Digital innovation in education: Perspectives, opportunities and challenges of educational open data and sensor data

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Abstract. The emergence of digital technologies and data has influenced every area of life, from business to education. Data are important not only for global economic growth, public services, and social change but also for education. To address the challenges of the digital shift, the ability to interpret data and make decisions based on those interpretations is becoming increasingly important for our younger generation. It will be imperative for future generations of students to be equipped with the necessary digital and data skills to face the challenges of a digital and data society. This paper will discuss the perspectives, future opportunities, and challenges of using educationally relevant open data and sensor data in schools to create new possibilities for digital and data innovation in secondary school education.

Keywords: Open data; sensor data, digital and data skills, digital innovation.

1 Introduction

Data and digital technologies are now entrenched in our daily lives. It is therefore vital for young learners to be equipped with digital and data skills, the ability to understand data, and a command of digital technology operation [1]. There has been a rapid increase in openly accessible data sources that can be used without permissions and restrictions, such as open data that are publicly available datasets about traffic, population, education, the environment, statistics, etc. [2]. Simultaneously, with advancements in sensor technology, using sensors for data collection activities is now widely available to schools to integrate into their curricula [3]. Sensors can play an important role in education [4], particularly for secondary school students, as students begin to consider their surroundings, including the various phenomena occurring within those surroundings. Sensors can provide students with new types of hands-on, real-world experience in their immediate surroundings [5]. Furthermore, incorporating IoT and sensors in the

educational sector can provide students with hands-on experience with digital technology. It can also aid at the beginning of a process of sustainability perception and attitudinal shift among young students. For instance, authors in [6] discussed how IoT-enabled energy applications, for example, could be integrated into school life. The findings show that IoT and sensors can provide educational and energy-saving benefits by engaging students and providing them with hands-on experience based on real-world data.

Open data and sensor data can both play key roles in bringing digital innovation to education by engaging students in data collection activities and allowing them to understand the concept of data via analysis and interpretation in relation to the real world [7, 8]. To build a digital and data-literate society, it is essential to initiate the acquisition of key data literacy skills early in education (fifth grade onward). For instance, how data is collected, published, and used in real life and what data platforms can be used to access educational relevant datasets. The scant research on the use of open data in elementary or secondary schools indicates a lack of awareness among educators [9]. Notably, there are challenges in integrating digital and data technology in schools, such as teachers being unaware of open data, including its potential as an educational resource, and the need for skilled teachers to integrate well-suited data into their teaching assignments.

Previous research studies [4, 10–14] conducted in close collaboration with Danish public schools identified opportunities for open data as an educational resource. For example, the use of data from students' municipalities can pique their interest, foster discussions, and explain problems in students' geographical or social environments, which helps them relate the data to their everyday lives [10]. Several issues that impede teachers' use of open data in education have also been recognized, such as the concept of open data being abstract and difficult for students to understand and the fact that hands-on data collection activities are required to grasp the concept of data [12]. To aid teachers, educational open data domains were identified from the national open data portal, and an open data interface was developed to assist with educational assignments using educationally relevant open datasets in a previous study [13]. Additionally, requirement models for curriculum-compatible sensors were developed for data collection activities and usability of open data interface has been tested by teachers and students [4, 14].

However, to take full advantage of these publicly available resources, further research is needed to better understand the value and opportunities of open data as an educational resource, including how to integrate real datasets into the learning process. This exploratory paper will explore the perspectives and future possibilities of using open data in education in a variety of contexts other than classroom activities based on our previously conducted research studies [4, 10–14]. We will discuss the perspective of open data and sensor data in a broader view in the following research question (RQ):

RQ: (a) What are the future opportunities for open data and sensor data in an educational context, and (b) what are the potential challenges to realizing these opportunities?

The following is the structure of the exploratory article. The research methods for identifying challenges and opportunities are presented in Section 2. Section 3 presents the results and in Section 4, the conclusions are presented. Finally, the limitations and future research are discussed in Section 5.

2 Research Method

In this exploratory research work, we reviewed our previous work [4, 10–14] to comprehend and analyze the future challenges and opportunities associated with the use of open data and sensor data as educational resources. Previously, we discussed open data and sensor data usage in separate studies [4, 10, 11, 14], identifying the benefits and existing challenges of open data and sensor data usage in school education, as well as proposing solutions to these challenges. In this study, however, we analyzed the overall data collected (in close collaboration with both teachers and students) in previous research studies to identify future challenges and perspectives for both open data and sensor data in school education. The overall data (collected in previous research studies) were categorized into three broad categories: future opportunities associated with the use of open data and sensor data in an educational context, challenges in using open and sensor data, and initiatives to reap the benefits of open data and sensor data in education. Table 1 provides a summary of the participants and research methods used in our previous research studies.

Table 1. Overview of the participants and research methods used in previous studies [4, 10, 11, 14] for data collection.

