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DATA VISUALIZATION LITERACY

Teachers' considerations on Professional Learning in a Science Centre

Ana Gabriela Santos Guzmán

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Examiner:	Annika Lantz-Andersson
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Abstract

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Purpose: The overall aim of this study is to explore in-service teachers' considerations regarding data visualization (DV) for their teaching practice and how a DV exhibition in a science centre can support their professional learning (PL) on this field.

Approach: The overarching approach that was chosen for analysing data from this study is that of PL. This approach was selected as it provides a means to capture the conditions in which teachers learn and the reasons that motivate this process. Within the PL approach, two analytical underpinnings were used for answering the research questions: the conceptualization of teacher PL was selected to understand teachers' considerations about DV; and a model of effective teacher PL was used to suggest the elements to support teacher PL at the science centre.

Method: The study consisted of two stages for data collection and analysis. A qualitative analysis approach was used in both. In the first stage, semi-structured interviews were conducted to understand in-service teachers' ideas on DV. Answers were examined through a thematic analysis method. In the second stage, a brainstorming session was conducted with in-service at the science centre. The aim was to capture teachers' ideas on how the exhibition can support their PL on DV. These ideas and findings from the interviews were used to suggest PL design principles.

Results: Findings from the interviews suggest that in-service teachers' considerations regarding DV include elements of both data and information visualization. Moreover, participants' accounts of their experiences with DV in the classroom and the challenges that students face, reflect the close relationship between DV literacy and digital literacy. Results also reflect that participants have positive beliefs and experiences on DV, and consider that it is valuable for their students. Based on the analysis of findings from interviews and from the discussion during the brainstorming session, this study suggests a set of 10 design principles for teacher PL on DV that can take place in the facilities of the DV exhibition at the science centre.

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Introduction

In the information age, everyday life exposes people to a wide variety of data representations (Börner et al., 2016; Lee et al., 2017), particularly through online browsers (Lee et al., 2017). Various data visualization (DV) approaches are actively used by the government, institutions, and other organizations to provide information and stories. These techniques offer several benefits. On the one hand, they allow to concisely represent complex underlying data sets to the public (Lee et al., 2017). On the other hand, visuals are regarded as convincing and appealing informational interfaces (Lee et al., 2017; Wolff et al., 2016). Under these circumstances, a person's ability to read, interpret and create data visualizations can strongly influence both his or her decisions and way of communicating (Lee et al., 2017). Given the substantial implications of this situation, some researchers have suggested that DV literacy is becoming just as significant as reading and understanding text (Börner et al., 2016; Lee et al., 2017), especially in a visually saturated environment (Kędra, 2018). Despite the lack of a unanimously accepted definition, researchers seem to agree that DV literacy entails the capacity to read, extract, and interpret information from visual representations of data (see Börner et al. (2016) and Lee et al. (2017)).

Where and how do citizens develop this type of skills? Wolff et al. (2016) contend that schools lay the groundwork for building a data-literate society. However, according to the authors, the importance of DV literacy is "yet to be reflected in current teaching practices" (Wolff et al. (2016), p. 19). In their study, Wolff et al. (2016) pointed out some limitations of teaching DV at schools. For instance, one is that the datasets that are used in the classrooms are generally small and simple. Therefore, they do not properly reflect the size and complexity of datasets that are currently available to citizens. For instance, those generated in real-time, like data gathered from sensors, are not yet commonly integrated into the classroom (Wolff et al., 2016). Similarly, Kędra (2018) argues that there are some mistaken assumptions around teaching and learning DV skills. In this regard, the author points out that it is commonly believed that visual skills are just by-products of everyday exposure to images. Hence, the opportunity to develop DV skills is limited (Kędra, 2018).

If schools are expected to lay the ground for developing a DV literate society, then it seems reasonable to suggest that teachers play a crucial role for this endeavour. As Timperly et al. (2007) put it, educators are the ones who work directly with students by translating curricular goals and theoretical ideas into the classroom. This situation reflects the high expectations on teachers to develop sufficiently high levels of professional DV competencies (Lindfors et al., 2021). Although researchers seem to agree on the reasons why teachers should develop DV skills, it seems less clear where, how and when teachers do so.

According to Havnes and Smeby (2014), professional learning (PL) is a continuous process that begins with professional education and continues as the individual starts their professional practice. With the aim to clarify what PL entails, some authors seem to agree on the necessity to distinguish professional development from PL (see Havnes and Smeby, 2014; Opfer and Peder, 2011; and Timperley, 2011). In this vein, Timperley (2011) argues that PL implies an internal process in which individuals develop professional knowledge by interacting with information, as opposed to professional development, which has taken on connotations of delivering information to teachers in order to influence their practice. However, in reviewing the literature about teacher PL on DV, two main gaps were identified.

First, the reviewed studies remain narrow in focusing only on what educators should do and implement in their teaching practice to foster DV literacy. For instance, Wise, A. F. (2020) offers a set of strategies and methods for improving students' visual learning and thinking skills. Similarly, Wilderson and Polman (2020) propose that teachers should make a commitment to develop both technical abilities and the adaptability to learn and create new tools and ways for working with data. However, teachers' voices seem to be missing in the literature: very little is known about how teachers view the role of DV in education and how they develop these skills.

In this regard, the study conducted by Shreiner and Dykes (2021) probably offers one of the most comprehensive analysis and discussion on the subject. The authors conducted a cross-sectional study to investigate the practices, beliefs, and knowledge related to DV literacy of 262 practicing U.S. elementary and secondary teachers of Social Studies. The study provided two crucial insights regarding teacher PL on DV. First, the authors found that only 21% of the participants reported feeling efficacious for integrating DV in their practice, and that fraction corresponded to experienced teachers. Thus, the authors suggest that the more teachers practice teaching DV, the more effective they will feel in doing so (Shreiner & Dykes, 2021). Second, the study revealed that only 11% of the participants reported feeling confident in their competence to support students in interpreting, creating, or evaluating data visualizations (Shreiner & Dykes, 2021). In this regard, the authors argue that this lack of confidence might be linked to an inadequate preparation to teach DV, as 97% of the participants reported they did not have any kind of training –coursework or PL– that prepared them to do so. Hence, the study showed that for most teachers, the only way to learn about teaching data literacy was by doing it in their own classroom (Shreiner & Dykes, 2021).

Second, it seems that research to date has tended to discuss teachers' data-related PL as a set of competencies that are needed to respond to accountability demands. In other words, to inform teaching practices based on data-driven decision making (see Jimerson & Wayman, 2015; Mandinach & Gummer, 2013, 2016; Wayman & Jimerson, 2014). For instance, by using data from learning management systems at school to help educators make decisions on their teaching practice. Thus, there seems to be a mismatch between what research establishes as the reasons for teachers to develop DV literacy, and the drivers that motivate research in this field.

In view of all that has been mentioned thus far, these studies outline the critical role of training and opportunities to practice teaching DV to support teachers in developing the competencies to integrate DV in the classroom. In this context, a variety of studies suggest that science centres can positively impact teachers' education (Adams & Gupta, 2017; Avraamidou, 2014; Thorén W., 2021). One of the main goals of science centres is to make science accessible for everyone. At the same time, these sites aim at influencing both children's and adults' attitudes towards science and technology by offering experiences that foster curiosity, deeper understanding, and enjoyment (Thorén W., 2021).

Researchers seem to agree that science centres have several benefits for teacher PL. Four aspects of this setting stand out from the literature. First, it enables educators to gain knowledge through collaboration with museum staff and diverse learners (Adams & Gupta, 2017; Avraamidou, 2014; Thorén W., 2021). Second, it provides a space to practice their teaching in resourceful and 'safe' environment (Adams & Gupta, 2017; Avraamidou, 2014). Third, it motivates teachers to acquire pedagogical and topic knowledge for their teaching practices (Avraamidou, 2014). Finally it helps teachers comprehend scientists' work, the inquiry process, and how science interacts with society (Avraamidou, 2014). The latter could be of special interest for teachers from fields other than science (such as language teachers) or for teachers interested in conducting a multi-subject project at their school.

In sum, DV has being recognized as a critical ability for making decisions and communicating in a visually saturated environment (Börner et al., 2016; Kędra, 2018; Lee et al., 2017). In this context, schools establish the foundation for creating a data-literate society (Wolff et al., 2016), which includes DV-related skills. Thus, teachers' role is a crucial element to consider in order to fulfil this expectation. However, few studies have explored teachers' views on integrating DV into their teaching practice (Shreiner & Dykes, 2021). In contrast, studies related to teachers' DV skills take primarily an accountability approach. That is, how data can inform practice. For instance, by evaluating data from learning management systems. Moreover, findings from Shreiner and Dykes (2021) revealed that teachers considered they do not have enough experience and knowledge to integrate DV effectively. This indicates a need to understand the views and experiences of in-service teachers on integrating DV into the classroom. In this context, research suggest that science centres can play a significant role in teacher PL by providing resourceful and out-of-school environments for developing and practicing DV-related skills (Adams & Gupta, 2017; Avraamidou, 2014; Thorén W., 2021). Drawing upon this notion, the overall aim of this study is to explore in-service teachers' considerations regarding DV for their teaching practice and how a DV exhibition in a science centre may support their PL on this field. To achieve this goal, I will attempt to answer the following research questions:

> RQ1. *What are in-service teachers' considerations regarding data visualization (associated concepts, perceived value for their teaching, challenges for their students)?*

RQ2. *How can a science centre exhibition of data visualization support in-service teacher professional learning regarding data visualization literacy?*

RQ3. What are the key elements for designing an effective in-service teacher professional learning programme regarding data visualization literacy in a science centre?

