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Defining the Essential Elements for Developing Open Data Competencies

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Abstract

Although schools are recognised as relevant actors in addressing the lack of skills of citizens for participating in Open Data ecosystems, educational approaches have not been clearly defined. In this paper, a design-based research methodological framework has been used to iteratively develop a learning design grounded in data literacy and real-world problem-solving to build Open Data competencies in elementary school. We conducted three cycles including five interventions in Danish schools with 117 pupils and nine teachers in 7th to 9th-grade. The first exploratory cycle provided contextual insights. The second cycle focused on designing an authentic game. The third cycle focused on supporting the Open Data competencies. We have iteratively developed The Open Data Newsroom, a role-playing game that immerses students in a data journalism process to solve a local environmental mystery with data. The results show how central design elements such as an authentic Open Data practice, local open data, physical and digital elements, and real-world complex problems support the development of Open Data skills, keeping students engaged, and creating an authentic experience in Open Data learning designs. The discussion section elaborates on how game-based and authentic learning approaches are central for integrating Open Data in elementary school education.

Keywords

open data learning design, open data education, open data ecosystems, game design

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1 Introduction

Although Open Data (OD) has been stated as a new resource available for all members of society for increasing citizen participation and generating social value (Janssen et al., 2012; Sieber & Johnson, 2015; Zuiderwijk et al., 2019), a large part of citizens face barriers associated with a lack of skills for managing data, and participating in OD ecosystems as users, data providers or intermediaries (Harrison et al., 2012; Janssen et al., 2012; Loenen et al., 2021). In the OD field, the integration of OD in school education has been proposed as a way to ensure inclusiveness and fairness in OD ecosystems (International Open Data charter, 2015). The growing significance of data in society underscores the need to educate citizens who can integrate data-based methods, tools and resources, and engage with data-driven systems, while not necessarily becoming specialists (Pedersen & Caviglia, 2019).

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Despite the importance of integrating OD into school education, our previous review shows that most learning experiments involving OD have been applied in higher education (Celis Vargas et al., 2023). Studies in school emphasise the potential of using real-world data in classroom activities for increasing authenticity and developing skills for civic engagement and data management (Cook et al., 2018; Saddiqa et al., 2021; Wolff et al., 2016a). For example, (Coughlan, 2020) highlights that the integration of OD in schools has been shown to both increase public engagement and develop data and digital skills. Additionally, (Saddiqa et al., 2019) have shown that the use of data from students' municipalities increases their interest in everyday life problems and fosters discussions about authentic data in the classroom. Although potentials of integration OD have been explored, the existing studies on integrating OD in elementary schools have mainly focused on the exploration of OD to teach subjects such as geography, history, or statistics rather than on the development of competencies for engaging in OD ecosystems (Atenas et al., 2015; Coughlan, 2020; Pellegrino & Antelmi, 2023). Furthermore, current studies focus on teachers' skills and motivations rather than on pupils' perspective (Coughlan, 2020; Saddiqa et al., 2019).

Although the potential and importance of integrating OD in elementary schools have been acknowledged, learning designs for OD competencies have not been clearly defined. This paper seeks to answer the following research questions: What are OD learning designs and the central design elements for teaching OD competencies in elementary school? This study contributes to both defining and implementing OD competencies in elementary schools and understanding the key elements of learning designs that prepare young people to engage in OD ecosystems.

2 Background

Learning designs focus on how to achieve a learning goal such as new knowledge, skills, and abilities that learners should be able to master (Beetham, 2007, 2019). According to (Beetham, 2007) interdependent elements such as the learners, other actors involved, the learning environment, and the learning outcomes need to be considered. Furthermore, learning theory creates a framework for the design of learning activities. Different learning theories determine different issues in activity design such as the role and significance of other people in the activity, the authenticity of the task and setting, and the structure, among others (Beetham, 2019). Aimed at creating a ground of the different elements that shape learning designs for OD competencies, we have explored the domains of Data Literacy and Real-world problem-solving in elementary school, deepening on the associated skills or abilities, and current educational approaches.

2.1 Data Literacy and Real-world Problem-Solving

A literature review on OD skills in education, including studies from primary school to graduate programs, has previously defined two core categories of skills: 1. Data Skills and 2. Context skills, both types of skills being central for successfully participating in OD ecosystems (Celis Vargas et al., 2023).

Data Skills comprises abilities related to data management such as "Computational Thinking," "Statistical Thinking," and "Data Visualization" (Celis Vargas et al., 2023). These abilities are encompassed by Data Literacy (DL) (Wolff et al., 2016a). DL has been defined as the combination of technical and statistical skills with the ability to draw meaning by posing questions, interpreting and analysing data, and creating visualisations (Coughlan, 2020). In contrast, according to Celis Vargas et al. (2023), the second category *Context Skills* involves abilities for engaging with local contexts and communities such as "Identifying problems in real-world settings", "Collecting data in real-world settings", and "Engaging with a community" and also suggest an inquiry-based approach to problem-solving by emphasising on abilities such as "Problem analysis", "Conceptualisation", "Local problem-solving" and "Decision Making". Given the focus on authentic tasks and the inquiry process, we have associated this group of skills with the domain of Real-world Problem-solving (RWPS) (Sarathy, 2018). RWPS is defined as a dynamic analytical process used to address complex or ill-defined issues typically encountered in real-world environments (Sarathy, 2018).