Research study	**Participants**	**Methods**
Research study 1 [11]	10 teachers and 21 students	One-on-one interviews and pilot test
Research study 2 [10]	10 teachers and 12 students	Open discussion, online questionnaire, observations
Research study 3 [4]	30 teachers and 38 students	Focus group, one-on-one interview, pilot test (indoor and out door)
Research study 4[14]	39 teachers and 16 students	Focus group, one-on-one interview, pilot test, online usability test

The following steps comprise the research methods used in this work:

1. Analyses of previous work in educational domain, including the use of open data and sensor data in tandem.

2. Identifying future challenges and opportunities for the use of open data in education.
3. Proposing initiatives to mitigate the barriers to the use of open and sensor data in education.

In the following section, the research results are briefly discussed.

3 Results

In this section, the main findings are discussed under the following categories:

1. Future opportunities for open data and sensor data use in an educational context
2. Challenges in using open and sensor data in education
3. Initiative to reap the benefits of open data and sensor data in education

3.1 Future opportunities for open data and sensor data in an educational context

Many institutions have already recognized the importance of involving schools and higher education institutions in open data research [15, 16]. Open data are an excellent resource for gaining hands-on experience with techniques and tools for searching, cleaning, and organizing data, whether by hand or with computers [17, 18]. Open data also impact subject learning, the development of digital and data skills, and even student motivation to learn by relating the subject to the student's environment. For example, Discover Kells[3] uses open data from the National Monuments Service and the National Inventory of Architectural Heritage of Ireland and provides information about national monuments and historical buildings. These datasets can be used in history topics to make them more interesting.

However, to reap the full benefits of open data, governments or educational administrators must also be involved in incorporating educational open data directly into educational plans. For example, secondary education plans could involve an introduction to basic data principles, such as structures, formats, and analysis. These kinds of measures are critical if we want to encourage students towards more active learning using open data. Norway[4] and the United Kingdom [18] have already launched projects with a particular focus on data literacy in elementary schools with positive results. However, when working with publicly available datasets, consideration should also be given to data privacy and ethical use [19].

Sensors, on the other hand, can be useful in understanding the concept of open data. For example, students can collect pollution data near a railway station using sensors and compare them to available open data. This allows the

[3] https://data.gov.ie/showcase/discover-kells
[4] https://site.uit.no/opendatainteaching/

students to understand how data are generated and what factors may influence the data collection process if there are differences between the sensor data and the open data. These types of activities expose students to real-time data collection activities outside the classroom [20]. They can better understand sensor data when it is collected in real-time and generally small in size. Using open data as an educational resource provides students a better sense of their surroundings, cities, and country. Sensor data, such as classroom temperature, humidity, pollution level, noise level, etc., can be shared with other schools by uploading them to a common platform.

Students can also compare their school data with those of other schools rather than with those of their immediate surroundings or cities. For example, they can reflect on why their school's noise or pollution levels are higher than those of other schools. Students may develop a wide range of skills through these activities, ranging from the use of complex technologies and the ability to analyze and argue to the development of vital skills, such as teamwork, critical thinking, and discussion. Figure 1 shows how sensor data relate to educationally relevant open datasets and existing national open datasets.

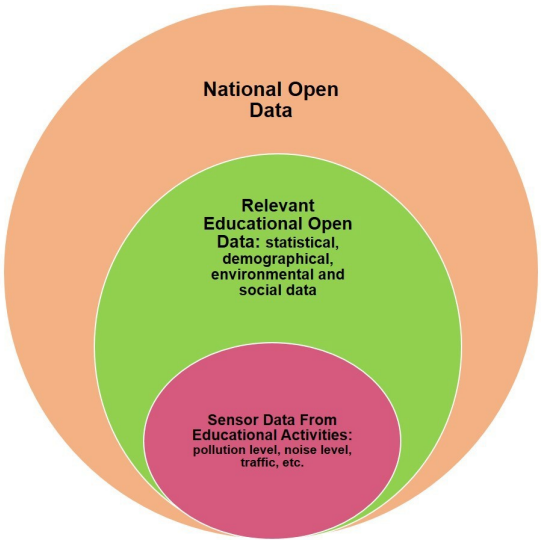

Fig. 1. The relation of educational open data and sensor data (collected through school educational activities and made available for other schools) to national open data (inspiration from [21]).

Figure 1 represents how educationally relevant open datasets, for example, can be identified and selected for use in education as part of school subjects. Simultaneously, using sensors, some educationally relevant datasets can be collected locally (in school surroundings) and made available to other schools via a

common educational open data platform. They can gain a better understanding of the concepts of open and private data. For example, sharing collected data with others or avoid exposing data to others in certain activities.

Without systematic planning, integrating open data as an educational resource will not yield the desired results. Systematic planning may include teacher training, access to additional resources, such as sensors in schools, and a shift from the traditional teaching methods toward more collaborative and problem-based learning methods at the school level. A common platform that could relate relevant educational open datasets to school subjects and allows students to share data collected during various educational activities using sensors or other technologies within or outside school could also be beneficial. These tasks will not only benefit teachers and students but will also enhance learning environments and citizen science.