The findings from this study can help unfold in-service teachers' associated concepts and experiences in integrating DV techniques in the classroom. For practitioners who are responsible for designing and implementing PL opportunities for teacher learning, this can then assist in shaping the design of teacher PL programs on DV in a science centre context. In the long run, it is hoped that this study contributes to offering some insight into teachers' learning needs on DV, as well as the best design elements for developing appropriate PL programmes, outside the school setting, to tackle these needs.

Literature review

This chapter presents a review of relevant literature on teaching and learning DV. It begins by describing the key concepts related to DV literacy. It will then go on to explain the context of teacher PL regarding DV. Afterwards, it outlines the affordances that science centres can provide for supporting teachers in this process. The last section presents a summary of the main topics in the literature and explains the relevance of the research questions in relation to these. The Procedure section in the Methodology chapter provides a detailed description of how the core literature for this study was chosen, as well as how the main topics were identified.

Key concepts

What is Data Visualization?

Information visualization (IV) and data visualization (DV) are often seen as similar but separate domains, and have attracted the interest from different sectors of academia and industry (Kim et al., 2016). In a systematic review conducted by Kim et al. (2016), the authors analyzed and compared the emerging trends and developments of IV and DV. The study involved research in both fields from 2000 to 2014. The authors concluded the two domains have co-evolved. At the same time, they are distinctively developing with their own scientific interests. In the context of this thesis, this shows a need to be explicit about exactly what is meant by IV and DV. The concepts suggested by Kim et al. (2016) provide an understanding of what each one is, and what is their purpose.

According to Kim et al. (2016), IV refers to “the study of interactive visual representations of abstract data to reinforce human cognition” (p. 124). In other words, IV refers to interactive, computer-generated graphical representations of information (Kim et al., 2016). The aim is to effectively and intuitively communicate complex and abstract ideas to its audience in a visual way, so that users can be stimulated for new insights. On the other hand, DV is typically regarded as a sub-domain of the first, and it refers to the science of visual representations of data (Kim et al., 2016). Like IV, DV also aims to help users make meaning of the data by presenting it in a visual context. However, it is important to note that *this context* is described by the authors as statistical graphics and graphical display that enable users to make comparisons or determine causality (Kim et al., 2016). Thus, a visual representation is valuable when it induces the user to recognize what might not be apparent in raw data. In other words, patterns, trends, and relationships can be easier recognized within a set of visualization techniques and software (Kim et al., 2016).

As pointed out by Kim et al., (2016), it is evident that both definitions share a number of key features, and also differ from each other from a few perspectives. As for the similarities, both IV and DV are concerned with communicating values which underlie data through visual representations. Effective and intuitive visualizations can improve usability and comprehension of complex data. Thus, it can help users analyze and reason about data and evidence. The shared aim of both domains can be divided into two categories. The first one, the aesthetic representation, aims to generate a subjective impression of a data set by evoking an emotional or cognitive response from the user. The second is the functional visualization, which uses symbols and metaphors that are easier for users to understand in order to convey a message or reveal patterns that are hidden in raw datasets (Kim et al., 2016). Therefore, Kim et al. (2016) argue that IV and DV can be considered both a science and an art. Now, what differentiates both domains depend on what each one handles to communicate messages to the audience. This means that while IV primarily works with abstract or non-spatial data, DV focuses on processing and displaying numerical or statistical input. Based on this analysis, Kim et al. (2016) concludes that the difference between both fields is that in DV, the raw data is numerical or spatial, whilst in IV, the data is not quantitative in nature. This difference is crucial to clarify in the context of this thesis, as it will help understand teachers' ideas regarding DV.

What is Data Visualization Literacy?

Researchers seem to agree on the view that the ability to use data effectively is a critical skill students should develop throughout their education (Börner et al., 2019; Kędra, 2018; Lee et al., 2017; Shreiner & Dykes, 2021; Wolff et al., 2016). Data is present everywhere, and citizens who fail to read it, analyze it, and understanding how it can be used to manipulate their decisions, run the risk of being easily deceived or misinformed (Shreiner & Dykes, 2021; Wolff et al., 2016). As Shreiner and Dykes (2021) point out, the importance of this skill is reflected in the fact that organizations such as the United States Department of Education and the Organization for Economic Cooperation and Development include the ability to make sense of data visualizations in their definition of the fundamental literacy abilities that an individual needs to function in society, to achieve his/her goals and to develop his/her knowledge and potential.

There is no agreed definition on what constitutes DV literacy. In this vein, Lee et al. (2017) point out that this term is not easy to define and that it's hard to measure, as it involves many possible tasks and visual routines. Additionally, the definition of DV literacy varies in the literature, and there seems to be terminological discrepancies among the most recent proposals. For instance, Börner et al. (2016) use the term '*Data Visualization Literacy*' to mean "the ability to make meaning from and interpret patterns, trends, and correlations in visual representations of data" (p. 200). Moreover, Lee et al. (2017) use the term '*Visualization Literacy*' to describe: "the ability and skill to read and interpret visually represented data in and to extract information from data visualizations" (p. 552). Even though these definitions are defined by using different terms (DV Literacy and Visualization Literacy) both seem to describe the skills for interacting critically with data.

In the context of this thesis, the definition of DV literacy suggested by Börner et al. (2016) will be used, as it seems to be more aligned with that of DV provided by Kim et al. (2016), which was described in the previous section. The aim is to clearly draw the line between examples of representations and processes associated with DV, and those related to IV. Examples of representations of data include charts, maps and treemaps (Lee et al., 2017).

Having described what is meant by DV literacy, it is important to point out that, regardless of the definitions suggested by researchers, the reviewed studies seem to agree on the notion that it is crucial to identify the skills of a visually literate individual (see Börner et al., 2019; Kędra, 2018; Lee et al., 2017). This means that, in order to create appropriate education/training to gain such capabilities, it is crucial to first comprehend and then define what skills and abilities constitute DV literacy (Kędra, 2018; Lee et al., 2017).

From the reviewed literature, the studies conducted by Lee et al. (2017) and Börner et al. (2019) stand out for discussing the developing consensus regarding the definition and assessment of DV literacy. In this regard, the study from Lee et al. (2017) has been one of the few to develop and test a method for evaluating DV literacy skills. For each type of visualization included in their test, the authors associated a cognitive task that was assessed in the test. The eight tasks are: retrieve value, find extremum, determine range, characterize distribution, find anomalies, find clusters, find correlations/trends, make comparisons, and others (Lee et al., 2017).

Unlike Lee et al. (2017), Börner et al. (2019) take a broader perspective by identifying the key process steps involved in DV construction and interpretation. The table below provides an overview of these steps.

Table 1. Key process steps involved in DV construction and interpretation, as proposed by Börner et al. (2019).

Step	Definition	Typology
Acquire	Gather relevant data sets and other resources based on clear insight needs. Selecting the best data sets and data scales will have a significant impact on the results.	**Data scales** Nominal, ordinal, interval, ratio
Analyze	Processes conducted before data is displayed. These includes data cleaning (identify and correct errors, handle missing data, anomalies, unusual distributions); data transformation and data analyses.	**Analyses** Statistical, temporal, geospatial, topical, relational
Visualize	This step consists of two activities: select a visualization type; and mapping data records and variables to graphic symbols and graphic variables.	**Visualizations** Table, chart, map, graph, tree, network. **Graphic symbols** Geometric symbols, such as area, surface and volume; linguistic symbols, such as text and numerals; and pictorial symbols, such as images and icons.

		Graphic variables Spatial, such as position; and retinal, such as form, colour, optics and motion.
Deploy	Different deployments will support various interactions using different human-user interfaces and metaphors. For instance, an interactive display will allow zooming or pinching in a touch panel.	**Interaction** Zoom, search and locate, filter, details on demand, history, extract, link and brush, projection, distortion.
Interpret	The visualizations are read and interpreted by the authors and other audiences. The DV results are translated into conclusions and narratives that impact when applied in the real world.	**Insight needs** Categorize/cluster Order, rank, sort Distributions (also outliers) Comparisons Trends (process and time) Geospatial Compositions (also of text) Correlations/relationships

Data literacy taxonomy

According to the situation in which an individual needs to make use of data for problem solving, Wolff et al. (2016) identified the skills associated to four different roles of what the authors define as a 'data literate citizen'. Importantly, as noted by Wise (2020), "the line between what data scientists and what data literate citizens need to know is itself moving rapidly" (p. 167).

1. Readers. This group increasingly encounter data as part of their everyday life, and so they need skills to interpret it.
2. Communicators. Those who make sense of data and tell stories through them so others can understand it.
3. Makers. Those who need to integrate data into strategies for identifying and solving real-world problems. They also need to be conscious of how their data contributions drive actions in society.
4. Scientist. They need to have an in-depth knowledge of the field of the data, and combine strong technical data skills with communication skills.

As argued by Wolff et al. (2016), by identifying the different types of data literate citizens, it is possible to understand the needs of a citizen in a specific environment. Hence, this categorization can help understand the skills that a data-literate citizen needs to develop according to their role, and to some extent, to their goals (Wolff et al., 2016).

Challenges students face when learning DV

Despite the common belief that data visualizations make information easier to understand, Shreiner and Dykes (2021) argue that students face a number of challenges when attempting to make sense of them. This view is supported by Kędra (2018), who notes that, seeing is perceived as something natural, 'learning to look' becomes a difficult, as it is assumed that it does not require any additional training. Thus, the opportunity to develop visual skills at school is limited (Kędra, 2018). The arguments from these authors suggest that, for students to successfully develop DV skills, it is crucial to understand the challenges they might face in the classroom. In their study, Shreiner and Dykes (2021) identify five of these challenges based on findings from their reviewed literature.

