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Open Data Interface (ODI) for secondary school education

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ABSTRACT

Advancements in data technology provide easy access to open data sets that can act as raw material to promote data competencies in the education domain. In this study, we investigate how open data can be used to develop digital and data literacy skills among secondary school students (ages 11–15). Using qualitative and quantitative research methods, we identify how data collection and analysis can be integrated into school education using openly available data sets. We also test the usability of a platform for secondary schools that allows teachers to identify and use open data sets when teaching school subjects such as math, science, and geography. The results suggest that open data have the potential to advance the digital and data skills essential for future generations, as well as enable them to understand their surroundings by using real data sets as part of their subjects. The results also demonstrate that the Open Data Interface helps educators utilize open educational data sets in schools.

1. Introduction

Through technological advancement and data availability, governments worldwide have launched open data portals, providing useful information e.g., about citizens, businesses, education, the environment, infrastructure Janssen et al. (2012) and Xu et al. (2020), etc. For example, Denmark has a national open data portal,[1] that provides free access to data sets published by government departments and institutions. Similarly, the European open data portal,[2] provides access to open data published by EU institutions and bodies. All the data available in these portals are free to use and reuse for commercial or non-commercial purposes, i.e., citizens can freely use and share these data sets for any purpose Ciociola and Reggi (2015) and Neto et al. (2018).

Open data also have the potential to be used in learning activities Atenas and Havemann (2015) and Vargianniti and Karpouzis (2020). Open data can function as a valuable source to educate students about the concept of data by providing them real information e.g., about pollution, traffic, and population conditions of their own neighborhoods and cities. By integrating these real data sets into school subjects, students would not only learn the data concept, but also develop data skills, such as collecting, analyzing, and interpreting data, as well as enhancing digital skills Coughlan (2020).

However, several challenges need to be resolved before open data can be integrated into education and their benefits reaped in the educational realm. The availability of open data in itself is not sufficient for it to become a source of innovation in education. It is also

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[1] http://www.opendata.dk/.
[2] https://data.europa.eu/euodp/en/data.

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important that users understand what kinds of perspectives open data unlock, and what potential uses are facilitated Susha et al. (2015) and Morelli et al. (2017). For instance, teachers lack information about openly available data sets and their potential use in education. Teachers with little expertise in data analytics require extra time and effort, e.g., to identify and visualize data sets as part of their subjects. Thus, strategies are needed to govern open data use in education by addressing these challenges EU (2018) and ODI-Spain (2019). Researchers have discussed various possible uses of open data in education, in which students may acquire data analytics skills. For instance, Shamash et al. (2015) discusses different ways of examining open data sets through visualization or acquiring data analytics skills by investigating and analyzing open data sets as an integrated part of social science education. However, the literature review presented in Saddiqa, Kirikova, Magnussen, Larsen, & Pedersen (2019a) indicates that open data is mostly used by students in higher education, and that a gap exists between open data use in education, particularly in public schools, and the educational prospects and potential innovation offered by open data. The gap exists due to lack of awareness about the use of open data in educational settings, as well as the fact that open data portals do not provide direct access to educationally relevant open datasets. Saddiqa, Rasmussen, Magnussen, Larsen, & Pedersen (2019c) investigated how to reduce this gap through interviews, pilot tests, and surveys with teachers and students ages 11–15. The studies indicated that for facilitating open data use in schools, a platform is needed that allows teachers to access suitable open data sets for educational purposes.

In this article, we identify the data skills that can be enhanced and developed using open data, and test the usability of an Open Data Interface (ODI) platform prototype developed by Saddiqa et al. (2019a) that helps teachers use open data in education with real-life scenarios. We investigate the following research questions:

1. What are the main challenges and data skills associated with integrating open data into secondary school education?
2. How can a learning platform be designed to address problems and assist teachers in the use of open data in secondary school?

The study is part of the Community Drive research project[3] with the focus of understanding how to educate young people to participate in the transition of cities with data-driven methods. The project focuses on the city's many types of data and how to put them into use - especially in an educational context. In the remainder of this paper, we refer to secondary school students ages 11–15 as 'students' and the Open Data Interface prototype as the 'ODI'. Our main contributions in this research article are:

1. Identification of data skills associated with open data in education
2. Identification of challenges for using open data in education
3. Evaluation of the ODI's usability in secondary schools

The article is structured as follows: Section 2 presents the background of open data use in education. In Section 3, we describe the research methods and test setups used. In Section 4, the results are presented, while Section 5 concludes the paper.

2. Background

Open data has the potential to cultivate transparency and scientific innovation Zuiderwijk and Janssen (2014), Neto et al. (2018) and Osorio-Sanabria et al. (2020). With the availability of openly accessible data sets, students can work with real data sets, e.g., about their city or neighborhood, grasp facts, and understand real-life problems at a local level. To discuss both the ODI's usability and the use of open data in education, the background section is divided into two subsections: open data in schools and technologies for open data in education.

2.1. Open data in schools

Digital and data literacy are important issues in the development of 21st-century learning skills, which are essential to interact with a digital society that entails the generation of huge amounts of data daily Drigas and Leliopoulos (2014) and Heinemann et al. (2018). Thus, it becomes crucial to equip the younger generation with skills so they can interact with data to understand environmental, statistical, and geographical issues relevant to their surroundings. Many aspects of open data merit examining how it can be used in education, e.g., students might be motivated personally at the prospect of learning more about their own neighborhoods. Atenas et al. (2015) examined fundamental ways to help educators empower students with essential 21st-century skills. The study presents the findings of an exploratory survey conducted with academics on how they used or incorporated open data such as archaeology data, medical data, city data, statistical data, etc., into their teaching practices to develop transversal skills, including digital and data literacy among students. The *Data Education in Schools* project, funded by the Scottish Government Farrell and Robertson (2019), has a particular focus on teaching data literacy and data citizenship skills to learners, developed an interdisciplinary data education curriculum and real-world data science teaching materials in collaboration with educational researchers, professional learning, and digital skills consultants for primary and secondary school teachers.

The literature indicates that generally, teachers view open data as positive influences on their learning environments Henty (2015), Guy (2016), Manca et al. (2017) and Adeboye et al. (2020). However, many challenges are involved in integrating open data in

[3] https://www.communitydrive.aau.dk/

education, especially in elementary and secondary school education. The limited research to date on the use of open data in education suggests a lack of awareness of its potential among educators according to Love et al. (2016) and Coughlan (2020). The studies indicates that learners and educators lack data literacy (e.g., the knowledge and skills needed to analyze and work with data), as well as resources to make full use of open data opportunities.

Henty (2015) list barriers that could influence the use of open data in education, e.g., lack of technical expertise, teachers' lack of understanding of open data, and how to integrate open data sets in school subjects. Both Tambouris et al. (2018) and ODI-Spain (2021) list factors that hinder open data integration into schools, such as lack of teacher training and challenges in adapting existing data (as most open data sets come from professional environments such as scientific research or public service administration), and that students and teachers may not have the literacy or resources to take benefit of them.

Saddiqa et al. (2019a) reveal a lack of research on open data use in education, particularly in schools, in terms of how to integrate open data in teaching practices. The study reveals challenges that hinder teachers' efforts to use open data in education, e.g., that the concept of open data itself was found to be too abstract and difficult for students to understand. They need hands-on experience with data collection to understand the data concept and how to use open data. The results of the study reported in Saddiqa, Larsen, Magnussen, Rasmussen, & Pedersen (2019d) indicated that simple open data visualizations representing students' municipalities captured their attention and encouraged discussions and reflections. These include topics such as population, pollution, geographical overview, traffic flow etc. Open data domains that easily could facilitate basic school subjects – such as mathematics, science, social science, and geography – were identified and discussed in Saddiqa et al. (2019b). The study also indicated a need for an interface tailored to educational purposes, i.e., an interface that allows teachers to link their subjects with open data sets suitable for educational purposes.