Data Literacy. In the school context, DL has been defined as the ability to understand, find, collect, interpret, visualise, and support arguments using quantitative and qualitative data to answer real problems (Deahl, 2014; Vahey et al., 2012). Furthermore, it has been defined as the ability to ask and answer real-world questions from large and small datasets to communicate stories from data (Wolff et al., 2016b). These definitions of DL in school education, emphasise creating arguments and stories that connect data to real problems. Educational interventions for DL have ranged from focusing on skills in statistics and data visualisation to more general dispositions and competencies in analysing and solving problems with data (Pedersen & Caviglia, 2019). DL has different levels of complexity, thus programs supporting a basic level have skipped lessons in manipulating raw data, focusing instead on analysing pre-existing data visualisations (Vahey et al., 2012). Integrating DL into school curriculums has been addressed in two ways: integrating data explorations with learning objectives from a specific subject such as mathematics or statistics, and splitting learning across multiple classes

Table 1. Skills and Abilities Mapped on Learning DL and RWPS in Elementary School.

Clusters	Data Literacy	Real-world problem-solving
Getting in contact with data	Access and find data. Collect own data	
Planning		Plan and manage activities
Handling data	Read, Work with, Use, Manage, Manipulate, Navigate, Clean	
Analysis, understanding and interpretation	Analyse, Comprehend, Interpret, Critically assess, Understand underlying principles and challenges of data, Critique, Ethically use, Ask and answer real-world questions	Identifying and defining Authentic problems and significant questions. Make connections between information and arguments.
Making decisions	Select, Observe, Evaluate, Reflect	Explore alternative solutions
Communicating	Visualise, Support Arguments, Present, Communicate stories	

(Vahey et al., 2012). Several authors have supported the cross-curricular and interdisciplinary perspective, emphasising the importance of interdisciplinary thinking for teaching DL in schools (Bhargava et al., 2015; Vahey et al., 2012). This cross-curricular approach has been highlighted to allow a better contextualization of the data (Wolff et al., 2016b).

Educational approaches to DL in school education emphasise the integration of authentic contexts as real problems, real-world settings or real data, active learning, and inquiry-based learning practices (Deahl, 2014; Vahey et al., 2012; Wolff et al., 2016b) to adapt pedagogical approaches to the context of learners (Bhargava et al., 2015). For example, current approaches in school stress the use of real-world data either as open datasets or self-collected data (Wolff et al., 2016b), and the investigation of authentic problems using data as part of evidence-based thinking (Vahey et al., 2012). Finally, cognitivist or constructivist principles, project-based, and problem-driven approaches have been suggested to achieve the learning goal of understanding real-world phenomena through data helping youngsters to experience data's real-world impact (Deahl, 2014).

Real-world Problem-Solving. RWPS is often dynamic and discontinuous due to the nature of real-world problems (Sarathy, 2018). Real-world problems are typically ill-defined and often have open-ended solutions which adds an aspect of uncertainty to the problem-solving process (Sarathy, 2018). According to twenty-first-century skills frameworks, problem-solving is a central learning and innovation skill often related to critical thinking and decision-making (Bellanca & Brandt, 2010; Romero et al., 2015; Van Laar et al., 2017; Wisniewski, 2010). According to the OECD's Programme for International Student Assessment (PISA), problem-solving relates to how students evaluate evidence, make connections between information and arguments and analyse alternative points of view (Binkley et al., 2012). Foremost, according to Dede (2010), four essential skills are associated with problem-solving: (i) defining authentic problems and significant questions; (ii) managing activities to develop a solution; (iii) collecting and analysing data to identify solutions; and (iv) exploring alternative solutions (Dede, 2010). Educational approaches to RWPS address notions of experiential learning (Wolff et al., 2016b). Experiential learning stresses the idea that learning should be situated within a real-world context and concerning students' experience rather than reliant on rote learning of a collection of facts (Dewey, 1933; Freire, 2000).

Skills from Data Literacy and Real-world Problem-Solving. We consider DL and RWPS as key concepts for the definition and the development of learning design for building OD competencies in elementary school. Table 1 presents the summary of skills mapped from the domains of DL and RWPS in elementary school. In the table, six clusters were made according to the topic.

2.2 Elements for Open Data Learning Designs in Elementary School Based on Data Literacy, Real-world Problem-Solving

By reviewing the domains of DL and RWPS, we have identified elements that create an initial framework for OD learning designs. We identified that learning activities are usually related to authentic and experiential learning (Wolff et al., 2016a, 2016b). Students engage with authentic elements such as real problems, real-world settings, real data or real activities (Deahl, 2014; Vahey et al., 2012). Learning activities tend to relate to the students' context and their own experiences (Bhargava et al., 2015). Experiential educational approaches such as Project-based, Problem-based (PBL), Inquiry-based, and Game-based learning are used to create active learning experiences (Deahl, 2014).

According to Beetham (2007), the learning activity is central in learning designs. Beetham's learning design model considers four interdependent elements for a learning activity to be completed: the learners, other actors in the learning process, the learning environment, and the learning outcomes. Figure 1 presents Beetham's learning design model. We have used this model to create a framework for our OD learning design considering the domains of DL and RWPS.