1. **Lack of understanding of intention, relevance, and function within a text.** When reading and interpreting data visualizations, such as graphs, illustrations or diagrams, students need to develop understanding of concepts like intentionality, relevance and extension. This means that they should understand that data visualizations are representations of information created with a specific intention by the authors. Also, when created properly, they are relevant to the surrounding information, often to extend what is found in the text (Shreiner & Dykes, 2021). For instance, the authors refer to a study conducted by Shreiner (2019), in which 74% of the participants (27 elementary, middle and highschool students) ignored a DV in a multimodal text, even though it was directly related to the question they were trying to answer. Thus, this finding suggests they did not understand its relevance in the context (Shreiner & Dykes, 2021).

2. **Difficulty in making sense of data visualizations.** Students might have significant difficulty reading, interpreting, evaluating, and integrating data visualizations, even if they pay attention to them. As an example, Shreiner and Dykes (2021) referred to a study from Brugar and Roberts (2017), in which they found that even when participants (326 elementary students) attempted to use graphs and maps to make meaning of the text, they did not do it correctly. Their answers about the DV were more frequently incorrect when compared to those about verbal written text. Moreover, these problems seem to persist into adolescence and adulthood (Shreiner & Dykes, 2021).

3. **Difficulty in identifying and interpreting data visualizations beyond the basic level.** Shreiner and Dykes (2021) refer to two studies to explain this challenge. One is a study conducted by Börner et al. (2016), involving 127 students aged 8 to 12, and 146 aged 18 or older. The aim was to determine if the students could name different types of data visualizations or interpret them beyond the most basic reference system. The other is a study from Shreiner (2009), in which the author concluded that while eight high school students

could extract basic information from bar and pie graphs, they failed at using evaluative strategies, such as sourcing, contextualizing, and making methodological considerations (Shreiner & Dykes, 2021). However, Shreiner and Dykes (2021) highlight that, naturally, various data displays pose distinct difficulties. This view seems to support the different cognitive tasks associated with each type of DV that Lee et al. (2017) included in their method for evaluating DV literacy.

4. **Reading and interpreting data visualizations is a complex task.** Making meaning of data visualizations, such as maps and graphs, is an activity that involves several mediating factors. First, identify graphical elements, such as the direction and numbers on an axis. Second, readers must understand what these elements represent. For instance, that an upward sloping line on a *x-y* graph indicates an accelerating relationship between variables. Finally, the reader must be able to connect the graphic representation to its context, such as immigrant population (Shreiner & Dykes, 2021). This view seems to support that of Kędra, 2018, who argues that interpreting data visualizations is a complex process that requires training.

5. **Irrelevant elements increase difficulties.** In, their review, Shreiner and Dykes (2021) included a study from Strobel et al. (2018) which concluded that irrelevant tasks associated with DV interpretation showed to increase errors and time processing. Additionally, irrelevant information within the visualization increased the cognitive load of the task. The study was conducted with university students.

Teacher professional learning on Data Visualization

Teachers' beliefs and experiences around DV

As pointed out by Shreiner and Dykes (2021), very little is currently known about how teachers' practices, beliefs, and knowledge related to DV literacy. Their study involved 262 practicing U.S. elementary and secondary teachers of Social Studies. Most participants were new teachers (202 vs 60 respondents). The authors defined new teachers as those with one to five years of teaching experience, while those with more than five years of practicing were considered experienced teachers. Their findings (explained below) revealed important insights regarding how teachers view the role of DV literacy in Social Studies education and how well prepared they considered themselves to teach it.

Self-assessment of their capabilities to teach DV

First, Shreiner and Dykes (2021) found that only 11% of all participants reported they regularly feel confident with DV related tasks. Here, answers differ according to teachers' years of experience. As for new teachers, 53% expressed some level of confidence in teaching students to interpret DV, as opposed to 80% of experienced teachers. Second, the study revealed that experienced teachers reported feeling more confident and enthusiastic about teaching DV (about 90% in most of the results) when compared to new teachers (only around 50%). Finally, 52% of all participants reported they felt confident in teaching students how to create visualizations, with slightly more experienced teachers feeling confident in using online tools and computer software (Shreiner & Dykes, 2021). The one exception was related to programming languages for creating visualizations, where 56% of new teachers felt confident in using this method, as opposed to 53% of experienced teachers (Shreiner & Dykes, 2021).

Perceived value of DV

The third finding is related to teachers' perceived value of DV and if they considered they have the necessary resources to teach it. In this regard, only 58% of all participants agreed on the view that it is crucial to teach DV, 61% agreed that it is relevant to teach students about how data visualizations they see in media are created, and 61% of participants thought that data visualizations are useful for enhancing content understanding (Shreiner & Dykes, 2021). The authors suggest two reasons why educators may view DV as unimportant. One is that they think they are not compelled to teach it in their subject (Social Studies). The other reason is that they may feel there are not enough resources to teach DV. The study revealed that only 62% of teachers reported they have access to online tools to teach DV, and only 50% said they have other resources at school for this aim. Finally, 56% of the participants shared the view that, if given more resources, they would teach more DV-related tasks (Shreiner & Dykes, 2021). Finally, Shreiner and Dykes (2021) also found that 92% of those who viewed DV as a valuable topic to teach reported they had positive experiences related with DV.

The fourth finding from Shreiner and Dykes (2021) relevant to this thesis is related to teachers' reports on opportunities they have had to develop skills for teaching DV. The study revealed that years of teaching practice seemed to be the main source that provided the opportunity for mastery, as 97% of all respondents expressed that they did not have college or PL courses focused on DV (Shreiner & Dykes, 2021). This finding is of great relevance for this thesis, as it suggests that teachers need PL opportunities to develop their DV skills, which are considered as a crucial literacy in the current society. In this context, it is therefore crucial to understand what teacher PL means, and where teachers can find such opportunities. The topics will be discussed in the following sections.

Teacher professional learning

In general terms, Havnes and Smeby (2014) describe PL as an ongoing process which starts in professional education and continues during the professional career as the individual initiates the professional practice (Havnes & Smeby, 2014). The authors argue that, even though a person is certified for entering professional practice after completing higher education, he/she is still not fully qualified for independent professional practice.

Therefore, in the teaching context, describing PL as a continuum suggests the importance of differentiating PL elements of pre-service and in-service teachers (i.e., after they have completed their basic teacher training). Since this study focuses on in-service teachers, it is important understand PL from this perspective. In this vein, Postholm (2012) conducted a theoretical review to understand how experienced teachers learn. The author argues that teacher PL means teachers' learning, how they learn to learn and how they apply their knowledge in practice to support pupil learning" (Postholm, 2012, p. 405). This view is supported by Timperley (2011), who suggests that teachers' PL needs to be situated in proximity with the teaching practice and students' learning – which is its core goal. Moreover, Postholm (2012) indicate various ways in which experienced teachers learn, both formally and informally. These include learning through participating in courses, by reflecting on their own teaching in the school context, and by observing and reflecting on the teaching practice in collaboration with colleagues (Postholm, 2012).

For the purpose of this thesis, it is important to highlight two elements from the studies described in this section. One is that the main goal of teachers' PL is to support students' learning (Postholm, 2012; Timperley, 2011; Timperley et al., 2007). The other is that reflection is a key activity in learning (Postholm, 2012). Together, these constitute key elements for designing the current study, as will be explained in the following chapter (Theoretical framework).

Science centres as a space for supporting teacher Professional Learning

In their study, (Mandinach & Gummer, 2016) advocate for a systemic approach to promote change in teacher PL programmes, as many players are needed to facilitate this change. Even though the system components differ in every country, some include, state education agencies, professional organizations, and professional learning providers, among others (Mandinach & Gummer, 2016). In this vein, McKinnon and Lamberts (2014) explored if PL programmes offered in education institutions such as science centres, could influence science teaching self-efficacy beliefs of pre-service and in-service teachers from primary school. The researchers found that PL workshops provided at science centres increased teachers' self-efficacy in science teaching for the majority of the participants (18 out of 21) (McKinnon & Lamberts, 2014).

Similarly, the study conducted by Sgouros and Stavrou (2019) provides some insights on the experience of a PL programme for teachers at a science centre. The programme consisted of the co-creation of a teaching module in Nano-Science and Nano-Technology. The collaboration was made between in-service teachers, science education researchers, nanoscience researchers and experts from science museums. The module included the development of an exhibition at a science museum aimed for students to visit (Sgouros & Stavrou, 2019). The findings from Sgouros and Stavrou (2019) showed that the challenges of integrating innovative aspects (e.g., science exhibits, interacting with peers in the community of learners), provided them with new resources and insights for their teaching practice related to Nano-Technology topics. Thus, the authors concluded that the teachers-researchers collaboration for curriculum design seemed favourable for teacher PL, especially for developing the competencies and building up their pedagogical repertoire for introducing current science topics in the classroom (Sgouros & Stavrou, 2019).

Taken together, the reviewed studies in this last section support the notion that science centres can provide not just an alternative for teachers to develop their DV skills, but also the appropriate conditions for supporting their PL on DV. Findings from Sgouros and Stavrou (2019) seem to suggest collaborative workshops as a pertinent approach for designing teacher training programmes in informal science learning environments.

Summing up the topics identified in the literature

In conclusion, DV is rapidly being recognized as a crucial skill for communicating and making judgments in an environment where there is a lot of visual information available (Börner et al., 2016; Kdra, 2018; Lee et al., 2017). Schools are seen as the starting point for acquiring these skills (Wolff et al., 2016). Therefore, it is essential to take into account teacher PL in DV skills. A review of the literature revealed that few studies had focused on the integration of DV in the teaching practice (Shreiner & Dykes, 2021). Even less is known about how teachers of topics other than mathematics or statistics (such as social studies and language instruction) incorporate DV into their lesson plans (Shreiner & Dykes, 2021). In this regard, research indicates that science centres can contribute significantly to teacher PL by offering resourceful and out-of-school environment for developing and practicing DV-related skills (Adams & Gupta, 2017; Avraamidou, 2014; Thorén W., 2021).