2.2. Technologies for open data in education

Open data can be viewed as a resource that can advance public services, induce transparency in government policies, and can also advances the educational management Vetrò et al. (2016) and Chen and Xu (2020). These data sets can also be integrated within educational domains to develop 21st-century learning abilities such as data and digital skills among students.

Several researchers have experimented with different digital platforms to facilitate and provide easy access to open data in higher education. For instance, Friberger and Togelius (2012) describes a game called Open Data Monopoly, in which students are provided with the means to visualize publicly available data about their countries and neighborhoods. Dunwell et al. (2016) developed a game that supports the development of healthy lifestyles among adolescents using the U.S. Department of Agriculture's open data portal. The results demonstrated how standard game mechanics could be applied to open data to provide useful and engaging educational experiences. Chiotaki and Karpouzis (2020) discussed a card game designed to teach environmental matters to early elementary school students using open data. The study shows how the game based on real data sets can gain students' interest in the subject and improve their performance and engagement to the course as compared to conventional teaching.

Despite the rapid development of open data platforms, the accessibility and ease of use of data portals are low and usability of open data sets available on government platforms presents challenges for citizens, teachers, and students Skopal et al. (2019) and Saddiqa et al. (2019c). Zheng et al. (2020) and Osagie et al. (2017) showed in their research that mostly the open data programs focus on data quality and organization and give less attention to platforms, their use, and impact. This fact restricted citizens, civil society institutions, and educational domains from utilizing open data for their goals. For instance, from an educational perspective, these data sets are often large, and teachers might need to devote much time and effort to identify simple information that can be included readily as part of lesson plans. Most teachers and students are not familiar with the process of data cleaning, i.e., removing irrelevant data from a data set, or with different forms of data structures.

The existing platform such as TuvaLabs[4] and Discover Kells[5] provide opportunity for improving data analytical skills and present history and education topics in a user-friendly feature respectively. However, to integrate open data into schools, research is needed to investigate how existing open data platforms can be utilized in education, and how educational open data platforms can be designed to facilitate teaching. There exists a need for an educational interface for schools that allows teachers and students to access education-specific open data sets, rather than spend time searching for relevant educational data sets through, e.g., national open data portals Saddiqa et al. (2019c). Requirement models for such an interface were defined in Saddiqa, Kirikova, & Pedersen (2019b). Based on these requirements, an ODI prototype was developed and presented in Saddiqa et al. (2019a). Available at https://odw.aau.dk/, the ODI allows teachers to select real data sets from their cities as part of school subjects, i.e., teachers can relate their subjects to actual data, e.g., pollution levels, noise levels, or traffic congestion near their schools. The interface is open source,[6] apart from the visualization tool Tableau.

In this paper, we report on open data use in schools in a real environment using the ODI and reflect on diverse ways of using open data sets in education, their influence on learning-activity behavior, and the usability of the ODI in schools.

[4] https://tuvalabs.com/.

[5] https://data.gov.ie/showcase/discover-kells.

[6] The ODI source code is available at: https://github.com/Open-Data-School/Open-Data-for-Schools.git.

3. Research methods

We used a variety of methods and approaches to investigate the research question and evaluate the potential of open data as an educational resource, including surveys, interviews, and observations with teachers and students using the ODI prototype. Saddiqa et al. (2019b, 2019c),Saddiqa et al. (2019c, 2019d) demonstrate teachers' perspectives on open data in education and their assessment of open data's potential impact on students. However, in the present study, teachers had the opportunity to interact directly with a range of pre-selected, school-related open data sets through the ODI. Thus, they could experience the ODI as developed based on the requirements they proposed in Saddiqa et al. (2019a).

We investigated the research question in two parts, with two particular focus areas, using an ethnographic approach, as this has proved to be beneficial for understanding problems with existing designs and for generating new designs (Kelly et al., 2014). Applying this approach, we investigated associated problems with open data practice in education using the ODI. This approach allows users to work with open data directly through the ODI instead of a theoretically informed design only, but also helps identify any usability issues associated with ODI, as shown in Fig. 1. Thus, in the first part, we investigated the associated opportunities with open data as an educational resource using the ODI. The second part focuses on the ODI's usability, e.g., whether the prototype fulfills the teachers' requirements.

3.1. Investigation 1: Open data as an educational resource

Investigation 1, focused on examining open data as an educational resource in an environment in which teachers have access to open data sets through the ODI. The teachers and students were the participants. Both qualitative and quantitative research techniques were used, such as one-on-one interviews, a focus group, online usability tools, a pilot test, questionnaires, online surveys, and open discussions to gather participant responses.

3.2. Investigation 2: Evaluation of our ODI prototype

In Investigation 2, the ODI's usability was evaluated. The methods applied in investigation 2 are:

1. Usability test of the ODI prototype: We tested the aspects of the interface prototype, viewed as general aspects of any web interface Islam and Bouwman (2016) and Condos et al. (2002), as shown in Fig. 2. During the testing of these aspects, the focus was on the platform's usability in relation to the educational domain. For instance, how it works as a learning tool in public schools, how it works in tackling educational challenges, and how well it fulfills the requirement models developed in Saddiqa et al. (2019a).
2. Modification of the ODI based on the usability test results: The ODI modified iteratively after each round of data collection and analysis in Investigation 2. Initial data were collected through one-on-one interviews in which teachers tested the ODI's various features and provided feedback. Before setting up the focus group meeting with teachers, we upgraded the ODI to reflect the interview comments. Likewise, before launching the online usability test, we upgraded the ODI to its final version based on the focus group comments.

3.3. Test setups

Details are provided below on the different methods used to investigate both parts of the research question, i.e., assessing open data's potential and challenges as an educational resource and testing the ODI prototype's usability.

1. One-on-one interviews: The main aim of using interviews was to get feedback from teachers after providing them with insights about open data and how they could use it as part of their teaching assignments using the ODI Kvale and Brinkmann (2015) and Bryman (2016). Using this method, we tested the usefulness of the pre-selected open data sets, their visualizations, and the ODI interface's overall user-friendliness, and asked for any new features that might be interesting for teachers.
2. Focus group: Focus groups help gather in-depth details about a group's actions, thoughts, and feelings, as participants are allowed to interact and converse with others while discussing a topic Parker and Tritter (2006). In our case, the focus group was a mix of teachers of different subjects and grades (fifth through ninth). The main aim was to investigate the awareness of open data as an educational resource among teachers and subsequently to test the ODI's usability.
3. Usability tests: With usability tests problems can be identified before the system is released to end-users Rubin (1995). We used the Loop11[7] online usability test tool, which allowed us to analyze our prototype's usability while users were performing real tasks. We choose Loop11 because it allowed us to carry out usability tests remotely, i.e., without having to bring teachers into the lab. Loop11 provides two types of user testing: moderated and unmoderated. With moderated testing, users shared their screen and audio with the moderator (live) as they performed their tasks. In unmoderated testing, users do their tasks at a time of their choice without a moderator, though screen and audio still can be captured. We did the online testing with both types.

[7] https://www.loop11.com/.