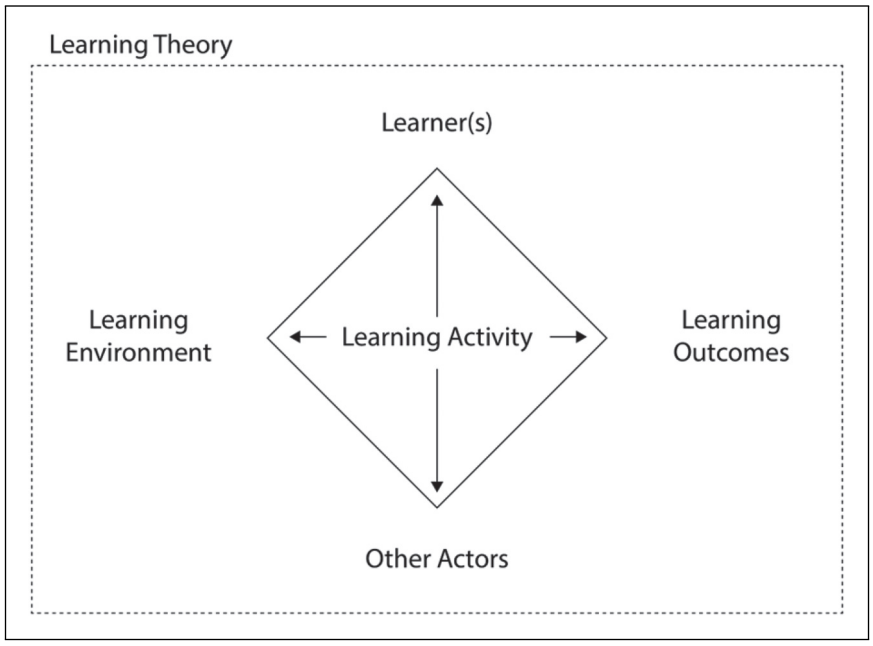

Figure 1. Beetham's learning design approach. Adapted from (Beetham, 2007).

Learning Theory. Authentic and experiential learning to create personally meaningful learning activities for the learners, to emulate the work of professionals in the OD field, and to reflect on learners' experiences of real and daily life.

Learners. A learner-centred approach considers the skills, abilities and interests of the learners. Considering that the basis of statistics and critical thinking are relevant for DL and RWPS, we have focused on learners in the secondary school from 7th to 9th grade.

Other actors. We consider teachers as facilitators of the learning activity and external experts to connect learners with a community of practitioners.

Learning environment. Although this study focuses on formal learning environments in school, previous research has identified that achieving the connection to authentic practices and setting are relevant. Therefore, we consider the creation of authentic settings by game environments or digital spaces.

Learning outcome. The expected learning outcomes or goals of our OD learning design for elementary school are the analysis of a real-world situation with OD and the critical analysis of OD for solving real-world problems.

3 Methodology

A design-based research (DBR) methodological framework has been used to iteratively develop a learning design for building OD competencies in elementary school while defining the essential design elements. DBR is defined as a theoretical and practical approach for the development of new educational approaches (Bakker, 2018). Iterative cycles are developed, aiming at producing actionable knowledge that can be used to achieve some educational goal through design (Anderson & Shattuck, 2012). Each DBR cycle is a design experiment that develops in four phases: problem definition, design, intervention, and analysis and redesign (Anderson & Shattuck, 2012).

3.1 Cycles and Interventions

Three cycles including five interventions in Danish schools were conducted to gradually develop an OD learning design with insights from students and teachers. The iterative development led to the design of a role-playing game called The Open Data Newsroom. Five interventions in different Danish schools were conducted with the total participation of 117 pupils aged 14 to 16 years and nine teachers in 7th to 9th grade. The discoveries and outcomes of one cycle drive the development of the next one. Figure 2 visualises the DBR approach applied to the current study.

The exploratory first cycle focused on providing contextual understanding about the elements of OD learning designs identified from the domains of DL and RWPS and presented in the section 2.2. The first cycle included a domain research

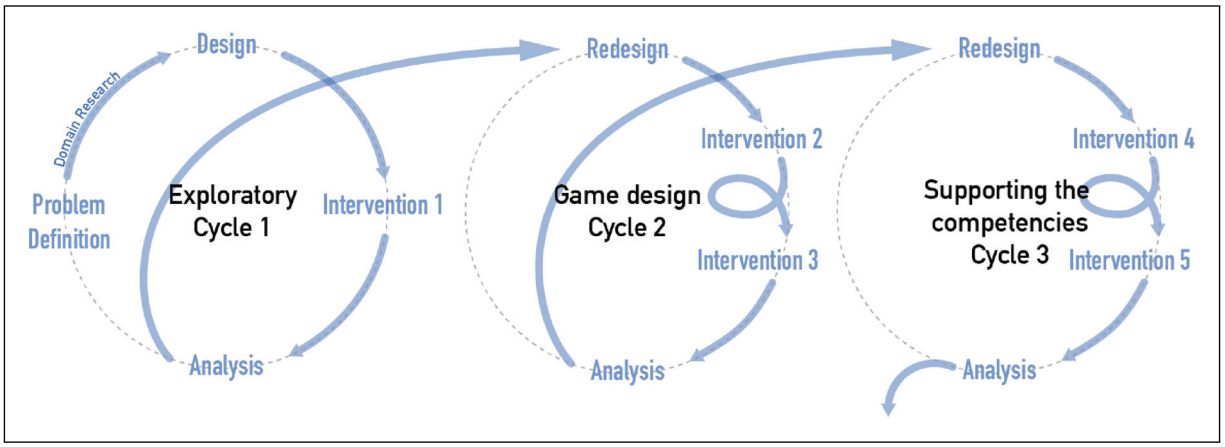

Figure 2. DBR approach applied to the current study.

Table 2. Interventions in Danish Schools.

