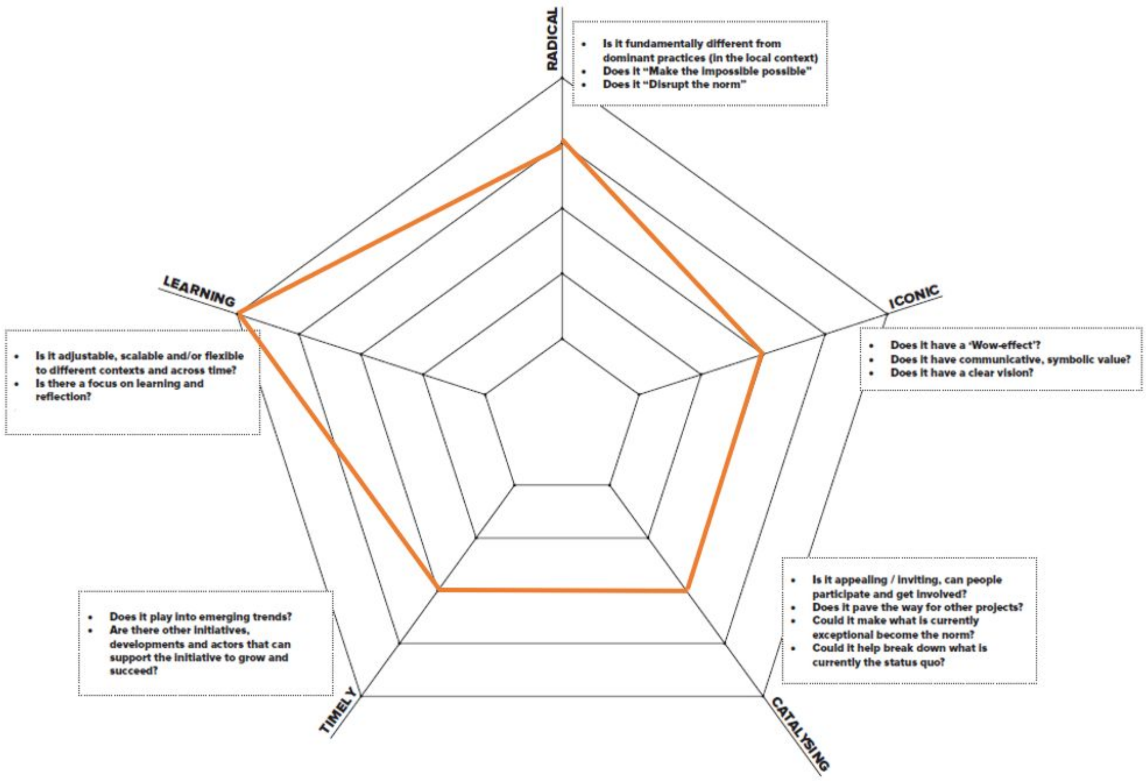


Figure 27: Transformative impact of the Air Quality Pilot according to citizen science project manager

The student pilot scores 4 out of 5 on Radical, because it provides a new education format, away from the traditional front-of-class teaching. The interdisciplinary activities cover different topics, from computer science to technology, science and society. Designing their own research project and presenting the results in a scientific manner to professional scientists was highly appreciated by the students and brought them closer to science and scientific thinking. Dealing with the topic of air pollution in a self-exploratory manner will foster a holistic view of a scientific and technological topic with relevance for both, the students themselves and society.

The project scores 3 out of 5 on Iconic. While the project does not have an enormous “Wow-effect”, the activities have been taken up by the teachers positively and also feedback from the students was positive.

With a score of 3 on Catalysing, there are some ways in which the project can inspire other activities that can break down the status quo. The activities have appealed to several teachers who participated with their school classes. The project might not directly “pave the way for other projects”, but it might give teachers new ideas for future education topics, to contact researchers from other disciplines to carry out other projects. This however, requires much own initiative by the teachers. The activities will probably also not directly “break down the status quo”. This would require changes in the curriculum, which is not always easy to implement. But it might have been inspirational for teachers to find ways to carry out similar projects within the given frameworks.