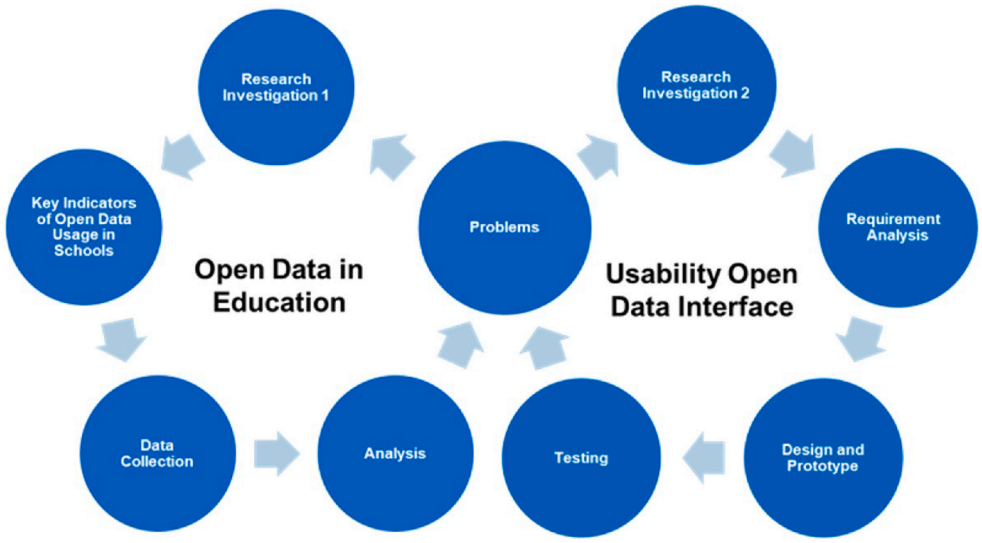

Fig. 1. Methodological approach inspired by the ethnographic approach (Kelly et al., 2014), with Investigation 1 examining open data in education and Investigation 2 studying the usability of the Open Data Interface (ODI).

Intuitiveness	• Do teachers and students understand the interface design and know how to use it?
Usability	• How satisfied are teachers with the interface? Does it fulfill their requirements?
Ease of Use	• Is the interface easy to use in general as part of specific school subjects?
Quality Content	• Is the content relevant for students?
Performance and Consistency	• How does the interface perform, and is it consistent, e.g., can teachers and students easily access the required data sets?

Fig. 2. General usability aspects used in testing the Open Data Interface (ODI). Inspired by Islam and Bouwman (2016) and Condos et al. (2002).

4. A pilot test that included students: One of the main aims of pilot tests is to increase research quality, reliability, and validity Gudmundsdottir and Brock-Utne (2010). As students and teachers are the main users of the ODI, we also have run a pilot test in a public school in the city of Aarhus, where teacher and students used the ODI in class as part of teaching assignments.

Teachers willing to participate in the research study were recruited based on their subjects, grade levels, and experience as follows:

1. Public schoolteachers with more than two years of experience
2. Grades: fifth through ninth (as in these grades, students start developing basic concepts on data and their presentation as part of mathematics and statistics.)
3. Subjects: math, science, geography, and social sciences

The participant details are provided in Table 1.

Previous research and usability guides indicate that four or five participants can reveal approximately 80 percent of the usability problems in most web interfaces Khan and Singh (2012). Similarly, using 10 participants usually will elicit detection of 90 percent of usability problems Dumas et al. (1999) and NN-Group (2012). Therefore, 4–10 participants were recruited for each test to evaluate the ODI's usability. Overall, 39 teachers and 16 students participated in research study from fifth to ninth grades. All the interviews were conducted in Danish and recorded with the teachers' consent. Procedural details on each test setup are provided in Table 2.

Table 1
Data collection setup and participating teachers and students.

Test setup	Participants	Schools	Grades	Subjects	Location	Duration
One-on-one interview	5	5	5th–9th	Math, Science	Aarhus, Horsens	1–1.5 h
Focus group	25	12	5th–9th	Math, Science, Social science	Aarhus	1 h
Moderated online test	5	5	5th–9th	Math, Science, Social science, Geography	Aarhus, Aalborg, Horsens	45–60 min
Unmoderated online test	4	4	5th–9th	Math, Science, Social science	Aarhus, Aalborg, Horsens, Copenhagen	20–30 min
Pilot test with students	16	1	9th	Science	Aarhus	6 h

Table 2
Procedural details for each test setup.

Test setup	Procedure
One-on-one interviews	**Investigation 1:** The concept of open data was introduced to the participants. Questions were asked about open data potential, skills required to work with data, and any obstacles to using open data as part of teaching. Teachers had access to the ODI, so they could interact with different data sets in a real environment. **Investigation 2:** Teachers tested the ODI and tried out its various features, then provided feedback on the design of visualizations and suggested designs for learning activities using open data sets.
Focus group	**Investigation 1:** Teachers listened to a short (10-min) presentation about open data and its possible use in public schools, followed by an open discussion on associated problems and opportunities in using open data in schools. Teachers discussed how often they use data in their teaching, from where they get the data, and in which subjects and grades they use data. They also discussed the impact of using data on students' learning skills, as well as obstacles of using open data in teaching assignments. Teachers also answered questions concerning the impact of open data on students in the form of a questionnaire. **Investigation 2:** Participants tested the ODI on their computers while suggestions and feedback were noted. The meeting ended with a post-test questionnaire to gauge participants' individual and subjective responses on the ODI's design and its usability in teaching activities.
Moderated online test	**Investigation 1:** For moderated testing, times and dates were set with users beforehand, with a brief explanation on how to participate in the online test. After solving different tasks to test the ODI prototype's usability, short, live interviews were conducted, in which we investigated the scope of open data in education and teachers' perspectives on open data and the ODI. **Investigation 2:** Tasks were designed to test ODI's usability. Six tasks and 10 questions were used. The tasks were designed to test teachers' understanding of the ODI using real data sets in their subjects. For example, teachers performed a task in which they identified pollution data sets from the City of Copenhagen as part of a science subject. The tasks details are given in Appendix A.
Unmoderated online test	**Investigation 1:** A link to the test was sent to participants via email. The test included a short survey in which we asked both open-ended and closed-ended questions about the use of data in teaching, different ways of integrating open data in education, and educational open data sets to be included in the ODI. **Investigation 2:** The unmoderated test comprised five tasks and 13 questions. The questions were both open-ended and closed-ended, focusing on ODI's ease of use and general usability (see Appendix A).
Pilot test with students	**Investigation 1:** The teacher started the day by briefly introducing the concept of open data and ODI to the students, using the concept of pollution with examples. The teacher also used the pollution data sets available in the ODI as real examples of their own cities' pollution levels at different locations. The conversations between teacher and students were recorded during the test. **Investigation 2:** The teacher handed out an assignment that comprised different tasks on pollution that students had to complete in groups with the help of data from the ODI (see Appendix D). At the end of the assignment, students also provided feedback on the ODI via an online questionnaire.

4. Results and discussion

In this section, we briefly discuss the results obtained from qualitative and quantitative data analysis. The results present our analysis on if and how open data can best play a central role in achieving learning goals, and how platforms like the ODI can help bridge open data and educational activities. The main themes arising from the results are summarized in Table 3 and discussed in more detail in the following sub-sections.

4.1. Open data in education

The results under this theme demonstrated that there are perceived opportunities associated with the use of open data in public schools. Some teachers already included real data sets in their teaching activities, but teachers also faced challenges in using open data in their teaching plans, e.g., they often were unaware of the open data portal for their city or how they could include open data sets as an educational resource in their teaching.

4.1.1. Relating things to the real world

Using the ODI, teachers developed a clear impression of the range of different educational data sets that they could include in teaching. They also provided their perspectives on how open data could help students develop data skills and what could be the impact of open data on education through the study's interviews, surveys, and focus group. For example, using real facts about their cities could capture students' attention and lead to more students participating in discussions. Teachers also believe that using open data in

Table 3
Overview of results – major themes and sub-themes with example quotes from participants.