Overarching approach and analytical underpinnings

The overarching approach that was chosen for guiding the analysis of data derived from this study is that of PL. This premiss was chosen as it offers a means to capture the complexities of the context in which teachers learn. In the context of this study, understanding the complexity of this phenomenon is crucial for addressing the research questions. The reason is because it lays the groundwork for comprehending what teacher PL is, particularly in relation to the distinctive characteristics that define it and set it apart from other professions. Thus, it helps in guiding the factors that should be considered when designing teacher PL initiatives.

Within the PL approach, two analytical underpinnings were chosen for answering the research questions of the study. For RQ1, the conceptualization of teacher PL proposed by Timperley et al. (2007) was adopted as a lens for analysing and interpreting data gathered from the interviews, in order to understand teachers' considerations regarding DV. As for RQ2 and RQ3, the model of effective teacher PL proposed by Darling-Hammond et al. (2017) was used to examine the suggestions for teacher training on DV that were discussed in the follow-up workshop.

Conceptualization of Teacher Professional Learning – Framework for RQ1

In their extensive literature review, Opfer and Pedder (2011) found that most of the research around teacher PL is predicated on the idea that teacher PL is made up of a variety of learning activities and methods, and that teacher learning is largely a function of how frequently these activities, structures, and other elements are used in professional development programs (Opfer & Pedder, 2011). In other words, they argue that this literature emphasizes the serial and additive perspectives on teacher learning (process-product approach). The authors highlight that a number of studies have revealed that despite its significance, many PL research has produced unsatisfactory findings, with teacher PL programmes frequently being labelled as ineffective (Opfer & Pedder, 2011). Opfer and Pedder (2011) argue that this issue is partly due to researchers' use of overly-simplistic conceptualizations of teacher PL that neglect to take into account how learning is embedded in professional lives and working conditions. Therefore, the authors suggest viewing teacher learning as a complex system as opposed to an event, in order to understand under what conditions, why and how teachers learn (Opfer & Pedder, 2011).

Likewise, other researchers have questioned the usefulness of the process-product approach. Timperley (2011) and Havnes and Smeby (2014) challenge this view by arguing for a shift from professional development to professional learning (PL). In their studies, the authors seem to agree on the need to differentiate both terms. For Timperley (2011), PL implies an internal process in which individuals create professional knowledge through interaction with information, as opposed to professional development, which has taken on connotations of delivery of some kind of information to teachers in order to influence their practice. Similarly, this view seems to support Opfer and Pedder (2011), who argue for need to shift from the serial, additive process approach (which consist of a repository or compilation of methods and activities for learning that an educator follows), to a system approach in which teachers interact with information in their context.

Furthermore, Timperley (2011) argues that the focus of PL should be the workplace itself. Her analysis focuses on the teaching profession. The need for teacher PL to be located near to teaching practice and its primary objective—student learning—is a critical factor. Therefore, the teacher PL model chosen for this study is described as "*Teacher inquiry and knowledge building cycle to promote valued student outcomes*". This model rests on the premise that it is increasingly clear that teachers' knowledge and practices is one of the most influential factors in students' learning (Timperley et al., 2007). The model is included in the 2007 report that is part of a series of best evidence synthesis iteration, commissioned by the Ministry of Education from New Zealand.

Framework key elements

As Timperley et al. (2007) put it, when designing PL opportunities for teachers, the knowledge must be developed by considering the context of student outcomes. The authors therefore propose a sequence of inquiries that combine the elements that comprise the teachers' learning cycle (see Figure 1). These inquiries include elements of self- and co-regulatory learning. A description of each inquiry is provided below.

First inquiry. This stage investigates students' learning needs. The authors argue that these goals must be informed by applying assessment tools for understanding what students already know, what they need to know and do. Doing so ensures that teaching is evidence-informed and targeted at student needs (Timperley et al., 2007).

Second inquiry. This inquiry stage focuses on two aspects: current teaching-learning links and learning outcomes for students. It asks teachers to reflect and define what they need to learn and do to support their students in achieving these goals. Since students are taught by various teachers in their course of education, Timperley et al. (2007) point out that this inquiry stage requires a collective rather than an individual analysis. Moreover, the authors argue that a key element of this inquiry is teachers' self-view as agents of change –both for themselves and their students–. The authors argue that most studies showing sustained outcomes have reported the latter condition as essential for co- or self- regulatory learning (Timperley et al., 2007).

Third inquiry. The final stage of the cycle aims at identifying and monitoring the effectiveness of the actions taken in the two earlier inquiries. This evaluation is made in terms of the impact on students' learning. The insights from this stage might lead to adjusting goals, plans, and implementation, cycling back to the students' learning needs inquiry (Timperley et al., 2007). As for the third inquiry, Timperley et al. (2007) concludes that given the difficulty for an individual to identify what they do not know, it is unlikely that these insights will be achieved without external support. This claim is supported by the findings from their synthesis.

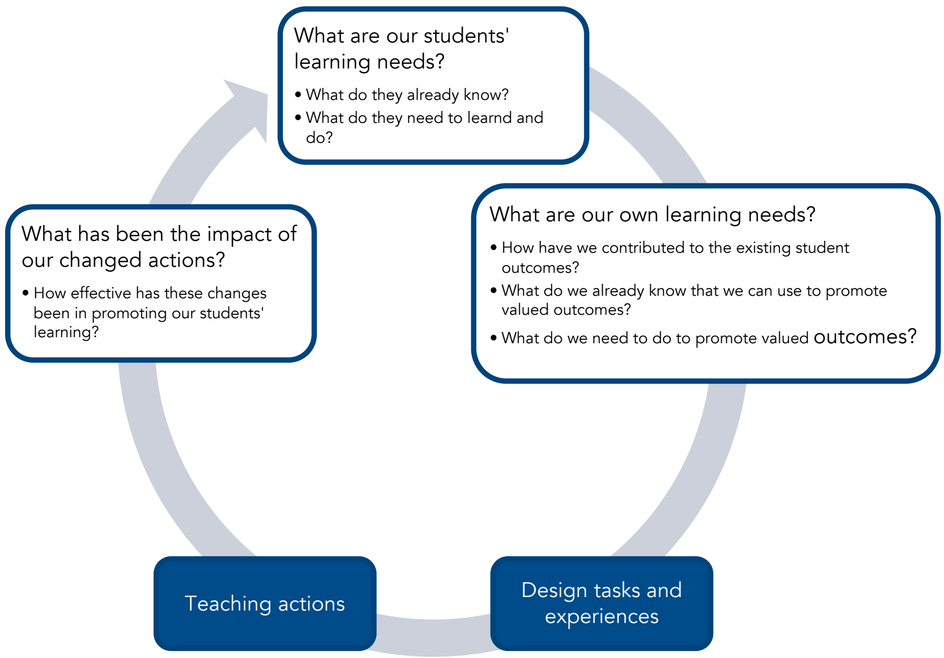

Figure 1. Teacher inquiry and knowledge-building cycle to promote valued student outcomes, as proposed by Timperley et al. (2007). Adapted from "Teacher Professional Learning and Development" by Timperley et al., 2007. p. xliii.

In sum, the model suggested by Timperley et al. (2007) supports two of the teacher PL tenets emphasized in the Literature Review: the first is that teacher PL should assist student learning (Havnes & Smeby, 2014; Postholm, 2012; Timperley, 2011), and the second is that reflection on the teaching practice is essential in the PL process, especially for in-service teachers (Postholm, 2012).

Effective teacher professional learning – Framework for RQ2 and RQ3

As explained by Lo (2021), for teacher PL, a frequently cited research synthesis is that of Darling-Hammond et al. (2017). This model identifies seven design elements of teacher PL (Darling-Hammond et al., 2017; Lo, 2021). It was developed by examining research on PL that has been shown to change teachers' practices and improve student results. By doing so, the authors identified the components that are common in successful PL models (Darling-Hammond et al., 2017). To determine the features of effective PL, the authors looked at 35 studies over the last three decades which empirically assessed student outcomes in relation to teacher PL.

As described by the authors, their aim is to inform policymakers and practitioners who are responsible for conceiving, planning, and implementing potentially fruitful opportunities for teacher learning (Darling-Hammond et al., 2017). Hence, the purpose of the model and its seven design elements provide the analytical underpinning for analysing the ideas on PL brought by the teachers during the follow-up workshop. It also offers the foundation for suggesting the elements that the DV exhibition could integrate for supporting teacher PL regarding DV literacy.

It is necessary here to clarify exactly what is meant by effective PL. According to Darling-Hammond et al. (2017), it consists of a systematic PL that leads to changes in teacher practices and improved student learning outcomes. The authors identified seven elements of effective teacher PL: 1) content focus; 2) active learning; 3) collaboration; 4) use of models of effective practice; 5) coaching and expert support; 6) feedback and reflection; and, 7) sustained duration learning (Darling-Hammond et al., 2017; Lo, 2021). Table 2 presents a description these elements. It also includes examples of programmes that exhibited each one of them according to the literature examined by Lo (2021) in his systematic review.

Table 2. Design elements of effective teacher PL identified by Darling-Hammond et al. (2017) and examples provided by Lo (2021).