Cycle	Intervention	Date	Grade	Participants	Duration
1	School 1	August 2023	9th-grade	Domain research: 5 teachers	1 h with each teacher
				39 students (dived in 3 groups of 13 students) 1 teacher	2 h with each group (6 h in total)
2	School 2	January 2024	7th-grade	17 students 1 teacher	3 h
	School 3	March 2024	8th and 9th-grade	17 students 1 teacher	3 h
3	School 4	May 2024	7th grade	21 students 1 teacher	3.5 h
	School 5	June 2024	8th and 9th-grade	23 students 1 teacher	4 h

phase where semi-structured interviews were conducted with five teachers and an intervention with 39 pupils aged 15 to 16 and one teacher in 9th-grade (Vargas et al., 2024). During the second cycle the concept of an authentic game grounded on data journalism practices was designed, it was tested and improved in two interventions in different schools, firstly testing a physical game, and secondly incorporating a digital platform. Each intervention in the second cycle was conducted with 17 pupils and one teacher, firstly, the intervention was conducted with students in 7th-grade, and secondly, pupils were in 8th and 9th-grade (Celis Vargas et al., 2024). Finally, the third cycle focused on increasing the complexity of the OD learning design supporting the competencies. The third cycle included two interventions, firstly with 21 students in 7th-grade and one teacher, and secondly with 23 students in 8th-grade and one teacher. Table 2 summarises the information about the interventions.

Interventions were conducted in the classroom during regular school time. Each intervention consisted of testing an OD learning design with a group of students and one teacher. Students worked in groups. Each student had a laptop to conduct the research and data exploration.

3.2 Data Collection and Analysis

During the interventions, the participation of students and teachers was documented for analysis using audio and video observations and photography. After each intervention, qualitative methods were applied to gain further insights into the most relevant elements for students' engagement and learning of OD competencies. A qualitative survey and a focus group were held with students, and semi-structured interviews were conducted with teachers.

The qualitative survey with students consisted of a brief online form with two open questions "What did you like about the activity? Why?" and "What was the most challenging? Why?". Afterwards, a focus group interview was held with the class. The focus group with students developed as a conversation for about 30 min following a guide addressing three topics: the game experience, the learning experience and ideas for development. Open questions drove the conversation such as "How did you feel as Data Journalists solving the mystery? What was different from everyday teaching? And how could the game be more interesting or fun for you?". Semi-structured interviews with teachers were held after the

intervention for about 45 min and consisted of two parts, one about the game and intervention, and the second about teaching for DL and RWPS. The first part about the game and intervention addressed the same three topics discussed with the students: the game experience, the learning experience and ideas for development. The second part about DL and RWPS addressed examples of their own practices and a discussion about these competencies in the game and intervention. Following a guide, open questions such as "What do you think were the main competencies practised by the students during the game? How do you think the game contributes to building DL and RWPS competencies in students? And how can the game do it better?".

According to data processing regulations, sessions with students and teachers were recorded, anonymised and transcribed. Sessions with students were conducted in their primary language either English or Danish, and translation to English was performed for analysis. Following a Thematic Network Analysis approach (Braun & Clarke, 2006) the data collected from the different research methods was coded and analysed for the identification of different themes or categories about the main elements for OD learning designs. Data from the five interventions was classified by a group of participants, students or teachers. Firstly, initial codes from textual data were made encapsulating insights about what students learn and how they learn it. Secondly, we identified categories or sub-themes of initial codes to summarise abstract principles. Finally, clusters or global themes encapsulating a main idea were identified (Attride-Stirling, 2001).

4 Results

The current study aims to iteratively develop a learning design for building OD competencies in elementary school and define the essential design elements.

4.1 Iterative Development of an Open Data Learning Design

By using a DBR methodological approach, we conducted three iterative cycles including five interventions with 7th to 9th grade students and teachers in Danish schools. In this section, we present the results of each iterative cycle and the final version of The Open Data Newsroom, a game-based learning design for developing OD competencies in elementary school.

First Cycle and First Intervention: Exploring the Context and Main Design Elements. Considering the novelty of the topic and the scarce number of previous research on learning OD competencies in elementary school (Celis Vargas et al., 2023; Pellegrino & Antelmi, 2023), the first cycle was highly exploratory, it was aimed at gaining contextual understanding of current practices associated with DL and RWPS as central OD competencies. Considering the review on DL and RWPS, this cycle also explored how an OD learning design could be authentic and close to the student's own context, and the use of game elements such as roles and simulations to make the learning design more appealing.

An OD learning design was tested in an intervention with 39 students in 9th-grade and one teacher. The OD learning design for the intervention was defined to be an inquiry-based and gamified hands-on learning activity. It was embedded in an ongoing school project about the creation of a utopian island, and our OD activity contributed to the definition of the health system. The goal of the activity was to create a data story answering the questions: How many doctors per person need their island and what kind of medical specialities (e.g., cardiology, paediatrics, dermatology)? Game elements such as roles were considered. Students played in groups as politicians and the teacher supported questions acting as the problem owner. The dynamic consisted of three main parts: exploring data, creating the solution, and presenting it to others. The complete cycle and observations are presented in (Vargas et al., 2024). Figure 3 shows the students performing different activities during the first intervention.

The first intervention provided two main insights for driving the second DBR cycle: firstly, the students found answers to the questions but did not conduct a data analysis process to support their arguments with data. In the final presentation they did not use data to support their arguments. Secondly, the activity was engaging but not authentic enough for them. The topic was not close to students' day life and experiences. The policymaker role did not allow them to immerse in an authentic OD practice. The creation of a data story was done as an assignment rather than as an authentic practice.