Themes	Sub-Themes	Example quotes
Open data in education	1. Relating things to the real world 2. Educational open data sets 3. Learning activities using real data	*"Students will learn more when they relate things to their own real world, e.g., information about traffic, population, pollution, etc., and open data provide us a chance to learn through these real data sets." (Teacher 1, Jan. 12, 2020)*
Learning skills associated with open data	1. Critical Thinking 2. Teamwork 3. Discussion	*"Open data will help in developing students' learning skills like teamwork, critical thinking, discussion, and the ODI works very well, as everything is gathered at one place." (Teacher 1, June 26, 2020)*
Data skills	1. Meaning of data 2. Data analysis 3. Data visualization skills 4. Statistical skills	*"Open data are fantastic, but at the same time, it is also important that students are aware of the meaning of data, and for this, they must generate and analyze their own data because if students have not tried generating data themselves, then they do not understand data." (Teacher 1, Feb. 20, 2020)*
Challenges for open data in education	1. Unfamiliarity with using real data sets 2. Relevant educational data sets 3. Lack of data skills 4. Time constraints 5. Lack of resources	*"I want to use real data sets in my teaching, but it was really difficult to find relevant data sets from government websites, and it is hard to sort out the information we needed before we use them in our everyday teaching." (Teacher 1, Feb. 27, 2020)*
Open data web interface	1. Identifying relevant and useful open data sets 2. Integrating educational open data sets 3. Intuitive/readily learned design 4. Usability 5. Ease of use 6. Quality content 7. Performance	*"Instead of searching and sorting data sets, and consuming too much time, I like the idea of a simple and easy-to-use ODI for schools. We can easily integrate real data sets into our teaching using this interface." (Teacher 2, Feb. 27, 2020)*
Challenges tied to ODI's integration in schools	1. Administrative constraints 2. Up-to-date 3. Training 4. Ministry of Education approval	*"ODI is great; it provides the information that will make our teaching activities more interesting, but for using it as part of our subjects, it is also important that it must be up-to-date, and it will be great if the Ministry of Education also approved it." (Teacher 2, June 26, 2020)*

education can help advance both digital and data skills. Teachers mentioned that students achieve a better understanding of a topic if they have relevant data in front of them. Furthermore, open data provide an opportunity for students to understand and interpret the data they observe in their surroundings.

4.1.2. Educational open data sets

Teachers suggested additional open data sets that could be interesting for students to include in the interface, such as water quality, forests, crimes, pollution sources, traffic, plastic pollution, lakes (locations, length, etc.), etc.

4.1.3. Learning activities using real data

One of the main obstacles among teachers is the lack of awareness in integrating open data in teaching. During Investigation 1, we also gathered suggestions from teachers about how to integrate real data sets into their assignments. For example, teachers suggested different ways to analyze the city's population in the past five years and predict future population aspects based on the data as part of social science. Similarly, geographical data sets could be used to help students understand their own cities' geographical structure from a variety of perspectives.

4.2. Learning skills associated with open data

During the focus group meeting, teachers discussed various learning skills that can be associated with open data depending on how data is used in an instructional design. At the end of the focus group meeting, in a post-test questionnaire, we asked teachers to select 21st-century skills according to students' grades that can be associated with open data among the skills listed by Atenas et al. (2015) and National Academies of Sciences et al. (2018) as important issues. Critical thinking, teamwork, and discussion are consider as important 21st-century learning skills according to teachers for students and can be improved and developed with the use of open data in teaching assignments. The details are discussed below.

4.2.1. Critical thinking

Critical thinking allows students to ask questions and make value judgments Alsaleh (2020). At the end of the focus group, teachers provides their response in a post-test questionnaire about various associated skills with open data, and critical thinking is one of them. Altogether, 23 of 25 teachers believe that students in fifth to ninth grades can develop this skill using real data, e.g., how to reduce pollution levels near their schools, how to reduce energy consumption, or how energy waste could affect the environment and the planet overall. During the pilot test, students were observed while making discussions with their teacher. Students asked questions about pollution levels in their cities during different times of the day and how to reduce them, considering critical aspects of pollution's effects on society.

4.2.2. Teamwork

Learning assignments based on educational open data sets provide an opportunity for students to work in teams, which is also an important skill for students' learning development. Altogether, 23 out of 25 teachers responded in a post-test questionnaire (during the focus group meeting) that through the use of real data, students in fifth through ninth grades can work in groups to solve problems by interpreting and understanding the data. During the pilot test, students worked in groups and discussed how they could reduce pollution in their cities. It also demonstrates how real information about students' cities makes the subject interesting, and group work can become more interactive when students have real information about their surroundings.

4.2.3. Discussion

Using real information, students will have more opportunities to discuss a topic. Using open data, students have access to the real information on their cities and surroundings that will make the class environment more interactive and open the door to discussions. All 25 teachers who participated in the focus group agreed that real information always captures students' attention, and that students in fifth through ninth grades can participate actively in discussions in class more easily when they are based on real data.

4.3. Data skills

Working with different types of data allowed students to build and improve data and digital skills, e.g., computer skills, visualization skills, data-handling skills, etc. However, students also encountered issues when working with open data, such as the data concept being too abstract, and they required additional assistance to understand how data is used to understand a problem. Furthermore, students also lose interest due to some out-of-date data sets. In some cases, teachers suggested that it is important for students to collect and interpret data themselves. This will help in understanding the concept of data and how to solve problems using data. The results are discussed below.

4.3.1. Meaning of data

The concept of data itself is difficult for students to understand, as they are unfamiliar with how data are collected, why data are important, and how data are used to find solutions to problems. Teachers have suggested including data collection activities in the classroom, so students can get familiar with data and their use in everyday life. One of the participants said:

> *"To explain the concept of data to students, they must work with different types of data collected by them. Students need prior knowledge before they can use and understand the data." (Teacher 3, Feb. 27, 2020)*

4.3.2. Data analysis

Introducing the concept of data collection in the classroom can give students the necessary background to sample, analyze, and discuss their data. Working with real data sets enables students to organize them into tables and different folders according to information types. Out of 25 teachers, the 24 who participated in the focus group meeting suggested that students in fifth through ninth grades can develop basic data-handling skills if they work with small data sets more often in their assignments. For example, students can use pollution data sets to get the information they need in the form of a small table to complete an assignment, instead of using all the details provided in pollution data sets.

4.3.3. Data visualization skills

Using open data, different information can be presented in the form of simple graphs and visualizations. This not only allows students to understand how data are used to present information, but also can enable them to examine graphs and visualizations to answer related questions and understand how to use different forms of graphs and visualizations while improving their computer skills.

4.3.4. Statistical skills

Using open data in the classroom can improve students' statistical skills, according to teachers' feedback. Students can perform basic mathematical operations, such as converting information from annual to month by division methods or calculating means, etc. Altogether, 24 out of 25 teachers participating in the focus group meeting agreed that students in fifth through ninth grades easily can improve and develop such skills.

4.4. Challenges for open data in education

Teachers also pointed out potential challenges to and suggestions on using open data in schools during the interviews and focus group meeting. Overall, the teachers were satisfied with the ODI's design, which allowed them to access educational data sets from their cities as part of different school subjects, but they also mentioned didactic challenges (see section 4.5.2) and the following technical challenges:

4.4.1. Unfamiliarity with using real data sets

One of the main challenges is unfamiliarity with open data as an educational resource. Teachers are not aware of the concept of open data and how they could integrate it into their teaching, but this lack of awareness could be alleviated through workshops, training, and seminars.

4.4.2. Relevant educational data sets

Teachers are unaware of open data portals, and they mostly use national statistical websites, in which they need permission in some cases, and also need to clean the data. Arranging workshops and seminars with success stories in which teachers share their own experiences accessing relevant data sets as part of their teaching could solve this problem.

4.4.3. Lack of data skills

Teachers need data skills to extract smaller data sets from bigger ones. They also might need computer skills to present or explain different graphs to students. Training and short courses can extend teachers' existing skills to work with open data.