Design elements	Description	Examples of how STEM[1] teacher PL programmes integrate the design element
Content focus	Activities focused on the content taught by teachers.	STEM teachers' content knowledge covers the topics in mathematics and science (e.g., counting and animal adaptations, accordingly). Teacher PL programme from Brenneman et al. (2019), as described by Lo (2021).
Use of models and modelling	Instructional models as a vision of practice (e.g., sample materials, demonstration lessons).	Guides with model lessons that included suggestions on how to modify them to fit teachers' needs and context at school (e.g., available resources and student ability). Teacher PL programme from Brenneman et al. (2019), as described by Lo (2021).
Active learning	Direct engagement in the practices which are connected to participants' (teachers') classrooms and students.	Teachers were engaged as students in several integrated STEM activities, which included design, build, and test-based engineering activities. Teacher PL programme from Williams et al. (2019), as described by Lo (2021).
Collaboration	Collaboration between teachers is facilitated at different levels: teacher, department, school, and/or district.	Interactions between teachers and community members were encouraged for different purposes, such as sharing information/designs, negotiate meaning, and building consensus. Teacher PL programme from Singer et al. (2016), as described by Lo (2021).
Coaching and expert support	Teachers are supported by coaching and expert scaffolding for implementing new curricula, instructional approaches, and tools.	Teachers were supported by district coaches in lesson planning. For instance, incorporating integrated STEM activities into their current curricula and schedule. Teacher PL programme from Brenneman et al. (2019), as described by Lo (2021).
Feedback and reflection	Time given to participants to reflect on their teaching practice, possible changes that can be made, and to receive feedback on it.	Lesson videos were used to assist teachers in reflecting about their teaching practice. Feedback was given with an emphasis on both the positive aspects and those worthy of improvement. Teacher PL programme from Singer et al. (2016), as described by Lo (2021).
Sustained duration	Multiple opportunities to engage in learning are offered to teacher participants.	The facilitators watched teachers' lessons and provided feedback throughout a year-long field placement. Teacher PL programme from Herro et al. (2010), as described by Lo (2021).

[1] STEM: Science, Technology, Engineering and Mathematics

The teacher PL design elements proposed by Darling-Hammond et al. (2017) were chosen for several reasons. First, it supports the premise that teachers' knowledge and practices are one of the most influential factors in students' learning, as argued by Timperley et al. (2007). Second, it provides the basis for a thematic analysis of specific effective PL elements by examining the ideas suggested by teachers in the follow-up workshop. Finally, it is considered as a list of design criteria to which the proposed PL programme should adhere.

Methodology

Overview

An interpretative design frame was used to answer the research questions (RQ's) of this study. The study consisted of two stages for data collection and analysis. A qualitative analysis approach was used in both. Each stage was designed to answer each of the research questions. In the first stage, semi-structured interviews were conducted to understand teachers' considerations regarding DV (i.e., associated concepts, perceived value for their teaching practice, and challenges for their students). The interviews were recorded and transcribed. Answers from teachers were examined through a thematic analysis method. In the second stage, a follow-up workshop with the six interviewees was conducted at Vislab exhibition, at Universeum. The aim was to conduct a brainstorming session for capturing teachers' main ideas on how Vislab can support their PL on DV. Finally, these ideas were categorized and translated into suggestions and design principles for teachers' PL on DV literacy at Vislab. The following sections provide a description of the procedures and methods used in this investigation for data collection and analysis.

Research setting

Universeum is a science center located at Gothenburg, Sweden. Its facilities and exhibitions provide visitors with opportunities to learn about science and technology. The organization offers school trips and educational programs for students. It also offers continuous education services, workshops and major educational initiatives for teachers and leaders from educational institutions: from preschool to adult education. The programmes include topics on digital competence, sustainable development goals, natural science, and technology. These trainings are offered at Universeum or elsewhere (Universeum, 2021b).

In recent years, Universeum has invested in exhibitions and programmes related to DV, as well as a professorship in data visualization and pedagogy. The next step in this endeavour is the Vislab project, which will be open to the public from January 2022. The aim is to respond to the challenge of interpreting research data, so high school students and adults have the opportunity to understand sustainability-related topics and act accordingly. The different stations at the exhibition show data through five different themes: sea, land, society, space, and humankind. The data is obtained from relevant organizations and institutions (Universeum, 2021a). Each station allows visitors to manipulate data and visualize it in different ways, such as graphs, maps and images projected in interactive screens. According to the definition provided by Jonas Boström, an educator at Universeum, "visualization is communication with the help of images, but at the same time, is not just about what you see but mainly about the interpretation you make in the brain" (Universeum, 2021c). Hence, the Vislab project offers an opportunity for high school teachers to develop DV literacy skills.

Procedure

The study consists of three phases. The first phase involved a literature review focusing on identifying relevant themes related to DV literacy. The second phase consisted of data collection, where two different methods were used to answer the RQ's. The final phase consists of data analysis. Figure 2 presents an overview of the three phases:

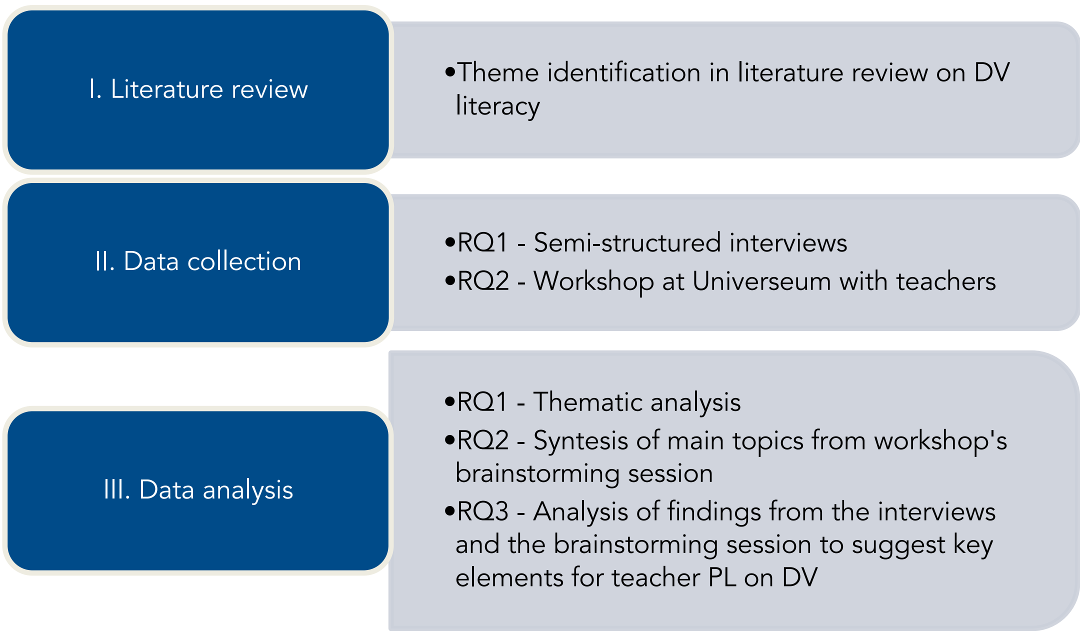

Figure 2. Processes followed for conducting the present study.

Phase 1. Theme identification in literature on DV literacy

For identifying relevant literature for this overview, a three-step process was used: planning, searching, and assessing resources. A description of each stage is provided below.

Planning

In this stage, the subject of interest was defined. The following key words were used in several combinations:

- Data visualization literacy
- Data visualization

Combined with

- Teachers
- Educators

- Professional development
- Awareness; Perceptions
- Learning
- Museums
- Science centres

The general eligibility criteria required that the articles were peer-reviewed and that their ranking in the Norwegian List of Scientific Journals was at least 1. The latter ensured that the journals in which the articles were published were recognized as for being of good or excellent quality. Additionally, other factors to select the articles were:

Inclusion criteria considered studies:

- With sociological, pedagogical/educational or technical approach.
- Published preferably between 2010 and 2022. However, those published before 2010 were considered if they provided relevant information for answering the RQ's (e.g., concepts, analysis of previous studies on DV).
- Focused on:
    - Teacher PL/DV literacy
    - teachers' understanding, practices and views of DV
    - students' experience in learning DV, and developing DV literacy
    - education or training in museums, both for the general public and for teachers.

Exclusion criteria considered studies:

- Focused on DV literacy outside the educational setting (e.g., those that were not focused on schools, universities or science centres).
- Focused on general public and mass media (for instance, DV in news, social media, etc.)

Finally, two data bases were selected, based on the three approaches/subjects selected for searching the articles. These were recommended by the Gothenburg University (GU) library website as 'subject-specific databases' related to pedagogy, sociology, teaching and learning, and technology.

- Subject 1 - Pedagogy
    - Scopus (both for Pedagogy and Social Sciences)
- Subject 2 - Technology
    - IEEE Xplore. (From the Institute of Electrical and Electronics Engineers) Full text database in computer science, electrical engineering and electronics. Journals, conferences and standards from IEEE and IET.

Searching

Three search techniques were used for locating relevant articles:

- Combining and truncating the selected key words; and by using phrase search (i.e. "teacher professional learning").
- Conducting a chain search using these criteria:
  - choosing text that followed the same subject term/keywords (e.g., those in the 'Related documents' suggestions on Scopus);
  - checking articles in which a selected article has been cited; and
  - checking and retrieving texts from the article's reference list.
- Examining and selecting articles from lectures.

Assessing resources

After considering the inclusion/exclusion criteria and the research questions, a preliminary literature list was generated. The located articles were clustered into three groups: 1) data literacy/DV literacy (15 articles); 2) teacher PL (16 articles); and 3) science centres for PL (6 articles).

A second review was conducted with the aim of identifying studies that included relevant findings associated with DV literacy in the educational context (i.e., schools or universities). The range of findings included discussions about definitions of DV, description of key elements (i.e., related knowledge and skills), teachers' roles and expectations regarding DV teaching, science centres for teacher training. Six articles were selected in this phase, considering that they conceptualized DV and DV literacy in the educational context, and that they explored in-service teachers' views on using DV in the classroom. These conformed the core studies of this thesis. The key ideas of these articles were summarized by using a structure which captured four elements:

1. a list of the main ideas of the article;
2. a list of topics (i.e., themes) discussed in each article;
3. the relevant contribution of each article (i.e., provide a definition, suggest a set of skills related to DV); and
4. comments regarding differences or similarities between the topics identified in the article.