The project is quite Timely, scoring 3 out of 5. Focus on the environment is increasing everywhere, also amongst the students. The activities tie in with this development and may foster more pro-environmental behaviour. They might also contribute to engage more female students in technology and research topics/activities.

The highest score is given to the aspect of Learning (5 out of 5). The activities cover different topics and students can learn a lot (programming; building sensors; how do sensors work – technology; air pollution – sources, effects on the human body, what can be done to reduce pollution; what are the effects on society, what can we do to avoid emissions to the air; scientific work – also through the poster for the student conference; working independently/exploring topics independently; …). The activities can be adjusted/upscaled/downsized according to the needs of the students and the frameworks given by the curriculum.

All in all, the project scores medium to high on transformative impact, which means the project contributes to changing business-as-usual towards a more sustainable world.

# 7. DISCUSSION

*The psychographic profile of pilot’s participants.*

Most of the engaged teachers show a pro-environmental worldview and pro-environmental behaviour already before the beginning of the pilot activities. Possibly, this is one of the motivations that led the teachers to start the pilot with NILU in the first place. Nevertheless, teachers declared that the pilot offered them the possibility to increase their awareness of air quality issues and that they learned from this experience.

The students too, show – in majority – a pro-environmental worldview at the beginning of the project. In the ex-post analysis run in the second round of the pilot, the number of students that show a pro-environmental behaviours increased. Also, their self-perceived efficacy appeared to increase, i.e. the feeling of being able to make a difference to the situation of our planet through their actions. Their willingness to behave in a sustainable way without the need of having their parents and peers to do the same also appeared to be slightly increased but more analysis would be needed in order to confirm this impact as the difference between the ex-ante and the ex-post analysis is not as high as for the other dimensions. Of course, we cannot be sure that these improvements are the direct effects of the pilot as we did not follow an experiment-like research process and many external-to-the-pilot factors might have influenced the results. Moreover social desirability, i.e. the tendency a respondent can have to reply in a way he/she deem to be more socially acceptable than would be their "true" answer, could have played a role. In this sense, students might have shown more pro-environmental attitudes and more interest for science as they might have perceived this as the answer both their teachers and the research team were looking for. However, teachers have other instruments for evaluating such changes (exams results, formal and informal exchanges with the students, observation to group discussions etc.) and in replying to our questions they also declare their students have learned more on air pollution, on technology and on science and they perceived their students as more interested in science, in air-pollution related topics and more motivated and this tends to validate the results of the students' survey. Nevertheless, as said in the methodological paragraph, this research is descriptive in nature and strongly relies on self-assessment.

Most of the teachers and of the students also showed a pro-science approach. This is coherent with the characteristics of the classes engaged that offer a scientific (STEM) curriculum, but also in this case the ex-post analysis shows an improvement. Indeed, as we have seen in the previous chapter, the attitude towards science improved slightly among the students compared to the ex-ante results. In fact, in the ex-post phase 91.9% of the students reported pro-science attitudes, while before the beginning of the pilot the percentage was 82.6%. Again, many external factors could have been involved in generating this change, but doing science in a "hands-on" way, the possibility to carry on a research activity from the research questions framing phase to the dissemination of the results phase appears as a promising path for increasing positive attitudes towards science. Indeed, the majority of the interviewed students declared that after the completion of the pilot activity their interest for science-related topics has increased and all the teachers declare that the project positively influenced their students' attitude towards science.

In conclusion, we can say that the pilot had positive impacts on the awareness of air quality issues, on the acquisition of news skills and competences (on the topic and on technology) and on the interest for the topic and for science more generally.

*From knowledge acquisition to behavioural change*

The impact on behavioural change is not as evident as the impact on learning, with only a minority of students thinking of changing their behaviours. It is true that the majority of students already show a positive attitude towards the environment at the beginning of the pilot, so the trigger for changing behaviours was less cogent than what it could be in other contexts. In order to better investigate this aspect, we suggest to the teachers that will carry on the third round of the pilot to dedicate a specific time and a dedicated activity to this topic in the next round of the pilot. More precisely, we suggest teachers to facilitate a conversation in their classes after the measurement phase, on how students can improve air quality in the areas where the measurement took place and how they could influence other people's behaviours in this regard. For the next pilot round, we will add a specific question to the teachers' questionnaire for finding out the main ideas and comments that arose in the open discussion and we will check if this will make any difference on the impact of students' behaviours. The hypothesis beyond this suggestion is that the link between the air quality measurement (the information) and what an individual can do for improving it (behavioural change options) is not that straightforward for students as it would appear and a group discussion could support a better framing of such link, leading to actions.