4.4.4. Time constraints

Teachers also need extra time to collect real data sets from their surroundings as part of their subjects. It will take both time and effort to identify relevant data sets using open data portals, and teachers need a platform from which they can get relevant data sets as part of their subjects. If the ODI could be linked with textbooks, teachers would get advice on when to use which data sets and visualizations to explain a certain topic and guide them on how to use educational open data sets without spending too much extra time and effort.

4.4.5. Lack of resources

One of the challenges that teachers discussed in integrating open data into schools is limited resources in public schools, such as computer labs not always being available, or students not having their own computers. However, these problems could be solved by managing the timetable. Some teachers pointed out to integrate the ODI into their teaching plans, it is also important for the Ministry of Education to approve it, and that such platforms must contain up-to-date information.

4.5. Open data web interface

Under this theme, we focus on the ODI's usability. We tested different aspects of the prototype during Investigation 2 and upgraded the prototype before the final online usability test. The ODI design was based on requirements identified by teachers using Enterprise Architecture Oriented Requirement Engineering approach Saddiqa et al. (2019a). The main page provides general information on open data and its use in education, and allows for navigating to open data of several cities categorized by subjects. Fig. 3 shows a sitemap of the final ODI platform, and Fig. 4 shows part of the front page and examples of data visualizations from the ODI. The platform is available at https://odw.aau.dk/and is open source,[8] apart from the visualization tool Tableau used to create graphs. Brief results on the ODI's usability aspects are discussed below.

4.5.1. Identifying relevant and useful open data sets

Real data collection can be time-consuming and otherwise impractical without data skills in schools. With the availability of open data, teachers can carry out learning activities using real data without needing to leave the classroom. However, teachers still need help with searching and filtering relevant educational open data sets from open data portals. According to the results from one-on-one interviews and focus group meeting, teachers believe that they can find educational data sets by subject category through ODI without spending extra time searching and filtering relevant information from different portals. Furthermore, they would use the ODI more often if more and different data sets and graphs were included. One teacher said:

> *"I think I would use the ODI often depending on what it contains; if there will be more data sets and graphs, then definitely I would use it very often." (Teacher 4, Feb. 27, 2020)*

4.5.2. Integrating educational open data sets

Teachers view ODI as helpful in integrating real educational data sets in the classroom environment. ODI provides access to open, direct, relevant, educational data sets as part of math, science, and geography subjects. Teachers also recognize the benefits of

[8] The ODI source code is available at: https://github.com/Open-Data-School/Open-Data-for-Schools.git.

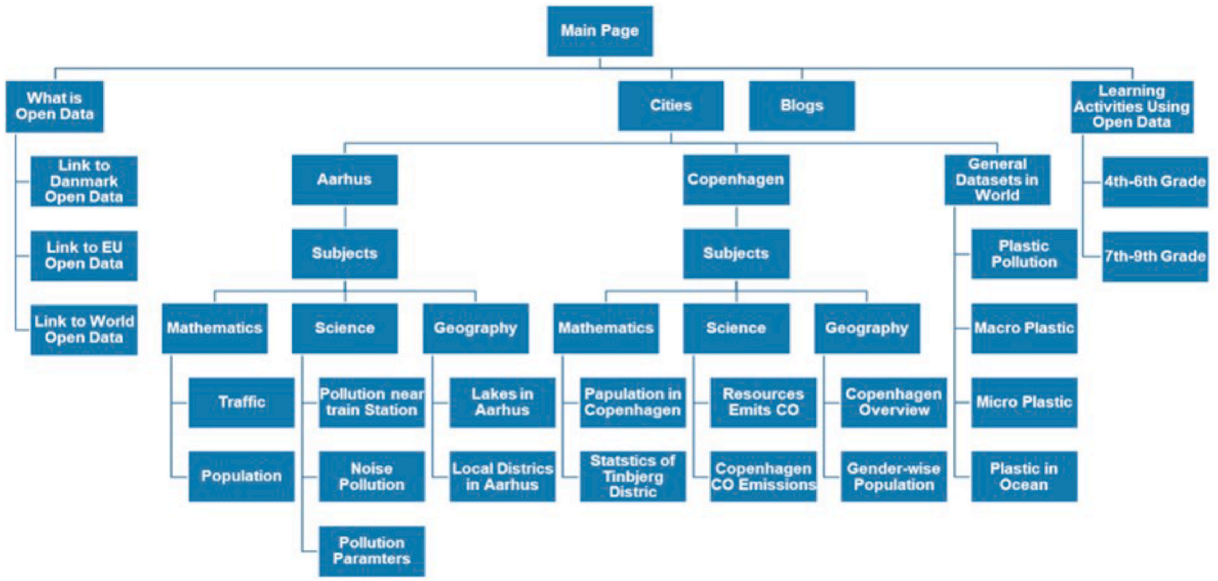

Fig. 3. Sitemap of the final Open Data Interface (ODI) prototype.

integrating open educational data sets in the classroom, as they facilitate students' active involvement in the learning process and teaching assignments.

4.5.3. *Intuitive/readily learned design*

Under this theme, we focused on identifying whether teachers easily can understand the interface design and use it in the classroom environment. During the initial one-on-one interviews and the focus group meeting, the teachers suggested that the main page requires a simple description and that text should be simple for students. They also suggested that figures, tables, and examples be included, instead of just text, to make it more interesting for students. Teachers also suggested including a comments section for each visualization to provide feedback. Before online usability test, we upgraded the main page and visualization sections according to the teachers' feedback.

4.5.4. *Usability*

To test the ODI's usability, we used both qualitative and quantitative data collection methods during the one-on-one interviews, focus group, and online usability testing with Loop11, through which teachers completed various tasks in the ODI. The results from the interviews and focus group meeting demonstrate that the perceived usability of the interface depends on the subjects and class grade. Teachers judge that students in fifth through sixth grades can use the ODI to utilize relevant graphs, and students in sixth through ninth grades can use the ODI to complete assignments based on these graphs. Moreover, the ODI was viewed as most useful for science subjects and maths, as science and math teachers found the ODI to be more relevant to their teaching. However, some teachers required extra knowledge about how to use these real data sets. The focus group post-test questionnaire results indicated (see Fig. 5) that teachers found it easy to use the ODI and found the visualizations relevant and simple (e.g., bars, pie charts, etc.) for use in schools as part of teaching activities. Before the online usability test with Loop11, the ODI was updated to its final version according to the requirements identified during the focus group, such as more detailed descriptions of visualizations, and a comment section added at the end of each visualization to get teachers and students' feedback.

The moderated Loop11 test results demonstrated that the ODI has the potential to help teachers use open data more often in their teaching practice, such as when explaining different topics using real information from students' surroundings (e.g., details on population or pollution levels), as well as to allow students to collect their own local data and compare them with the city's open data. The average time duration needed to complete such tasks are provided in Table 4. The average time varies between 0:57 and 1:57min, and the standard deviation varies from 23 to 53s for performing a task. Teachers performed 90 % of the tasks successfully. They also answered open-ended closed-ended survey questions regarding open data and the ODI. Teachers also provided their response to standard system usability questionnaire (see Appendix B).

Teachers who were not frequent users of computers took longer to complete the tasks, e.g., three out of nine teachers who took longer than the rest of the participants did not use computers in their everyday routines. Also, the math and science teachers understood the tasks quickly and completed them with a few clicks. For example, geography and social science teachers took a little longer (average, 01:15 min) and longer paths (average page views: four) to complete the tasks than math and science teachers (average, 00:50 min, with two page views on average).