The result of this process facilitated the identification of current discourses and topics related to DV research. This step was crucial for shaping the research questions of this study, as it helped identify the key aspects of the research problem area presented in the Introduction.

Process 2. Data collection

For RQ1 – Interviews

RQ1. What are teachers' considerations regarding data visualization (associated concepts, perceived value for their teaching, challenges for their students)?

Interview approach choice

Data for the first RQ was collected by conducting interviews with each participant. This method was selected for two reasons. First, interviews allow to explore individuals' ideas on specific matters. That is, their views, experiences, beliefs and/or motivations (Gill et al., 2008). This aspect is fundamental for answering RQ1, as it aims at exploring individuals' ideas on DV in terms of their individual knowledge and teaching experience, rather than a collective view of it. Second, this method is recognized for providing a deeper understanding of social phenomena, which would not be obtained from quantitative methods (e.g., questionnaires). In this regard, interviews seem more appropriate when little is known about the topic of interest, or when thorough insights are required for understanding the study phenomenon (Gill et al., 2008). Given that very little is currently know about how teachers' integrate DV in their practice (Shreiner & Dykes, 2021), this approach seemed appropriate.

Moreover, a semi-structured interview approach was used. This allowed participants to express their opinions and ideas on DV, since a list of issues was brought to the conversation, whilst allowing the freedom to follow-up on comments from the participants as necessary (Thomas, 2013). The semi-structured interview was chosen over the structured interview and the unstructured interview for two reasons. First, because the research question was formulated to explore participants' ideas about a set of specific topics on DV (associated concepts, perceived value for the teaching practice, and students' challenges). This implied that a structure was needed to ensure that the topics of interest were covered, while having the flexibility to follow up points as necessary (Thomas, 2013). Thus, the structured and unstructured interviews did not provide the required conditions for answering the first RQ. The second reason for choosing a semi-structure approach for interviews is that is the most common arrangement for small-scale research due to the combination of structure and flexibility described before. In summary, a semi-structured interview format offered the required configuration for answering the first RQ.

Interview guide and pilot tests

An interview guide was designed following the scheme for semi-structured interviews proposed by Thomas (2013), as it clearly identifies the topics that would like to be explored, the possible main and follow-up questions to get more insights from participants, and probes for encouraging further discussion. The design process of the guide involved two pilot test interviews. The participants were university teachers from Guatemala (my country of origin), and were recruited using a convenience sample technique. The aim of the pilot test was twofold: first, to test the interview guide and make the necessary adjustments; second, to gain practice in conducting the interview. The latter was especially relevant, as it allowed to develop experience in bringing and managing follow-up questions, and to discuss the topic in a foreign language (English). The final version of the guide is presented in Appendix 2 – Interview guide.

Eligibility criteria

For this study, the primary eligibility criteria required individuals to be in-service teachers from 7th grade and upper who taught at a school in Sweden. This means that pre-service teachers were not considered. The focus on in-service rather than pre-service teachers was motivated by three reasons. First, research regarding PL on DV from this group seems to be scarce. Secondly, literature suggest that DV is a new type of literacy that many in-service teachers need to develop in order to support students in becoming DV competent (Shreiner & Dykes, 2021). Thus, PL outside the traditional higher education setting is necessary to consider for this group. Finally, the distinction between these two groups is necessary from a PL design perspective, since the learning context of both is different (Postholm, 2012).

Therefore, the learning activities must be adapted to these conditions in order to achieve the learning goals. The subject which they taught was not considered an exclusion criterion. Additionally, gender and age were not considered in the eligibility criteria since it was not expected to be representative with this respect. However, the group was evenly distributed in this regard (three female and three male participants). Accordingly, the study excluded pre-service teachers, teachers who were not currently teaching, those who were teaching in a country other than Sweden, and/or those who taught in lower grades than 7th or at higher education. It is also important to mention that two of the teachers participated in a pilot test with their students at Vislab. Thus, both were familiar with the exhibition prior to the interview. The implications of this situation are presented in the Discussion section.

Recruitment

The participants in this study were recruited from a list of teachers from grades 7th to 9th who were interested in participating in pilot tests related to Vislab and STEM (Science, Technology, Engineering and Mathematics) education. The list was provided by an Educator from the Pedagogy department at Universeum, who collected the contact information from teachers during 2021. That is, before the Vislab exhibition was officially opened to the public (which was in January 2022). In addition to this list, teachers from other contexts were contacted through different media to invite them to participate in the study. This included a Facebook group of international teachers in Sweden, a LinkedIn publication shared by a former employee from Universeum, and a language teacher who was contacted using a convenience sample technique. Nonetheless, no person contacted through social media showed interest in participating in the study, and the latter agreed but the study was well advanced. Thus, I decided to proceed the data analysis with the six interviews that were already conducted.

All 10 teachers from the list provided by Universeum's staff were contacted via email. The information in the email included:

- an invitation to participate in the study and a description of what their participation will consist of (i.e., interviews and the possibility to participate in a follow-up workshop at Universeum afterwards);
- the relevance of the study in current society, and why their participation was valuable for contributing to this understanding;
- the context in which the study was conducted and its purpose. That is, as a collaboration with Universeum through a Master's thesis;
- a description of how interviews would be conducted and an informed consent with the details of the conditions of the participation (See Appendix 1 – Information letter and Informed consent).

Participants

Six teachers from the list agreed to participate in the study. All the participants worked at schools in Gothenburg, teaching in grades ranging from 7th to 9th. This stage is called *högstadiet* in Swedish, and it is part of the compulsory schooling in Sweden. The participants in the study taught different subjects. Their teaching profile is presented in Table 3.

Table 3. Participants' teaching profile.

Teacher	Subjects taught	Years of teaching experience	Grade in which he/she teaches
TCH01	English and Swedish languages	33	7th – 9th
TCH02	Science (Chemistry, Physics, Technology, Programming)	7	7th – 9th
TCH03	Math, Science, Biology, Physics, Chemistry, Technology	26	7th – 9th
TCH04	Chemistry, Biology, Physics, Technology and Math	35	9th
TCH05	Chemistry, Biology	6	7th – 9th
TCH06	Chemistry, Biology, Physics, Technology and Mathematics	25	7th

The table shows that all participants from this study are experienced teachers according to Shreiner and Dykes (2021) definition, as all of them have more than five years of teaching. Moreover, it can be argued that four of them are highly experienced, as they have been teaching for 25 years or more.

Interviews and transcripts

The interviews were conducted between March the 25th and May the 11th 2022. As stated in the Information letter, teachers could choose whether to have the interviews on-site or online. Four interviews took place at the teacher's school, while two were conducted online using Zoom as the videoconference platform. Each interview took around 45–60 minutes, and all participants agreed to record the audio from the conversations. This process was also followed in the online interviews, so no video recording was generated in this study.

The audio recordings were made using Otter, a software for capturing and recording audio meetings, and which automatically generates written transcriptions of the speeches. The transcripts generated from the interviews were reviewed by checking the accuracy between the audio recordings and the correspondent text and corrected accordingly. The main consideration during the reviewing and transcribing process was to guarantee that the text was readable and coherent for the reader, while ensuring that the meaning of the interviewee's answer remained intact. These comprised the final version of the transcripts and those used for data analysis.

Ethics

Ethical issues for gathering data from people through interviews were considered for this study. These were based on the guidelines recommended by the Swedish Research Council. In this regard, the guidelines conducted through recording were followed for designing this study.

First, potential participants should be informed about the purpose of the research project and the conditions of their participation. This includes an explicit statement about their voluntary participation, and information about how data will be collected, stored, protected and deleted for ensuring confidentiality and anonymity. Second, the researcher must ensure that only authorized persons have access to the recordings, and shall respect the conditions agreed with the participants (Swedish Research Council, 2017). In this research project, these details were provided in the Information letter and the Informed consent (see Appendix 1 – Information letter and Informed consent). The Information letter was sent in the recruiting process.

The Informed consent was also sent during the recruiting process so potential participants were informed about the conditions of the study. It included the option to grant permission for the interview to be audio recorded and transcribed, how data will be managed and anonymized, and the option to decline answering questions or withdraw from the study at any time. For those interested in participating, the informed consent was provided again before the interviews. Thus, the participants had the opportunity to review it and ask questions if needed. Since all participants agreed on recording the audio from the interviews, they were informed when this process was started and ended. After the interviews were finished ant the transcripts completed, the correspondent files and the names of the participants in all quotes were coded to ensure anonymity. Moreover, names of the schools were omitted if they were mentioned.

For RQ2 and RQ3 – Workshop with teachers

A follow-up workshop was conducted to get insights on how the Vislab exhibition can support teacher PL regarding DV literacy. The activity lasted one hour. My supervisor and I organized the workshop. I was the facilitator and lead the activities. My supervisor, whose role at Universeum is as Professor of Pedagogy, supported me on suggesting and reviewing the structure and content of the workshop, as well as organizing the space for conducting it (learning room). During the workshop, she took notes of the activities and helped teachers at the Vislab exhibition.

The aim of this activity was to bring some key points, according to the participants' point of view and expertise as educators, for contributing to design a teacher-training program at Vislab. The workshop consisted of five phases. First, a summary of the key results from the interviews was presented to the teachers. This included the teachers' considerations on DV (what it is), and the skills associated to it. In the following phase, the main discussions around DV in the literature were briefly presented and discussed. The topics focused on:

- Key concepts around DV (data, data literacy, and data visualization literacy)
- Characteristics of the 'new ecosystem of data' and arguments on the need to integrate new approaches to education to be competent within that ecosystem
- Types of data literate citizen according to Wolff et al., (2016).