3.2 Challenges in using open and sensor data in education

In this section, we will discuss the future challenges (that still need to be addressed) that may influence the use of open data and sensor data in educational activities. Generally, open data research is concerned with the data type, quality, structure, and design of real-time applications to access and publish datasets. However, there has been less emphasis on developing tools or applications that can make these datasets more accessible and usable for students [22]. Access to relevant educational datasets as an educational resource has been identified as a major challenge in previous studies [13]. This issue still needs to be addressed at the national level in the future. A national educational open data portal that not only provides access to relevant educational datasets from various cities but also visualizes these datasets in the form of interactive graphs, could benefit teaching and learning processes in a broader sense. Different cities publish different themes of open datasets based on their geographical and demographic backgrounds that can be useful in an educational setting. For instance,

Table 2. Open datasets of various cities in Denmark City.

City (inhabitants)	**No. of Datasets**	**Main Datasets**
Copenhagen (638K)	288	Transport, environment, districts, education, population, tourism
Aarhus (283K)	123	Education, traffic, population, bicycles, sensor data, tourism
Vejle (59K)	99	Floods, education, bicycles
Odense (181K)	30	Culture, education, transport

Table 2 shows the main open data themes of various Danish cities. Each city

has different datasets themes based on its historical background, location, and population. For example, Copenhagen, the largest city with the highest population, mostly has datasets about traffic, the environment, noise, etc., whereas Vejle has also datasets about floods due to its location, as well as other datasets such as education [5]. This information of different cities could also be interesting for students both for quantitative and comparative studies.

With access to educational relevant datasets of different cities, students can further learn how the demands and services of cities can vary depending on their population and geographical location. In an educational setting, applications that allow students to access, use, and share their own data (collected during various educational activities) are also required. Previous studies have also shown that it is critical for students to have access to up-to-date datasets when working with real-world datasets [13] and this issue must also be addressed in future studies.

Another challenge that could affect the successful use of open data and sensor data is teachers' motivation, instructional design, and training. One possible solution to motivate teachers could be sharing success stories through national educational open data platforms. Awareness can also be spread by setting up small competitions based on data. These would not only involve students but also motivate teachers to learn more about data-related activities. The associated learning skills are not achieved simply by using open data in school teaching; they are also dependent on how open data is used pedagogically, and this requires revision in schools' curriculum strategies. When working with data and technology, ethical, privacy, ownership, and legal considerations need to be reviewed, such as copyright, authorship, and content. It is also important to teach students about the ethical use of data when they publish on common platforms (i.e., use correct information).

3.3 Initiative to reap the benefits of open data and sensor data in education

The following measures must be implemented in the future to reap the maximum educational benefits from open data and sensor data use in the educational domain.

1. Providing schools with access to relevant up-to-date educational data
2. Providing schools with access to curricula-compatible sensors and technology in an educational context
3. Developing a national educational open data platform that provides access to existing relevant educational datasets and allows the educational community to share their experiences and publish data collected through educational activities
4. Training and awareness programs for teachers
5. Involvement of government or educational administration in open data initiatives

[5] https://www.opendata.dk/

4 Conclusion

With the introduction of technology in schools and a push for more accessible government data, there are many opportunities for better data collection and analysis in education. One way to assist students in developing digital and data skills is the use of open data in the classroom as an instructional resource. The literacy of these skills has become vital in the early stages (e.g., secondary school) of education to build a strong, informed, and talented workforce that is ready to face future challenges and opportunities.

The availability of open data has many associated opportunities from not only a technical or governmental perspective, such as improving public services and bringing transparency to government policies but also from the educational perspective, such as using open data as an open resource to help students learn essential future skills and provide a learning environment that allows students to relate their subjects with their immediate surroundings. Open data and sensor data also provide students with information that, in some cases, requires significant time and effort to accomplish a task or draw a conclusion.

5 Limitations and future research

The results presented in this research study are limited to schools (teachers and students as participants) in Denmark. However, it provides the educational community an overview of the possibilities, opportunities, and challenges in using open data and sensor data in educational activities. To fully exploit the benefits of open data and sensor data, research is needed to discover ways to successfully integrate open data and sensor data in curricula and develop a common platform that allows the teaching community to share their success stories and upload the results of data collection educational activities for others. The organization of seminars or courses is also required to increase the awareness of and motivation toward the use of open data among teachers. Lastly, there is a need for government or administrative involvement in successfully integrating open data into the school system.

The value of open data and sensor data in the learning process has not been sufficiently investigated to date; therefore, more investigations are needed to reap the full benefits of open data and sensor data in future research. To successfully integrate open data and sensor data learning into schools and gain the full advantage of open data opportunities, the initiatives and challenges discussed above need to be addressed.

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