During the unmoderated test, the average time and standard deviation for the unmoderated test vary between 0:39 to 1:03 min and 17 to 41s for performing a task respectively. The users performed 100 % of the tasks successfully and provide their response to

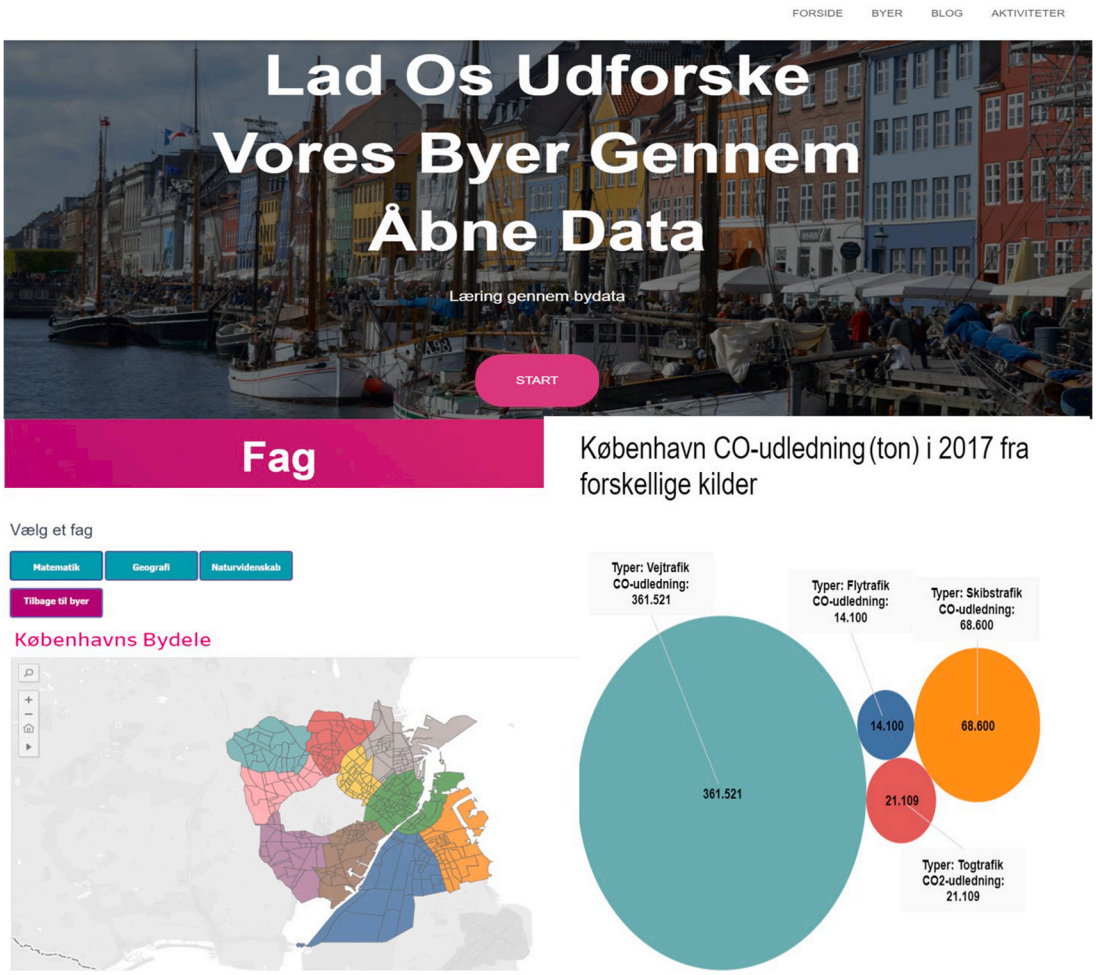

Fig. 4. Front page and example of data visualization available in the ODI prototype.

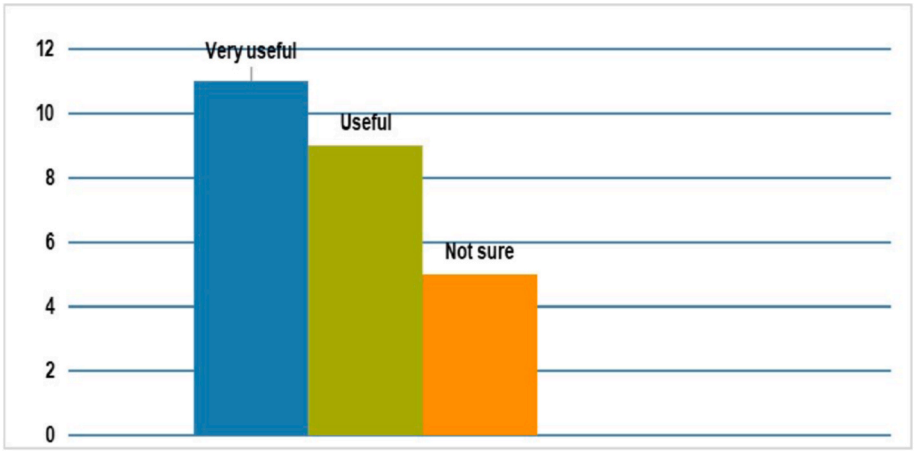

Fig. 5. Perceived usefulness of the Open Data Interface (ODI) from the focus group post-test questionnaire (N = 25).

Table 4
Average duration, standard deviation (S.D.), and avg. page views per task in the moderated usability test (N = 5).

Task	Description	Success	Duration (min)	S.D. (sec)	Page views
1	Main page	80 %	1:57	42.11	3
2	Open data in geography	80 %	1:52	52.50	3
3	Finding relevant blog	100 %	1:01	22.71	3
4	Open data in mathematics	80 %	1:32	26.01	5
5	Open data activities	100 %	0:57	30.02	4
6	Comments	100 %	1:05	26.11	5

Table 5
Average duration, standard deviation (S.D.), and avg. page views per task in the unmoderated usability test (N = 4).

Task	Description	Success	Duration (min)	S.D. (sec)	Page views
1	Main page	100 %	0:51	40.46	3
2	Open data in geography	100 %	1:03	38.79	7
3	Finding relevant blog	100 %	0:39	24.25	4
4	Open data activities	100 %	0:46	17.22	4
5	Comments	100 %	0:50	25.54	6

standard system usability questionnaire (see Appendix C). Table 5 provides the results on average time duration, standard deviation, and page views per task in the unmoderated test.

During the pilot test, students also provide feedback on the usability of ODI in an online questionnaire. In general, 2 out of 16 students thought that some graphs were difficult to use, such as finding lake locations, and that more descriptions should be added. However, 15 students found it simple to switch between graphs. They also provide feedback on the overall design of the ODI, such as suggesting the use of facts box with general information as well as the use of larger text fonts in bright colors, and the use of symbols in descriptions text.

4.5.5. Ease of use

As the main users of the interface are students and teachers, it is important that they can use the ODI easily and understand the information provided. During the interviews and focus group meeting, participants tried different features of the ODI and found it easy to use overall. However, they pointed out minor navigation problems, e.g., a missing back button, which was resolved before the online usability test. Figs. 6 and 7 provide teachers' responses collected during the focus group concerning ease of use with the ODI and visualization. During the pilot test, students were observed and recorded while they completed assignments on pollution using the ODI. Generally, they used ODI without problems. Altogether, 14 out of 16 pupils said that ODI is easy to use, and 15 out of 16 found it easy to complete assigned tasks using ODI. Among nine teacher participants, eight in the online usability test rated ODI as easy to use, simple, and well-integrated.

4.5.6. Quality content

During the one-on-one interviews, the teachers suggested that data sets should be categorized under subjects for each city, and they suggested that data sets – such as plastic pollution, environmental pollution, forest, etc., be included for each city so that students can compare the information with other cities easily. We upgraded the ODI, i.e., categorized educational data sets under subjects for respective cities and included pollution and environmental data sets in the final version before launching the moderated and unmoderated tests with teachers and the pilot test with students. Fig. 8 provides teachers' responses collected through the focus group concerning ODI content quality. During the pilot test, 14 out of 16 students found the graphs and visualization easy to understand, but two students had some difficulties in understanding the graphs.

