# Increased knowledge and scientific thinking following participation of school students in air-quality research

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**SUMMARY**
Public participation in scientific research, also known as citizen science, is claimed to have many social, educational and civil benefits for participants. The current study focuses on students' participation in an air-quality citizen science initiative in schools. As part of the European "CITISENSE" project for developing sensor-based citizen observatories, air-quality sensors which continuously monitor air-quality were installed within school premises. Seventh grade students participated in different stages of the research including planning sensor locations, developing research questions and analyzing air-quality data. Students' knowledge, attitude, behavior, and scientific and critical thinking regarding air-quality were examined using pre and post questionnaires. Results demonstrate an increase in students' content knowledge and scientific thinking ($p<0.05$), but no difference in attitude, behavior or critical thinking. These results exhibit the educational benefits of citizen science for knowledge construction and scientific understanding and provides better understanding of the potential use of citizen science as a learning method.

**PRACTICAL IMPLICATIONS**
This work provides insight into the social and educational benefits of citizen science for participants. It further highlights the potential of citizen science for creating a more aware and informed community and as a tool for formal and informal science education.

**KEYWORDS**
Citizen science, air-quality, schools, science education, content knowledge

## 1 INTRODUCTION

The field of citizen science has increased rapidly in the past decade, providing many opportunities for the public to actively participate in scientific research (Dickinson, Zuckerberg, & Bonter, 2010; Franzoni & Sauermann, 2014). Zooniverse.org is an example for a well-known citizen science platform aggregating many citizen science projects in various disciplines. With over 12 million daily observations of users, Zooniverse provides insights into the contributions and participation patterns of users and indicates the potential of citizen science to the advancement and production of scientific knowledge (Sauermann & Franzoni, 2015).

The contribution of public participation in science is apparent for both citizens and scientists, and has shown to benefit the environment, society, and government (Raddick et al., 2009). Specifically, active participation of publics' in citizen science projects has been shown to be a key factor in increasing participants' content knowledge (Brossard, Lewenstein, & Bonney, 2005; Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011), in addition to increasing positive attitudes towards science (Price & Lee, 2013), and increased awareness and involvement in social and environmental issues (Overdevest, 2004). Accordingly, studies among school students demonstrate an increase in learning and understanding of scientific research process, following participation in citizen science projects (Kountoupes & Oberhauser, 2008; Silva et al., 2016). In addition, students express a sense of pride in their research products, a feeling of belonging and connection as they are involved in something big and important (Sickler & Cherry, 2012).

Air pollution is a significant risk factor for multiple health conditions. Exposure to air pollution is a fundamental component in understanding air pollution and its effects. To this end, monitoring of the pollution level in the atmosphere is a mandatory building block. Today, most of air-pollution research is based on data acquired from regulatory Air Quality Monitoring (AQM) Stations. While AQM provides continuous measurements and is considered to be accurate, AQM stations are expensive to build and operate, and therefore are scattered sparingly. Air quality Micro Sensing Units (MSUs) offer a tool to increase the density of the air pollution monitoring grid. Increasing the spatial density of the measurements does result in a spatial interpolation with smaller uncertainty. Yet, these low-cost devices require calibration and maintenance, which might call for heavier staffing than the research team can handle. Thus, public involvement in the research may be beneficial on both parties.

Although citizen science has grown tremendously and spread across all scientific fields, evaluation of impacts and benefits of citizen science projects, on the public involved, is still undeveloped. This is especially true in the context of schools participating in citizen science initiatives where evaluation of learning processes is very important and generally quite advanced. The main goal of this study is thus to examine the impact of student participation in a citizen science initiative of air-quality research in schools. We study students' gains in terms of knowledge, perception and behavior, and scientific and critical thinking.

## 2 METHODS

**Research setting.** This study is part of a citizen science initiative conducted by scientists at the Technion in collaboration with residents of Neve-Shaanan neighborhood in Haifa. Haifa hosts a sea-port and a heavy petrochemical industrial area. In recent years there has been a political and public debate on the influence and future of this industrial area. The study is part of the European "CITI-SENSE" project for developing sensor-based citizen observatories, for improving the quality of life in cities. Throughout the school year (a six month period), four air quality MSUs (ELM™ of PerkinElmer, USA), measuring ozone, nitrogen dioxide, total volatile organic compound (tVOC), relative humidity and temperature, were distributed in the neighborhood middle school which continuously monitored air quality in the local environment. The sensor installation took place in several locations within the schools premises, according to teachers', students' and scientists' priorities. Sensors were relocated within the school every two months, and were placed in a number of different class rooms (science lab, private lesson class room, teacher's room etc.) in addition to several outdoor locations.