The first two phases took around 15 minutes. In the third phase, teachers had the opportunity to explore the exhibitions at Vislab. Four questions were raised prior to this activity. The aim was to help them approach the exhibitions at Vislab during their inquiry. The questions were:

- What do students need to know? (core skills to become DV literate)
- What would you like to learn/explore for supporting your students in this process?
- How can Vislab support it?
- How should that training be organized?

The teachers explored freely the exhibition for 20 minutes. No predetermined schedule was programmed for them. However, my supervisor and I were there to provide general guidance, or to answer questions that teachers might have.

In the fourth phase, the six teachers were divided into three groups. The pairs were formed voluntarily. The aim was to do a brainstorming session for discussing the questions raised in the previous phase, and to bring their ideas considering their impressions and experience on the exhibition. We provided *Post-it* blocks and pens to encourage them to write down their insights on each question. After a 10-minutes discussion, each group was encouraged to express their ideas to all participants in the workshop. The main ideas were written down by my supervisor, while I was moderated the discussion. The workshop was closed by wrapping-up the main ideas that were brought, and the *post-it* from each group were collected. This last phase lasted 15 minutes. When the workshop concluded, the participants were given the opportunity to explore Vislab and the rest of Universeum's exhibitions

Process 3. Data analysis

For RQ1 – Thematic analysis

The thematic analysis approach was chosen for analysing data from the interview transcripts, as it allows the identification, analysis and report of patterns (i.e, themes) derived from the data set. A theme represents a patterned response within the data set, which in turn captures important aspects of these data in regards with the research question. Furthermore, the relevance of a theme is not defined in terms of quantifiable measures. Rather, it depends on whether it captures something critical in relation to the research question (Braun & Clarke, 2006). As Braun & Clarke (2006) point out, this means that "more instances do not necessarily mean that the theme itself is more crucial" (p. 10).

A major advantage of the thematic analysis is that it can usefully summarise key features of a large body of data, and offer a wide description of the data set. Similarly, it allows highlighting similarities and differences across the data set. It is helpful for generating unanticipated insights (Braun & Clarke, 2006). These benefits are considered relevant for the present study, as one of the aims is to capture and understand teachers' ideas on DV by conducting interviews.

Defining the type of thematic analysis

Following the criteria for thematic analysis explained by Braun & Clarke (2006), three decisions were made for defining the most appropriate type of analysis for answering the first RQ.

First, it was defined that a rich description of the entire data was needed in order to get a sense of the most important or predominant themes around the research topic. This means this type of analysis is particularly useful in obtaining an accurate representation of the overall data set, as opposed to focusing in providing a detailed account of one particular theme (Braun & Clarke, 2006). Since the focus of the research was not to delve into a specific theme or question within the data set, the rich thematic description approach was chosen.

Second, the patterns within the data set were identified using an inductive or 'bottom up' approach, rather than a deductive or 'top down' one. This means that the identified themes are strongly linked to the data, and so the coding process is not expected to fit into a pre-existing coding frame or the researcher's analytical preconceptions (Braun & Clarke, 2006). Though Braun and Clarke (2006) point out that one associated drawback of this approach is that some depth and complexities are unescapably lost, they also argue it is useful in two situations. One is when the field of study is unclear or under-researched, or when studying populations whose perceptions are still unknown. Given that little is known about how teachers integrate DV in their practice, and about their views and experiences on the topic (Shreiner & Dykes, 2021), the inductive thematic analysis was considered appropriate for providing a framework to interpret data from the interviews.

The third decision dwells on the level at which the themes are to be identified theme (Braun & Clarke, 2006). Braun and Clarke (2006) describe two possible options: an explicit level or an interpretative level. For this study, the latter was chosen. The reason is because it involves a progression from describing the data to interpreting the meanings and implications it, often in relation to previous literature (Braun & Clarke, 2006).

Conducting the thematic analysis

A five-step process was followed for the thematic analysis: 1) familiarization with data; 2) coding the identified features to generate initial patterns; 3) define major themes by reviewing the identified patterns; 4) deciding on a final set of themes; and 5) naming the themes and provide a definition for each one. It is important to note that the process was iterative rather than linear, which meant moving back and forth throughout the phases as needed (Braun & Clarke, 2006; Nasiopoulou et al., 2021). A description of each phase is provided below.

Phase 1. Familiarize with data

An iterative reading of the transcripts from the interviews was made to familiarize with the content and identify features that were potentially interesting (Braun & Clarke, 2006; Nasiopoulou et al., 2021). This process was conducted in two steps. The first round was done parallel to the transcripts review. An understanding of the overall view of the participant derived from this round. In the second round, the final version of the transcripts was read again, so preliminary ideas for the coding and pattern identification across all data set was initiated in this stage.

Phase 2. Generating initial codes

The second phase involved the production of initial codes. The coding process consist of organizing data into meaningful groups regarding the phenomenon. The codes are different from the themes (i.e., units of analysis), which are broader phenomenon (Braun & Clarke, 2006). For this aim, the transcripts were analysed using NVivo 2020: a qualitative data analysis software.

It is important to point out that the aim in this stage was to code the content of the entire data set to provide a rich description of it. Therefore, two considerations were followed: a) coding for as many potential themes/patterns as possible b) individual extracts of data was not limited to a single theme (Braun & Clarke, 2006). However, one theme over many was prioritized, and some extracts were uncoded in the final iteration if it was considered that it fitted better in one specific theme. This process guaranteed that all data was coded for further analysis, and that little context was lost (Braun & Clarke, 2006).

Extracts from one transcript was reviewed with my supervisor in order to have some suggestions on how to proceed with the coding process. This session served as an exercise before doing the process with NVivo. The table in Appendix 3 provides an overview of the framework used for coding. This comprises the codebook generated after analysing the data set in NVivo. Eleven codes or categories were initially identified at this stage. For the final results, eight were kept for answering the RQ. These were reviewed in the following steps for defining the global themes.

Phase 3. Searching for themes and reviewing them

In this stage, the identified patterns in the codes were reviewed to define major themes. In the first iteration, eight groups emerged from the 11 codes that were identified, clustering together those with similar data. The 'Non-DV related topics' code was discarded, as it did not provide information for answering the first RQ. In the second iteration, the eight groups (now subthemes) were discussed with my supervisor, and combined in two overarching themes. Braun and Clarke (2006) point out that this approach allows to demonstrate the hierarchy of meaning within the data.

Phase 4. Naming the themes and provide a definition for each one

The final set of themes was decided by reviewing the theme structure defined in the prior stage. A definition was created for each global theme, and those for the subthemes (created initially for the codes) were reviewed and adapted accordingly. The result from this process is shown in Table 4.

For RQ2 – Synthesis of main ideas from brainstorming session

In the final stage, and immediately after completing the workshop, my supervisor and I reviewed individually the main ideas each one of us captured from the brainstorming session. Afterwards, we presented our notes to each other. In terms of the main ideas captured from the final discussion at the workshop, no disparities were found when comparing the notes. A summary of the ideas is provided in Table 5. The next step was to compile the ideas in one list.

It is important to mention that a brainstorming session was chosen for this phase, as the aim was for teachers to have a 'hands-on' experience at Vislab. Thus, no recordings were held. The advantages and limitations of this approach are examined in the Discussion section.

For RQ3 – Analysis of the findings from the interviews and the brainstorming session

Finally, the findings from the interviews and the main ideas from the brainstorming session were translated into suggestions for the design of a teacher PL programme on DV literacy at Vislab. The PL design elements proposed by Darling-Hammond et al. (2017) were used as the design criteria to which the proposal should adhere.

Findings

The findings derived from the interviews and the follow-up workshop are presented in three sections, related to each research question.

RQ1 – What are in-service teachers' considerations regarding DV?

The first question in the study sought to explore teachers' considerations regarding DV. Two overarching themes emerged from the thematic analysis.

- The first one is the associated concepts and skills regarding DV. In the context of this study, the concepts that teachers used to describe their understanding of DV include different elements for conceptualizing it, the skills associated with it, and students' DV literacy level as perceived by teachers.
- The second theme centres on the practical applications of DV in the classroom, as accounted from participants' experiences. This theme comprises the uses in the classroom, the tools applied to integrate it, the perceived benefits that DV offers to the students, the challenges students face with DV-related tasks, and reports form teachers on how they have learned about DV for their teaching practice.

The themes and subthemes that were identified are presented in Table 4.

Table 4. Description of themes and subthemes identified in the interviews.

Theme and definition	Subtheme	Description
Associated concepts and skills regarding DV. It refers to how teachers understand DV. It includes the associated concepts and skills concerning DV. It answers the question: What does DV mean for teachers?	1.1. DV associated concepts	DV. Ideas that come to mind when asked about the term 'data visualization'.
	1.2. DV-associated skills	Skills students need to use in the classroom for DV-related tasks. It also includes teachers' overall impressions of students' DV literacy level.
Aspects related to the practical applications of DV in the classroom. It reflects the purposes, elements, and situations related to using DV in the classroom. It answers two questions: 1) Why and how is DV applied for your teaching practice? and 2) What elements and situations are involved when applying DV for teaching?	2.1. Uses in the classroom	Reasons to integrate DV in teaching practice.
	2.2. Tools	Digital tools teachers use in the classroom for DV-related tasks.
	2.3. Perceived benefits for students on developing DV literacy	Teachers' perceived value for students to develop DV literacy
	2.4. DV-related challenges faced by students	Main difficulties students face in the classroom with DV-related tasks, and ways teachers help students overcome them.