4.5.7. Performance

The performance aspect includes response time, wait time, load time, CPU utilization, and memory utilization. The ODI's overall performance was viewed as satisfactory according to feedback from teachers, but in some cases, the visualization software took a while to load. Fig. 9 provides teachers' assessments of the ODI's overall performance during the moderated and unmoderated testing.

4.6. Challenges tied to ODI's integration in schools

During Investigation 2, we identified challenges or barriers that could influence use of the ODI.

4.6.1. Administrative constraints

According to feedback from teachers, there may be administrative constraint hurdles to integrate the ODI, such as permissions to install visualization software or computer labs' availability.

Fig. 6. Perceived ease of use of the Open Data Interface (ODI) – from the focus group post-test questionnaire (N = 25).

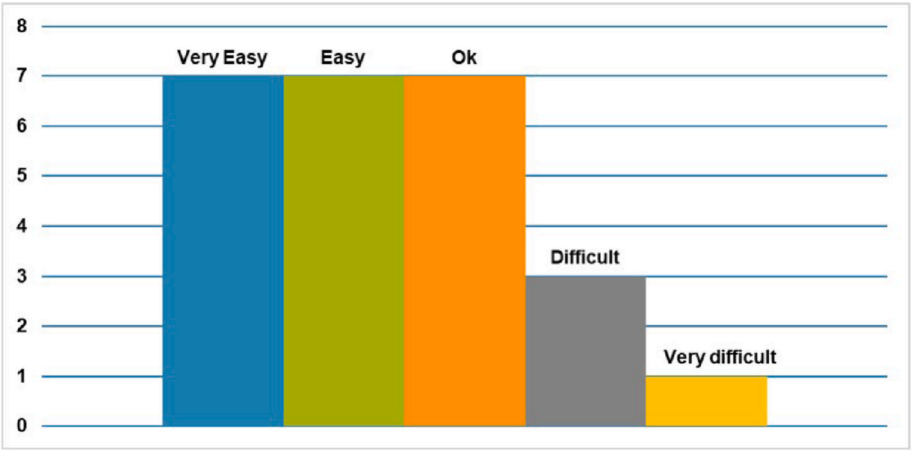

Fig. 7. Perceived difficulty of the visualizations used in the Open Data Interface (ODI) – from the focus group post-test questionnaire (N = 25).

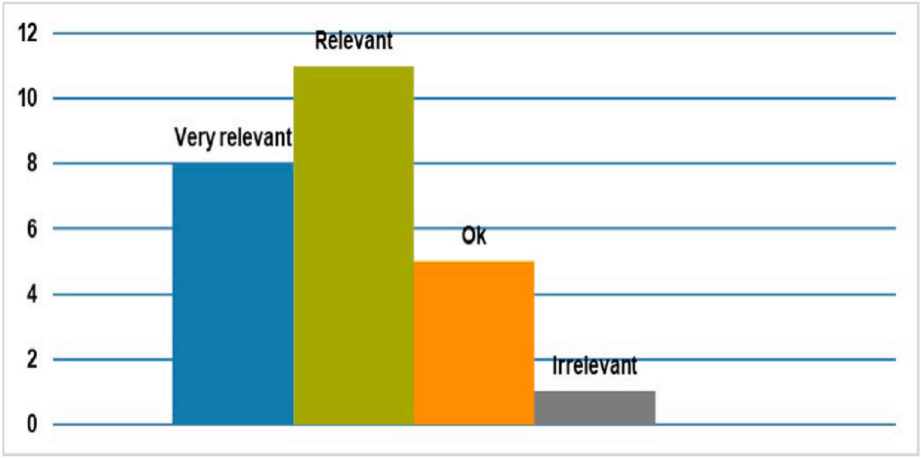

Fig. 8. Perceived quality of the Open Data Interface (ODI) content – from the focus group post-test questionnaire (N = 25).

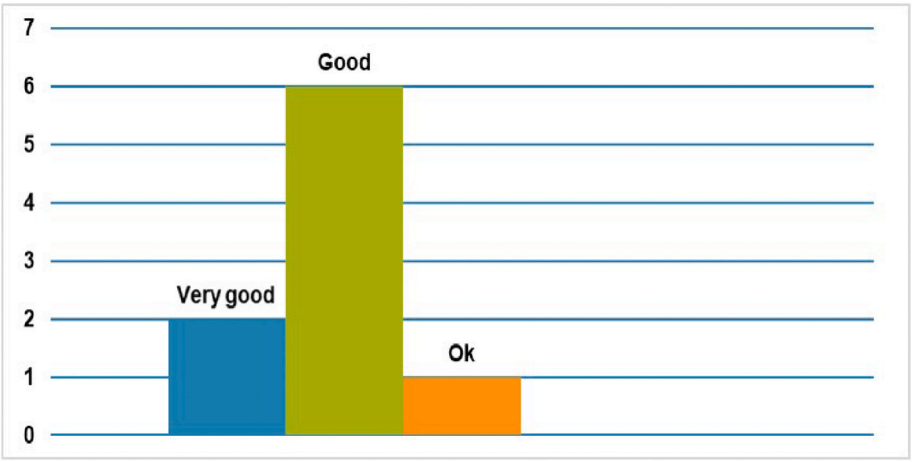

Fig. 9. Perceived level of performance by the Open Data Interface (ODI) – from moderated and unmoderated usability tests (N = 9).

4.6.2. Up to date

It is also important that ODI contain up-to-date information. Some data sets contain information from the previous year, but others that contain data on topics such as temperature shifts and pollution should be up-to-date so that students can make comparisons with their own data sets, e.g., temperatures during different parts of the day. As one participant said:

> *"The ODI is interesting because you can get data at one place; it will be more useful if it will be up to date periodically. For example, if I want to compare our school temperature data collected through Data-logger, then with the updated information on ODI, it will be possible to compare own temperature data with the center of Aarhus." (Teacher 5, Feb. 27, 2020)*

4.6.3. Training

The results also demonstrate that teachers who are not frequent computer users find it difficult to use data portals or the ODI. They need training and workshops to learn how they can use data to facilitate their subjects.

4.6.4. Ministry of Education approval

Teachers also have suggested approving the ODI from the Ministry of Education. It will make teachers more confident in using ODI as part of their teaching activities and overcoming any administrative barriers. As one teacher said:

> *"We spend a lot of time with the students to teach them that they can't just choose any website. If the ODI is approved by the Ministry of Education, then it becomes easier to justify why to choose this instead of others." (Teacher 6, Feb. 27, 2020)*

5. Conclusion

In this article, we have investigated and tested the ODI's usability in terms of real educational data sets in public school teaching. The ODI can bridge the gap between open data opportunities in the educational sector and its frequent use in educational activities. With the development of the ODI, we can open data exploration practices to the younger generation of learners as part of their subjects. In four different setups, we investigated our research question, i.e., examining the opportunities and skills associated with open data in education and the ODI's usability in public schools. Teachers also provided views on data skills that can enhanced with the use of open data in education. Based on teacher and students feedback we upgraded the ODI to the final version by removing minor problems and adding more features. For example, detailed and simple guidelines for each visualization have been added so that teachers and students can understand and interact with visualizations, and comment boxes were added at the end of each visualization so teachers can provide feedback on different graphs and visualizations. In the future, we will study data collection methods using sensors and applications in schools that could provide students with a solid understanding of the concept of data and its use in their surroundings and the use of sensor data in combination with open data.

CRediT author statement

Mubashrah Saddiqa: Conceptualization, Methodology, Software, Writing- Original draft preparation. **Rikke Magnussen:** Conceptualization, Supervision, Writing - Review & Editing. **Birger Larsen:** Conceptualization, Supervision, Writing - Review & Editing. **Jens Myrup Pedersen:** Conceptualization, Supervision, Writing - Review & Editing.