**Study participants and research design.** Study participants were seventh grade students from two classes in a middle school in Neve-Shaanan, Haifa. One class served as an intervention group while the other as a comparison group which respectfully did or did not participated in project activity.
Pre and post questionnaires were given to students of both groups, at the initiation and termination of the study (beginning and end of the school year). Four groups were compared throughout the analysis, consisting the following sizes: pre- comparison n=25, pre-intervention n=27, post- comparison n=23, post-intervention n=25.

**Intervention**. Participation in the project included meetings with project managers, planning sensor locations, student research projects and dedicated lessons on air quality topics. An initiation meeting took place with participating students at the beginning of the school year, which included an interactive class conducted by Technion experts presenting the air quality topic, monitoring and project plan. Throughout the year, students conducted a research project, based on data received from the sensors located within the school and submitted a report summarizing their research questions, hypotheses, results and conclusions.

**Research tool.** The main research tool was written questionnaires. Questionnaires were completed by students anonymously (due to ethical considerations) and comparisons were done in the group level.
Questionnaires structure. The questionnaires were composed of five sections: knowledge, attitude, behavior and scientific and critical thinking. The intervention group had an additional section with open questions examining participation, satisfaction and perceived personal benefit, as part of the post questionnaire.
Knowledge questionnaire- This questionnaire was comprised of 13 true/false questions written by the authors, regarding air quality and pollution topics. The questions were divided to four themes: general air quality, air quality in Haifa, pollutants and legislation.
Attitude and behavior questionnaires- Each of these sections was comprised of 15 statements with a 1-4 likert scale option. The statements were based on the measurements of the general ecological behavior (GEB) (Kaiser, 1998) and on one of its version translated to Hebrew (Peled, 2014), with modifications to fit the specific topic of air quality. Each part was divided to 4 topics: Attitude questionnaire - attitudes towards the environment, attitudes towards air pollution, responsibility for action, legislation and enforcement. Behavior questionnaire - general environmental behavior, awareness and reducing personal exposure, involvement in environmental action, reducing air pollution behavior.
Scientific thinking questionnaire - This sections was developed by the authors, and comprised of a figure presenting a building with potential air-quality hazards. Students were asked to identify these hazards and accordingly choose four locations for sensors arrangement throughout the building. Students were further asked to phrase research questions that could be answered using information obtained by the allocated sensors.
Critical thinking questionnaire- This sections was developed by the authors, and comprised of four newspaper headlines expressing opposite facts and views of air-quality in a number of cities in Israel. Students were asked to determine which of the cities was most polluted, explain their choice and state which additional information they would want in order to develop an informed opinion.

**Validity and reliability**. Each of the sections was examined for reliability and validity with the assistance of seven independent judges, five school students and one school teacher. The knowledge questionnaire was also validated by an air quality professor and Ph.D. student.

**Data analysis.** Pre and post questionnaires were statistically analyzed using SPSS software. Pre-Post comparisons were done in the group level consisting of four groups- pre-comparison, pre-intervention, post-comparison and post-intervention.
One way ANOVA was used on the knowledge and scientific thinking sections of the questionnaire and the non-parametric kruskal-wallis test was used for the attitude, behavior and critical thinking sections of the questionnaire.

**Ethical considerations**. An IRB approval was obtained from the authors' institution committee (approval: Nov. 2014). Permission for collecting data was obtained from the chief scientist office of the ministry of education (approval: 8579, March 2015).

## 3 RESULTS

Analyzing questionnaire responses, demonstrate an elevation in student knowledge of air quality concepts among the intervention group and a decrease in number of times they replied "I don't know", ($p<0.05$). Specifically a major increase was found in questions regarding air quality in Haifa ($p<0.05$), for example in reply to the question: "air pollution in Haifa has decreased significantly over the past 20 years" (true). An increase was also found in the participants' content knowledge of air quality and pollutants, between the pre and post intervention group ($p<0.05$), for example in reply to the question: "Ozone is not considered an air pollutant since it is a major factor in filtering the radiation from the sun" (false) (see *Figure 1*).

Student scientific thinking was also found to increase following participation in the project (see *Figure 2A*). This increase was represented by student phrasing better research questions and identifying factors influencing air quality in specific situations. In addition, the open post-questionnaire section indicated students' sense of acquiring new scientific skills such as reading and understanding graphs, writing research questions and performing experiments. Despite the elevation seen in participants' knowledge and scientific thinking, no differences were found between groups in critical thinking, attitudes or behavior towards air quality (see *Figure 2B, 3*). Attitudes toward the environment and air quality issues were fairly positive in all four groups with an average of 3-3.2 on the likert 1-4 scale. These positive attitudes are illustrated by agreeing to statement such as "it is important for me to protect the environment" and "I am worried about the medical implications of high air pollution". Behavior towards the environment and air quality resulted in 2.2-2.5 average on the likert 1-4 scale, demonstrating students sometime engage with pro environmental and air quality behavior. For example: the statement " I would rather walk or use public transportation, in order to reduce pollution" received a total average of 3.1 on the likert 1-4 scale, on the other hand the statement "I talk with family and friends about environment and air pollution issues" received an average of 1.95 on the likert 1-4 scale.