Results of this cycle consider authentic, inquiry and situated learning approaches as important elements for designing impactful OD learning experiences based on the central competencies of DL and RWPS (Vargas et al., 2024).

Second Cycle and Second and Third Interventions: Designing a Game. In the second cycle we focused on enhancing game elements to create an involving narrative and a game goal associated with the development of OD competencies. We strengthened authentic aspects, and theoretical and experimental practices by assigning students the role of Data Journalists in the game. We designed the concept of an authentic game based on Data Journalism practices. In the game called The Open Data Newsroom, the students had to unravel a mystery affecting the health of teenagers. Students conducted a three-phase process based on Data journalism to unravel why and how the health of teenagers got affected after swimming

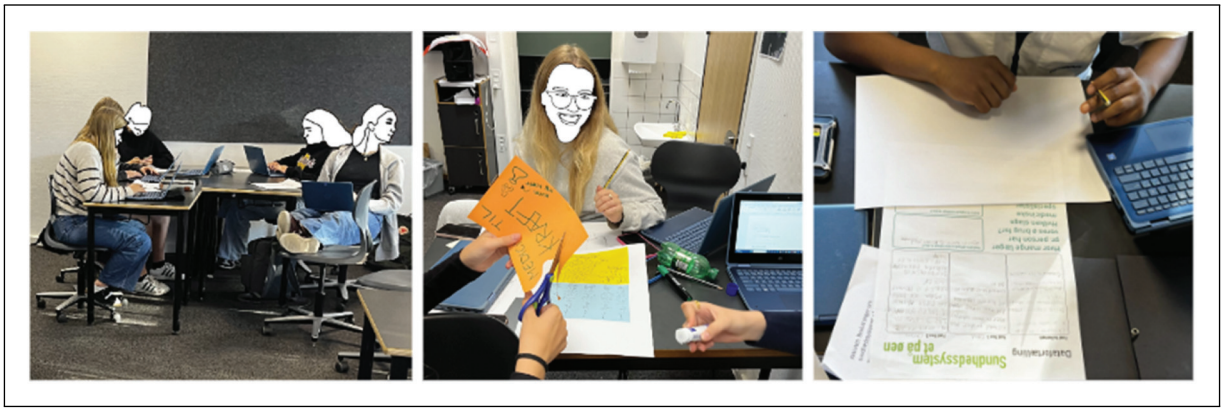

Figure 3. Students during the first intervention engaged in different phases (anonymised) taken from (Vargas et al., 2024).

Figure 4. Players during the third intervention engaged in different game phases (anonymised) taken from (Celis Vargas et al., 2024).

in the harbour. Students explored OD and presented their story using data arguments to the public in a simulated press conference (Celis Vargas et al., 2024).

Two interventions focused on the iterative development of a game. Interventions took place in different schools, each one with 17 students and one teacher. During the second intervention we tested a physical version of the game with 7th-grade students. The focus was on testing if the game created an authentic experience for students as data journalists for the development of OD competencies and the general engagement of the students with the game narrative. Results show that the mystery was not sufficiently challenging and satisfying for students, the role of data journalist was not convincing for the students, and it did not contribute to solving the mystery, and the data being highly abstract and in a rigid format not facilitating deeper analysis. Based on the results from the second intervention, during the third intervention with 17 8th and 9th-grade students, the game was further developed to address areas of improvement regarding the struggle, the goal and the use of data. A digital platform was incorporated for the analysis of data through visualisations. The complete cycle and observations are presented in (Celis Vargas et al., 2024). Figure 4 shows the students during the third intervention.

Results of the second cycle show that various design challenges remained to be addressed to make the learning design more relevant and connected to the students for the development of OD competencies (Celis Vargas et al., 2024).

Third Cycle and Fourth and Fifth Interventions: Supporting the Competencies. The third cycle focuses on supporting the competencies and increasing the complexity of the learning design. Main challenges addressed during the third cycle are the team formation, the possibility of choosing the mystery, the development of feedback mechanisms and addressing more OD competencies such as working with fragmented data and different stakeholders as it occurs in real OD ecosystems and data journalism practices. The Open Data Newsroom was redesigned keeping the main structure but making the narrative more complex by creating four cases instead of one and adding a plot twist where the four cases were connected in a big mystery that needed the collaboration of all students to be solved.

The fourth and fifth interventions focused on systematically developing The Open Data Newsroom with students and teachers. The fourth intervention had a duration of 3.5 h with 21 students and one teacher in 7th-grade. During this intervention four teams were made and each one engaged in an individual case. For the first time, the teacher played as the

Figure 5. Players during the fourth and fifth interventions engaged in different game phases (anonymised). From left to right: 1. Players creating a case board while defining storylines (Getting data). 2. Players interacting with the online tool during analysis of data and finding data insights phase (Understanding data). 3. Players presenting their storyline to the editor (Editorial meeting) 4. Players presenting their data story in the final Press conference (Delivering data).

chief editor in the local newspaper and an external expert who joined online represented the international network of data journalists. During the analysis phase after the intervention, main observations addressed the low collaboration among different teams which did not support the work with fragmented data and a lower engagement after the plot twist, even though it was surprising and interesting for the students. For the redesign, we focused on how to support more collaboration among the teams as it occurs in real OD ecosystems, and we applied small changes to the game flow and dynamic to create more space for the students to iterate on their analysis exercising more complex OD competencies like the evaluation of several hypotheses. The fifth intervention had a duration of 4 h with 23 students and one teacher in 9th-grade, smaller initial teams of two or three people were made to work on the different cases in a deeper way. Two teams per case were made and during the editorial meeting the teams joined according to the case to collaborate until the end of the game. Figure 5 shows the students engaged during the fourth and fifth intervention.