Declaration of competing interest

None.

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Appendix A. Tasks used in the usability test

All the tasks used in the online usability test were in Danish language and their description are given below. These tasks are used both in moderated and unmoderated usability test setting. Participants also provided their responses to system usability questionnaire given below.

Opgaver 1: Forside

Se om forsiden giver nogle grundlæggende informationer omkring åbne data samt links til danske, europæiske og internationale åbne data portaler. Når du gennemført opgaverne bedes du højt og tydeligt verbalisere dine tænker og handlinger.

Opgaver 2: Åbne data i geografi

Du underviser et emne omkring strømme og søer i geografi i 6. klasse. Du vil gerne vise forskellige vandløber og deres længde i Århus til dine elever. Se om du kan find relevant information på hjemmesiden.

Opgaver 3: Find relevant blog

Du har hørt, at Aalborg Universitet har publiceret en interessant artikel "Hvorfor åbne data", omkring brugen af åbne data i skoler, og du vil gerne læse denne. Se om du kan finde teksten på hjemmesiden.

Opgaver 4: Åbn data i matematik

Gå ud fra at du underviser matematik til en 7. klasse, og du vil gerne inkludere et eksempel på befolkningen i Københavns distrikter (befolkning i København). Hvordan vil du forsætte?

Opgaver 5: Åbn data aktiviteter

Du har hørt om den succesfuld brug af åbne data i skolerne som del af forskellige undervisningsaktiviteter, og du vil gerne bruge disse virkelige datasæt i dine egne undervisningsopgaver. Men du ved ikke, hvordan du skal starter, og du har brug for nogle eksempler på designe af aktiviteter til 6. klasseelever til brugen af åbne data. Hvordan vil du fortsætter?

Opgaver 6: Kommentarer

I den klasse, som du underviser i naturvidenskab, diskuterer I forskellige kilder, som er ansvarlige for forurening. Du vil gerne vise, hvor meget CO som udledes i København fra forskellige kilder. Da du åbner grafen, opdager du, at der mangler information, og du vil gerne skrive en kommentar for at forbedre grafen. Hvordan vil du gøre dette?

Opgaver 7: System usability survey

Angiv hvor enig eller uenig du er i følgende udsagn på skalaen:

1.	Jeg tror, at jeg ville have lyst til bruge dette system ofte.
2.	Jeg fandt systemet unødvendigt komplekst.
3.	Jeg synes, at dette systemet var let at bruge.
4.	Jeg tror, at jeg ville få brug for support for at kunne bruge dette system.
5.	Jeg fandt ud af, at de forskellige funktioner i dette system var godt integreret.
6.	Jeg synes, at der var for meget inkonsistens i dette system.
7.	Jeg kan forestille mig, at de fleste mennesker ville lære at bruge dette system meget hurtigt.
8.	Jeg fandt systemet meget besværligt at bruge.

(*continued on next page*)

(*continued*)

9.	Jeg følte mig meget sikker i at bruge systemet.
10.	Jeg havde brug for at lære en masse ting, før jeg kunne komme i gang med dette system.

Appendix B. Responses to system usability questionnaire during moderated online usability test

All 9 participants filled out the system usability questionnaire during the online usability tests using loop11. 5 participants participated in moderated usability test. Below is the overview of the responses with details.

	Meget uenig	Uenig	Hverken enig eller uenig	Enig	Meget enig
Jeg tror, at jeg ville have lyst til at bruge dette system ofte	0 0.0 %	2 40.0 %	2 40.0 %	1 20.0 %	0 0.0 %
Jeg fandt systemet unødvendigt komplekst	1 20.0 %	2 40.0 %	2 40.0 %	0 0.0 %	0 0.0 %
Jeg synes, at dette systemet var let at bruge	0 0.0 %	0 0.0 %	1 20.0 %	3 60.0 %	1 20.0 %
Jeg tror, at jeg ville have få brug for support for at kunne bruge dette system	2 40.0 %	0 0.0 %	2 40.0 %	1 20.0 %	0 0.0 %
Jeg fandt ud af, at de forskellige funktioner i dette system var godt integreret	0 0.0 %	0 0.0 %	2 40.0 %	2 40.0 %	1 20.0 %
Jeg synes, at der var for meget inkonsistens i dette system	0 0.0 %	3 60.0 %	2 40.0 %	0 0.0 %	0 0.0 %
Jeg kunne forestille mig, at de fleste mennesker ville lære at bruge dette system meget hurtigt	0 0.0 %	1 20.0 %	2 40.0 %	1 20.0 %	1 20.0 %
Jeg fandt systemte meget besværligt at bruge	2 40.0 %	2 40.0 %	1 20.0 %	0 0.0 %	0 0.0 %
Jeg følte mig meget sikkeri at bruge systemet	0 0.0 %	0 0.0 %	1 20.0 %	2 40.0 %	2 40.0 %
Jeg havde brug for at lære en masse ting før jeg kunne komme i gang med dette system	1 20.0 %	2 40.0 %	1 20.0 %	1 20.0 %	0 0.0 %

Appendix C. Responses to system usability questionnaire during unmoderated online usability test

4 participants participated in unmoderated usability test and filled the system usability scale. Below is the overview of the responses with details.

	Meget uenig	Uenig	Hverken enig eller uenig	Enig	Meget enig
Jeg tror, at jeg ville have lyst til bruge dette system ofte	0 0.0 %	0 0.0 %	2 50.0 %	2 50.0 %	0 0.0 %
Jeg fandt systemet unødvendigt komplekst	0 0.0 %	3 75.0 %	0 0.0 %	1 25.0 %	0 0.0 %
Jeg synes, at dette systemet var let at bruge	0 0.0 %	0 0.0 %	0 0.0 %	4 100.0 %	0 0.0 %
Jeg tror, at jeg ville få brug for support for at kunne bruge dette system	0 0.0 %	3 75.0 %	0 0.0 %	1 25.0 %	0 0.0 %
Jeg fandt ud af, at de forskellige funktioner i dette system var godt integreret	0 0.0 %	0 0.0 %	0 0.0 %	4 100.0 %	0 0.0 %
Jeg synes, at der var for meget inkonsistens i dette system	0 0.0 %	2 50.0 %	0 0.0 %	2 50.0 %	0 0.0 %
Jeg kan forestille mig, at de fleste mennesker ville lære at bruge dette system meget hurtigt	0 0.0 %	0 0.0 %	0 0.0 %	4	0 0.0 %

(*continued on next page*)

(*continued*)

	Meget uenig	Uenig	Hverken enig eller uenig	Enig	Meget enig
				100.0 %	
Jeg fandt systemet meget besværligt at bruge	0 0.0 %	3 75.0 %	0 0.0 %	1 25.0 %	0 0.0 %
Jeg følte mig meget sikker i at bruge systemet	0 0.0 %	0 0.0 %	1 25.0 %	3 75.0 %	0 0.0 %
Jeg havde brug for at lære en masse ting, før jeg kunne komme i gang med dette system	0 0.0 %	3 75.0 %	0 0.0 %	1 25.0 %	0 0.0 %

Appendix D. Tasks used in the pilot test with students to test the usability of ODI

Opgaver 1

CO2-udledning i København – hvilke data kan du finde?

Opgaver 2

Hvilke CO-kilder er de værste i København? Hvad kan man bruge tallene til?

Opgaver 3

Sammenlign luftforureningen i Århus. Hvad kan man udlede af data?

Opgaver 4

Måling af CO, NO2, TEMP og Lyd i Århus - Hvad kan man bruge disse data til?'

Opgaver 5

Hvor mange vandløb løber til/fra Egå Engsø? Hvor mange af disse er naturlige?

Opgaver 6

Find alders- og kønsmæssig fordeling af befolkningen i København. Hvad viser denne og hvad kan vi bruge den til?

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