*Impact on social relations*

It is interesting to mention that the pilot did also positively impact, at least from the point of view of the teachers, the relationships within the engaged classes. Probably the format of group-work, doing something new together, and starting from the same level of competences, enabled new and more collaborative attitudes among the students. In the next round of the pilot it is worth further investigating this aspect both from teachers' and from students' points of view.

*Transformative impact and potential*

As described more elaborately in section 6.4, transformative impact of the project is medium to high, which means the project has the potential to disrupt the status quo. To increase this transformative potential, we see two ways forward.

First, the project has potential to change school curricula to make more space for citizen science or other active learning approaches. The project cannot do this by itself, but a first step could be to connect to other citizen science projects done in schools in Norway. Forming an (informal) network of these projects could leverage change, in the sense that more schools will see the benefit of citizen science approaches and can implement it. Another step in the right direction has already been made by the project, by linking to a national organisation with connections to STEM teachers that will make the tutorial and material available.

Second, the project has potential to contribute to more awareness of air quality and associated behavioural change. A promising next step would be to connect to other 'niches' (innovative initiatives with the aim of decreasing air pollution) and together forge change in the way we approach air pollution. This change includes social innovation, by activating citizens on the topic, instead of having only the established institutions deal with air pollution. The citizen science approach to air pollution, as well as the young age of the citizen scientists, fits very well with this aspect of social innovation. Another tipping point towards more citizen participation in air quality issues would be to run the project in schools that do not have a science and technology focus. This might not only have more of an effect in terms of attitudes and behavioural change, but might also re-align the gender balance and have a wider reach in general.

# 8. CONCLUSIONS

## 8.1 The pilot in relation to the ACTION objectives

The pilot on air quality has contributed to the ACTION methodologies, tools and guidelines to understand the requirements of different stakeholder groups in citizen science - in this case, the requirements of teachers and high school students. The activities have been contributing positively to the objectives of WP2 Citizen Science Accelerator through providing real world experiences and giving feedback from both students and teachers. This information has also contributed to WP3 Open call by shaping the requirements for the application and review process. The resources and information material developed within the school activities (codes, tutorial, posters, measurement data, lessons learned) have been taken up by WP4 Digital infrastructure for citizen science and are now freely available at the Resources section on the ACTION web pages (Data Portal). Experience from the school pilot will also feed into WP5 Sociotechnical citizen science toolkit. This deliverable contributes specifically to WP6 Enhancing reflexivity, impact assessment and policy road mapping by demonstrating the impact assessment methodology applied in ACTION. Learning outcomes and lessons learned are also subject of dissemination activities for the remaining time of the project.

## 8.2 Lessons learned

The ACTION impact assessment framework has been a useful approach to assess the impact of the pilot activities in high schools since it combines the views and information from both students, teachers and the citizen science leader.

We could see positive impacts on the awareness of air quality issues amongst the students, on the acquisition of news skills and competences and on the interest for the topic and for science more generally.

It is always challenging to measure behavioural change. Thus, we will investigate this issue further in the next round by asking the teachers to initiate activities to improve the students' self-efficacy. We will then be able to see at least self-reported changes in the students' ex-post questionnaire.

The assessment revealed further that the format in which the activities have been carried out did positively impact social relations amongst the students. This is also an issue that we have to investigate in the next round of activities.

The pilot activities bear further potential for changing school curricula by implementing citizen science approaches.

We can conclude that the impact assessment of the air quality pilot activities revealed a number of positive impacts. However, there is room for improvement and the assessments from the first and second round of the pilot activities have revealed opportunities to further improve the questionnaires to obtain more and more precise information.

It should also not be unmentioned that in order to be able to carry out a comprehensive impact assessment, careful preparation and discipline is needed to prepare questionnaires on time and ask both students, teachers and the CS project leader the right questions at the right time. This is a time-consuming process and requires good management skills from the consortium.

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