4.2 *The Open Data Newsroom*

The Open Data Newsroom is a role-playing game with the goal of solving a real-world problem with OD. Grounded in DL and RWPS, the learning design is aimed at supporting elementary school students in developing competencies for participating in OD ecosystems and facing complex real-world challenges with OD. In the game, elementary school students adopt the role of data journalists to solve a local environmental mystery using data and open data. The Open Data Newsroom revolves around unravelling several incidents that have been recently affecting local teenagers, schools and the surrounding environment. What at first were four apparently isolated cases, after the investigation were connected to a bigger case of water and environmental damage caused by a company. Geographical and water quality OD are essential to unravel the mystery by analysing the impact in several locations and time periods.

The game builds a narrative where the chief editor of the "Data Journalists Hackers", an international network, invites professional data journalists in a local newspaper to analyse several mysterious events occurring over the past two weeks in their surrounding environment. The data journalists (students) need to unravel the mystery and present the truth behind to the public in a Press Conference. A local editor (teacher or external facilitator) guides the work of the data journalists in the newsroom, provides feedback to ensure the interests of the newspaper and the citizens and challenges the data that the students' outcome is based on. Simulating real interdisciplinary data journalist teams, students are divided into teams of two or three people, made by the class teacher, trying to ensure a variety of skills and interests. Initially, four cases are presented to the data journalist teams (students). These cases develop close to different water sources such as canals, lakes and rivers, and involve the health of teenagers, the unusual state of some fish, a strange condition affecting some forests and the status of some schools. The teams select a case to dive deep and engage in the game to solve it. The game dynamic immerses the players in an authentic data journalism practice where activities relate to OD abilities such as finding and analysing data, assessing the reliability and relevance of OD, connected fragmented data, creating visualisations and presenting a data-based story explaining a problem. Table 3 presents the game flow showing six game phases.

The game flow consists of mainly six phases: (1) introducing the mystery and goal, (2) getting data and understanding data, (3) editorial meeting, (4) plot twist (5) preparing a data story and (6) delivering data in a press conference. First the mystery, game goal and dynamic are introduced to the players. Then, the players team chose a case to work with. The second phase of getting and understanding data immerses the data journalists' teams in two activities supported by physical and digital elements. Firstly, the data journalists are provided with all the known information about the cases to start defining storylines creating a case board. Secondly, journalists get access to an open data repository with relevant sets

Table 3. Game Flow.

Game phase		Description
Introducing the mystery and goal		The chief editor presents the mystery, game goal and dynamic. Teacher creates groups. Teams choose a case.
Getting and understanding data	Defining storylines	Players receive physical envelopes with news and social media posts about the mysterious events to build their own case board.
	Finding data insights	Players analyse OD through visualisations in the platform. OD repository with water quality data and cases data.
Editorial meeting and open repository		All teams working in the same case join and meet the chief editor. Create an open online repository to avoid publishing unsupported claims.
Plot twist - One big case		"Data Journalists Hackers" network presents the hypothesis of a bigger case and introduces self-collected data.
Preparing the data story		Players prepare for communicating their solutions to local citizens in the press conference.
Delivering data: Press conference		Each team presents. Critical audience makes questions. The chief editor presents the mystery's solution.

of OD visualisations about the water quality and the reported cases for teenagers, fish, forests and schools in an interactive platform to analyse the facts behind the mysterious events and identify data insights to unravel the mystery. In the third phase, all data journalist teams working in the same case join and meet with the editor to present their initial storylines. During the editorial meeting, the chief editor meets the teams to hear their hypothesis and challenge the storylines and the data behind. The editor asks the journalists to register their arguments about their solution in an open online repository to avoid publishing unsupported claims. The initial outcomes presented to the editor reveal that the apparently isolated cases might be related. In the fourth phase, the editor and the "Data Journalists Hackers" present to the newsroom the hypothesis that the cases are not just possibly connected, but they could be connected to a bigger case related to environmental high-risk companies. A new set of data visualisations is presented to the students. Following, the journalists receive instructions to continue working on their case, building their final data story, and prepare for the press conference where they will deliver a realistic and convincing story based on data to the local citizens. Finally, the sixth phase for delivering data has arrived. Each team presents their story in the press conference, receiving questions from the critical audience. An official solution is presented by the chief editor. The game is finalised with comments from the chief editor to each team and an introduction to work on a future press release and to leverage the data generated during the investigation. Figure 6 shows the interaction and engagement of players during the different phases.

4.3 Essential Elements of an Open Data Learning Design

Regarding the data collected after each intervention through surveys, focus groups, and interviews, the results in this section focus on uncovering the essential elements of an OD learning design according to students and teachers from 7th to 9th grade. Three essential themes highlight the most relevant aspects regarding (i) the skills developed, (ii) keeping the students engaged, and (iii) an authentic experience. Firstly, the results about the competencies and skills developed show to be aligned to the practice of data journalists, but also emphasise on the combination of critical thinking and data analysis to achieve the game goal of solving a real-world problem with OD. Secondly, the results about keeping the students engaged show what kind of pedagogical approaches made the OD learning design relevant for the students, for example, pupils experienced a more active role in the teaching which gave them more freedom, they were motivated by the right level of challenge and a guiding game structure helped them to progress on practising different OD competencies. Finally, results show that creating an authentic experience was relevant for students and teachers. This authentic experience was achieved by connecting to students' everyday life, to a real-world situation and to an authentic professional practice. Table 4 presents the results categorised by themes and sub-themes. The conventions (S) from students and (T) from teachers show what was relevant for one or both groups of participants.