Overall, students attained a sense of achievement and had positive feelings during participation. 54% of students stated participation had increased their awareness towards air quality concepts and an additional 25% stated it increased their content knowledge.

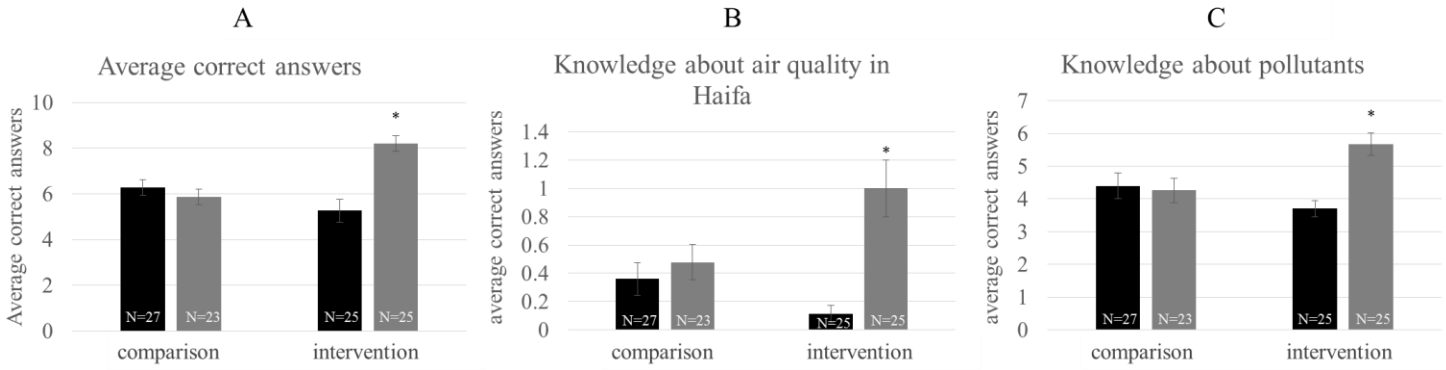


Figure 1. Average correct answers on knowledge questionnaire (air quality and pollution topics). A. Average correct answers of all 13 questions. B. Average correct answers in the topic of air quality in Haifa (3 questions). C. Average correct answers in the topic of air pollutants (8 questions). Four groups consist of pre/post questionnaires (black and gray respectfully) of the comparison/intervention classes. N's are indicated in the bottom of columns. Statistically significant results ($p<0.05$) are marked with an asterisk.

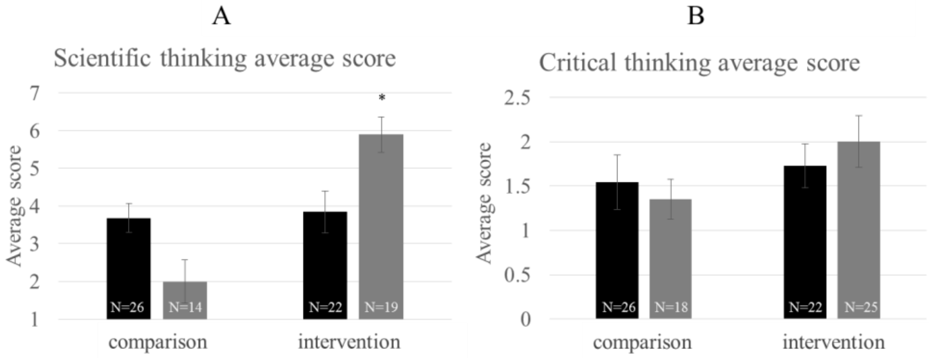


Figure 2. Scores of scientific (A) and critical (B) thinking questionnaire. The scores were determined according to an index developed for each questionnaire and consists of a maximum score of 10. Four groups consist of pre/post questionnaires (black and gray respectfully) of the comparison/intervention classes. N's are indicated in the bottom of columns. Statistically significant results ($p<0.05$) are marked with an asterisk.