Skills Developed. Students and teachers discussed the skills and competencies developed with the OD learning design. These may relate to the learning outcomes. The results show to be aligned to the practice of Data Journalists and the three main steps proposed in the learning design: getting, understanding and delivering data, and include elements of real-world problem solving such as creating hypotheses and making decisions. Four sub-themes that encapsulate several skills were identified. (i) Finding the right, relevant and useful data, (ii) Identifying a problem, evaluating hypotheses and

Figure 6. Players (anonymised) during the six game phases of The Open Data Newsroom. From up left to bottom right: (1) introducing the mystery and goal, (2) creating a case board with their storyline, (3) presenting data insights in the editorial meeting, (4) presenting the plot twist (5) preparing the data story and (6) players presenting in a press conference.

Table 4. Results.

Theme	Sub-theme
Skills developed	Finding the right, relevant and useful data (T + S)
	Identifying a problem, evaluating hypotheses and making decisions (T + S)
	Synthesising and putting all together (T + S)
	Communicating to others (T + S)
Keeping students engaged	Challenging activity (S)
	Students doing themselves (S)
	Being active and creative (T + S)
	Accessible for all the students (T)
An authentic experience	The local aspects in game narrative and the data (T + S)
	The simulation of a real-world situation (T + S)
	Exercising an authentic professional practice (T + S)

making decisions, (iii) Synthesising and putting all together, and (iv) Communicating to others. Teachers stressed on the combination of critical thinking and data analysis. Meanwhile, students stressed on the ability of finding connections or correlations.

Finding the right, relevant and useful data considers navigating different sources (S), being critical about what data and sources are trustworthy and reliable (T), assessing what data is relevant and what is not (T + S), and creating an overview of the issue and the data (T + S). For example, students elaborated on finding the data always connected to solving the mystery and emphasis on its relevance, "The work with data was good because I like to solve mysteries" Int 4_student, "I liked the challenge and the perfect amount of data for us to find out the problem" Int 3_student, "The most challenging was deciding what data was relevant and what wasn't" Int 3_student. On the other hand, teachers related critical thinking to the ability of assessing reliable and relevant sources or data. For example, teachers commented "The game was about being critical… students had to make judgmental calls as to whether the sources were reliable or not" Int 3_teacher, "there was a big part of critical thinking and being able to consider different sides, what is relevant and what is not" Int 5_teacher.

Identifying a problem, evaluating hypotheses and making decisions considers seeing a problem (T), creating hypotheses (T + S), connecting data and seeing correlations (T + S), creating arguments and discussing with the data (T + S). For

example, teachers elaborated on the ability to see a problem behind the data and the data behind a problem, "Being able to read through some articles or data and pinpoint the important parts of it" Int 5_teacher, "There is something about being able to see correlations and being able to see a storyline happening" Int 5_teacher. Students stressed on finding correlation by making and answering questions from the data, they talked about these correlations as ideas, hypothesis or theories to be evaluated "You are trying to make connections between lots of information that may or may not be connected" Int 3_student, "we should explore, we got different information from different places and then connect all the things and find the truth" Int 4_student, "it was interesting to investigate and find reason why our theory was or wasn't right" Int 3_student, "The most challenging was filling in all the bubbles" Int 3_student, "... picking up the right idea as we found holes in all of them" Int 3_student.

Synthesising and putting all together considers creating a solution to a problem (T + S), making an accurate conclusion or solution to explain a problem with data (T + S). For example, students described their process as "Take a lot of information, making it into one thing and connect things" Int 4_student, "making sure that everything we said was connected to the data and finding the most accurate conclusion" Int 3_student. On the other side, teachers mentioned "They don't just accept the first, but they need to look at both (physical material and data), and they got to synthesise all and putting it in a press release" Int 3_teacher, "They have to collect the most important parts of their work and putting out for other students" Int 4_teacher.

Communicating to others considers presenting (T + S), making a story (S), and using data visualisations to communicate (S). Teachers mentioned "they have to make a very clear press release to inform the public" Int 3_teacher, "The communication gets both, telling other and giving others some knowledge" Int 4_teacher, "The press conference is a formal announcement and it's good, so students know they are responsible for sharing that learning" Int 3_teacher. Although for some students it was challenging to present "I think the most challenging was to make the press conference at the end and present and tell the other what has happened and what we figured out" Int 4_students, the narrative and the authentic role as data journalist was helpful to build this ability "It helped me to put together my words" Int 3_student.

Keeping Students Engaged. The engagement of students was highlighted by teachers as essential for their learning, in a way that students can find the motivation for putting their effort and attention in an activity. Results show a variety of options that are not exclusive but rather complementary. Students and teachers emphasised on four characteristics of the OD learning design that contributed to keep the students engaged such as (i) the challenging activity (S) which was "Easy to follow but not easy to solved" Int 2_student, (ii) the students doing themselves (S) regarding to switching the focus on listening the teacher to instead doing the activity themselves, "I like that we could work ourselves and explore because it's more fun that just making assignments" Int 4_student, "we could make it ourselves, we had more freedom" Int 2_student, (iii) being active and creative (T + S), in a way that students are not sitting down and listening, but are actively engaged in an activity that "allows them to use these competencies without realising" Int 5_teacher, "it was nice to do something creative, and not just sit down" and "it was more creative, it wasn't in a book" Int 4_students. Finally, (iv) accessible for all the students (T) by including different data formats and materials that students could use according to their interest and academic level, "make sure you've got a variety of text, materials and difficulty, so, everyone can be engaged" Int 3_teacher, "the framework was good because it had different components and different ways of working" Int 2_teacher.

An Authentic Experience. The OD learning design created an authentic experience for the students and teachers. Students and teachers valued the authentic elements such as (i) the local aspects in game narrative and the data (T + S). These local elements connected the OD learning design to students' everyday life, "I like that the topic was based on places in Denmark, because it was easy to find the different places" Int 3_student, "It was an engaging story for them, it was relevant for them because it was very local... something that all kids do" Int 3_teacher; (ii) the simulation of a real-world situation (T + S) through the cases and the game narrative made the students more interested and immersed in the learning activity, for example "it was a problem that could have been true and take place in real life" Int 4_student, a real case makes them feel like they are part of it" Int 2_teacher, "a real-world problem makes learning motivational" Int 3_teacher. Finally, (iii) exercising an authentic professional practice (T + S) as data journalists was motivating and enjoyable during the game and learning experience "engaging story which actually made me want to find the answer" Int 3_student. Furthermore, the game flow based on the data journalism practice served as a guiding structure that helped the students to conduct the analysis of data for solving a real-world problem and achieved the goal in a step by step way, "The path helped them, they got the mystery and act like detectives, they got some data, not everything at once, and they need to research the data to find the solution" Int 4_teacher. In this way, it was not overwhelming, and students gained confidence during the game, "it didn't feel overwhelming, but it felt like it was something that they could do" Int 5_teacher.

5 Discussion and Conclusions

This study introduces a novel OD learning design aimed at developing OD competencies in elementary school students. While previous research has highlighted the potential of OD to enhance authenticity and civic engagement in schools (Cook et al., 2018; Saddiqa et al., 2021; Wolff et al., 2016b), our study moves beyond using OD as a tool to teach school subjects such as geography or statistics (Atenas et al., 2015; Coughlan, 2020) to develop a learning design for building competencies to participate in OD ecosystems grounded on DL and RWPS. Participating in OD ecosystems can be achieved by adopting several roles such as users, providers or intermediaries (Loenen et al., 2021). The Open Data Newsroom is a learning design that supports students in practising the different roles in a game-environment. For example, students use open and non-open data from different stakeholders to identify, understand and define problems, they also provide data from their analysis and are aware of the need to collect their own data which could be later provided as open data, finally, students act as intermediaries when creating hypothesis explaining issues with data to the public. This study contributes to the growing body of knowledge on OD education in elementary schools by providing insights into the essential elements of OD learning designs such as an authentic OD practice, local open data, physical and digital elements, and real-world complex problems. We highlight the importance of game-based and authentic learning in preparing young students to participate in OD ecosystems. Furthermore, we add to the existing literature by shifting the focus from teacher-centric approaches to learning designs that emphasise the active role of students.

Learning Designs for Building OD Competencies in Elementary School. The current paper showcases *The Open Data Newsroom,* a game-based learning design that focuses on fostering competencies that enable elementary school students to actively engage with OD ecosystems and use OD in solving real-world problems applying practices from the Data Journalism profession. Our findings suggest that the integration of a game-based simulation grounded on an authentic practice and centred on an analysing local OD in learning environments, supports the learning of abilities and increases the awareness for critically engaging with OD for solving real-world problems in OD ecosystems. Both learning design and game design approaches emphasise clear goals, meaningful challenges, structured experiences, and interactive engagement to promote learning and achievement (Vargas et al., 2024). Integrating game design elements such as roles and challenges, into OD learning designs can further enhance engagement and motivation within authentic and inquiry-based frameworks. A game-based approach helps to make the knowledge that is abstract and common for OD experts more concrete and embedded in a situation (Gee, 2004; Greeno & Gresalfi, 2008).

We identified authentic, inquiry-based, and situated learning approaches as essential elements in designing OD learning activities. Firstly, in the game the students play as data journalists engaging in a simulation of an authentic OD practice to get, understand, and deliver data to explain a mysterious event to the community. An authentic activity has been defined as the ordinary activity of the practitioners (Brown, 1992), a realistic task is presented to students to think in the same ways as professionals working in real-world contexts would do (Clinton & Rieber, 2010; Oh, 2011). Secondly, the game develops around a mystery which is relevant for students and close to a real-world complex challenge. Immersing students in environments that resemble authentic contexts, while adapting activities to their interests and backgrounds, fosters deeper engagement and relevance (Clinton & Rieber, 2010; Oh, 2011). Finally, the students engage in the analysis of authentic local geographical and environmental data.

Further Research and Limitations. Although this study provides important insights into the main elements of learning designs for developing OD competencies in elementary school, the scope of this study is limited by several factors that future research could address. Further research is needed to deepen the analysis of the learning outcomes presented in this study and the understanding of OD literacy in elementary school. While this study presents a game-based OD learning design for elementary education, more studies can examine the specific impacts of the game on students' engagement in OD ecosystems. The results of this study are based on empirical research conducted in Danish schools, the findings may reflect certain cultural and educational factors unique to this context. Further research can address the validation of the current outcomes in different cultural contexts.

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Statements and Declarations

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