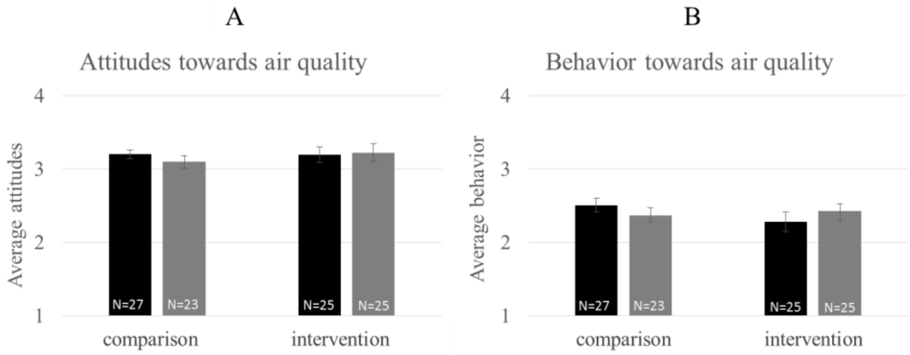

Figure 3. Attitudes and behavior towards air quality. Scores are averages of 15 statements on a 1-4 likert scale. Four groups consist of pre/post questionnaires (black and gray respectfully) of the comparison/intervention classes. N's are indicated in the bottom of columns.

## 4 DISCUSSION

Research has shown that following participation in several citizen science projects, an increase was demonstrated in participants' content knowledge and understanding of scientific concepts (e.g. Brossard et al., 2005; Jordan et al., 2011). Similar results have been demonstrated with students participating in citizen science initiatives in schools (Kountoupes & Oberhauser, 2008; Sickler & Cherry, 2012). Accordantly, in the study presented here we have found an elevation in student content knowledge about air pollutants, and about air quality in Haifa. We have also found an increase in student scientific thinking, represented by phrasing research questions and isolating factors influencing air quality. Although these are important outcomes contributing to student knowledge and empowerment, our results do not demonstrate an increase in positive attitudes toward the environment nor do they exhibit behavior changes.

During the study, as part of the intervention program, students learned about air-quality in their class room, had dedicated lessons on these topics and connected the concepts studied to the general science curriculum. It is therefore not surprising (but yet, satisfying) to obtain increased content knowledge as a result of participation in the project. Since science education focuses on increasing students' scientific knowledge as its main goal (Baram-Tsabari & Osborne, 2015), it may significantly benefit from embracing citizen science as a tool for science teaching. The increase seen in student's scientific thinking demonstrates a higher level thinking acquired by the students. This higher level thinking is often the result of inquiry based learning, defined as "the creation of a classroom where students are engaged in essentially open-ended, student centered, hands-on activities" (Colburn, 2000). Thus, engaging in scientific studies through citizen science projects can be a form of inquiry based learning. This offers the potential to deepen the experience and understanding of the environment, of scientific ideas, and of how scientists study the natural world.

A surprising decrease was exhibited in our results, in the scientific thinking of the post-comparison group. This unpredictable decrease may be explained by the low number of students answering the post questionnaire in this group (N=14) and the short and uninformative answers received by them. This may be due to the low motivation of this group (non-participants) to complete the questionnaires especially towards the end of the school year. A decrease in replies was apparent only in the scientific and critical thinking sections since they consist of open questions which are time and mind consuming. Another limitation of the study is the overall low number of participants which were all students of two classes in one school. Broadening the study to diverse environments and locations may result in different findings and outcomes. On the other hand, since a major part of the intervention in this study is conducted by the school teacher, including several teachers in the study might create a bias in interpretation of the results.

Citizen science can also have significant social outcomes, such as providing opportunities for communities to use science to address community-driven questions (Bonney et al., 2014), raise awareness and involvement in social and environmental issues (Overdevest, 2004) and help protect and preserve the local environment (Wals, Brody, Dillon, & Stevenson, 2014; Wilderman, 2004). These outcomes were not examined extensively in the current study, although an increased awareness to the environment and air quality was expressed by students. Future work should further investigate the promotion and achievement of diverse social outcomes following participation in citizen science projects. This is of special interest in the context of participating schools and students, and as a form of informal science education (Bonney et al., 2009).

## 5 CONCLUSIONS

In this paper we describe a citizen science project focusing on air quality monitoring within school environments. We have demonstrated student increased content knowledge and scientific thinking following participation, however found no change in student attitudes, behavior or critical thinking.

Considering the goals set for science education in schools (increased scientific knowledge) and the scope of activities the students participated in, these outcomes are both exciting and rewarding. These results further clarify some of the uncertainty regarding citizen science benefits for participants and highlight the potential of citizen science as a useful tool for science education in schools and for informal science teaching. Prolonged work with students, emphasizing the nature of science and setting goals for higher level thinking may further promote critical thinking and a global understanding of what science is.

We further argue that although participation in citizen science research has the potential to contribute to socioecological challenges and create new collaborations, participation in itself may not be sufficient in order to receive these desirable outcomes. Additional guidance and goal setting is necessary in order to create integrative projects that have multiple scientific and social outcomes. Projects of this sort will not only engage volunteers in collecting data and preforming research, but also engage them in action for improving the local environment.

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