	2.5. How teacher support students in overcoming DV-related challenges	Methods used by teachers in the classroom to help students in the perceived DV-challenges.
	2.6. Reports from teachers on how they have learned about DV for their teaching practice	Highlights from teachers on ways in which they have learned about DV for their teaching practice.

The following section provides a description of the findings on each theme and subtheme. These were obtained by reviewing the ideas expressed by teachers in the interviews, identifying the main topic from them, and finally, making an interpretation of each topic. Some representative citations are included to exemplify or highlight the findings.

Theme 1. Associated concepts and skills regarding DV

1.1. DV associated concepts

DV is defined by participants in terms of six features: 1) as visual representations (participants mentioned graphs, diagrams, and numbers); 2) as a process (description of the transformation of numbers into visual representations); 3) its associated attributes (dynamic, complex and effective); 4) as a pedagogical method; 5) as the associated events; and, 6) in association with a Swedish icon (Hans Rosling and his work). A description of these topics is provided below.

DV as visual representations and a process

When asked about the first ideas that come to mind around the concept 'data visualization', both TCH02 and TCH04 describe it in terms of visual representations, which included graphs, diagrams, and numbers. In this regard, TCH04 also described it from a process-oriented perspective. In other words, how data is transformed. The comments below illustrate these ideas:

> "Well, I have associated with having long sheets of numbers and someone has transformed them for a graphical representation for diagrams or for well…more, more graphical way easier to understand, like Gapminder for instance, or when you are using colors in order to represent how world temperature is changing. So, that's the kind of things I think of, but I suppose there are many more". (TCH04)

Attributes associated to DV

The participants also described DV in terms of its attributes. A variety of characteristics were expressed, including dynamicity, complexity, and effectivity. The quotes bellow provide examples of these descriptions.

> “The most likely definition is stuff like what Hans Rosling did with his type of data showing. Not only that data is static, but it can also change over time. So, you can see… it's been quite good at having circles moving, representing different things” (TCH05).

> “I think all people understand that there is a lot of data in the society. And you have to condense them to get some picture of what all this data is about. Yeah, the only thing that can do this is some kind of program, because it’s too complex for a human to sort it out. You need some algorithm, you need some program. And then you have to understand how this program is working. And if you don’t understand anything about this, then you can be cheated” (TCH02).

> “[…] a more graphical way, easier to understand, like Gapminder for instance, or when you are using colours in order to represent how the world temperature is changing” (TCH04).

DV as a pedagogical method

Additionally, two participants described DV in terms of how it’s related to teaching and learning. The following quote represents this view.

> “I guess it comes to mind also, that it is a pedagogical way of presenting information. And I think newspapers: they do it a lot these days. And television also, whereas before, they would just like, say facts” (TCH01).

DV in terms of events

Two participants also described DV according to the events they associate with its application in society:

> “I’m mostly thinking right now about the Ukraine, and the crisis, COVID and Hans Rosling” (TCH01).

> “Actually, elections… I guess that's another thing that comes to mind” (TCH05).

DV as associated with an iconic character

Interestingly, half of the of participants mentioned Hans Rosling [2] in their accounts of the main ideas they associate with DV. As explained in the subtheme *2.2. Tools*, the relevance of Hans Rosling and his work was echoed by other participants who use Gapminder resources in their classroom.

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[2] Hans Rosling (1948–2017) was a Swedish physician and statistician who founded the Gapminder Foundation. The organization’s mission is to “fight devastating ignorance with a fact-based worldview everyone can understand” (Gapminder, 2022). Thus, Gapminder provides a set of free tools and teaching material for working with data related to global trends and proportions (e.g., world population, economic growth, and global warming, among others).

> “Obviously, I did read his [Hans Roslings’] book *Factfulness* in English, and I saw some of his online talks, I think a TED talk. So that’s what comes to mind. Him and his work” (TCH01).

> “The most likely definition is stuff like what Hans Rosling did with his type of data showing” (TCH05).

> “I think about Hans Rosling. Visualization of data concerning World Health. Yeah. Because that made an impact. And it I’ve been using that tool” (TCH06).

1.2. DV-associated skills

The DV-skills that participants consider as fundamental for students to develop can be grouped in two categories. One is critical thinking for finding and assessing resources, which was also identified as one of the main challenges that students face. The other is skills for data processing. These include being proficient at collecting, transforming, and using data, especially large and complex data sets. Finally, four participants explicitly expressed that even though they see diverse abilities among students, their impressions on their DV-literacy level are positive. They highlighted that students’ strengths are related to programming and creating appealing visualizations.

Critical thinking

Issues related to DV skills were particularly prominent in the interviews with teachers. In other words, their explanations of how they integrate it in the classroom, and the experiences of students with DV, were primarily expressed in terms of abilities. A common view amongst all teachers was that critical thinking for finding and assessing sources is core skills students need to develop when performing DV-related tasks. In the same vein, all teachers agree that this represented the greatest challenge for students. The comments below illustrate this view:

> “We as teachers and grownups. Everyone needs to be more cautious about fact checking. And visualizations need to take care of that as well, because you put a lot of data. And how can we know that the data, that’s put into the visualization, is fact checked?” (TCH04).

> “First, they need to be sceptic. And I think that the kids of today […] they’ve grown up with the internet, and they know that everything is not true. But still, they say: ‘Well, the page: it looked so professional! So, it looks good’. […] So, I think, just to teach them not to just make it easy for themselves, to go the extra mile, to check the facts. What’s the purpose of this site?” (TCH06).

Data processing

Other skills associated with DV were related to data processing (i.e, collect, transform, and use data). In this regard, TCH05 expressed:

> "I think I was hoping that it would be good to make the students, together, generate quite a big data set. So they can get a feel for how to organize it. I have one exercise for them when it comes to gathering data" (TCH05).

It is interesting to note that these comments echoed that from TCH02 when describing DV in terms of its attributes. That is, the complexity of understanding and handling large data sets. This suggest that teachers recognize the benefits and the need to integrate these activities in the classroom.

Students' DV literacy as perceived by teachers

A common view amongst participants was that DV abilities among students varied, but overall, they consider them to be proficient with DV. However, they also pointed out some related challenges, as will be further discussed in section *2.4. DV-related challenges faced by students*. The comments below illustrate this view:

> "I think they're very, very good. Yeah, of course, there's a range. But the average student, there are very, very, very good. And the ones that are in the top are really good" (TCH02).
>
> "Well, I think they are rather good. But, in my subject, Mathematics, you know, they are not going out to the search for information. I think that's more […] with religion, or something like that. What is right? How do you know these sources are trustworthy? That's a big challenge" (TCH03).

It interesting to note that three participants were unanimous in the view that students were highly proficient in programming and creating visualizations. The comments below are representative of this view.

> "In average is higher than mine. But again […] in some levels, I guess some guys can do very advanced programming. And we have a gaming club, and they can like, create their own games or narratives, within the game. And I'm like: ok, what exactly are you doing? I have no idea" (TCH01).
>
> "[…] that was when they were programming. And they were programming games. And I was just blown away. They were so good, and so complex, and at a very high level. That was amazing. And also, when they were making models in 3D. Oh! Some of them were just so good at it. It just comes so natural to them" (TCH06).

Theme 2. Aspects related to DV in the teaching practice

2.1. Uses in the classroom

Practical applications of DV in the classroom can be grouped in three categories. The first is for *facilitating the development data-related skills*. Participants emphasized abilities for collecting, transforming, and interpret data. Similarly, teaching students about data-lifecycle was considered important by two teachers. The tools and methods used for this purpose is programming and collecting data from the environment with sensors. The other application focused on the use of DV for enhancing the learning experience in the classroom. These included the integration of DV tools, like simulators, for complementing on-site, experiential activities (e.g., gravity in Physics, or molecule's structure in Chemistry). Another application was the use of DV for engaging students in the classroom by encouraging a readiness to learn.

DV for teaching data transformation and data-lifecycle

First, teachers described using DV for facilitating students to develop specific data skills. In this regard, three participants (TCH02, TCH04 and TCH05) emphasized those for collecting, transforming, and interpreting data. The comments below describe some activities teachers have conducted for this aim:

> "I gave them an assignment to go out and measure sound levels in the area where they normally are. So, they were on the trams, and in traffic sites, and they collected the data of the decibel measurement. And they really enjoyed that. And we tried to put it together: where did the different sound levels were high and low, and what you could do about it" (TCH04).

Likewise, this approach served the purpose of working on a multisubject project focused on learning about data-life cycle. When describing the initiative, two teachers commented:

> "Our idea is to end this semester with the project: you're going to follow some subjects from raw data and the basic science, to publications, to when it goes into public media and continue to YouTube and TikTok. I think that this IPCC reports and what comes out from them could be a really interesting subject to study. Because […] there is a lot of data and a lot of data visualization, and there's so many opinions. (TCH02)

> "He wants us to do a project called "From the research report to your tape", saying how this scientific paper first published –perhaps in nature or Scientific American–, how does this kind of "travels" to a very short, funny video clip (TCH01).

DV for enhancing the learning experience

Simulators to encourage experiential learning

The second approach includes the use of simulators for allowing experiential learning. Examples include the simulation of natural phenomena in subjects like physics, chemistry, and biology. In this view, the most striking observation from both teachers was that it is the combination of simulation tools with on-site experiences in the classroom what helped students learn and engage. In other words, combining digital tools for DV with experiences that involve on-site, physical experiences. Two citations represent this notion:

> "In organic chemistry, it's the way I quite often make them build the molecules that we talk about. So, you get sort of a feeling for the relation in between not just drawing them on paper, but also

> feeling them. […] If you try to use these nice apps, where you can actually suspend things in three dimensions, which is nice. But it's even nicer if you build it because then you get a feeling for how big it is, how hard is it to put pieces all rather than something that's fixed on this screen" (TCH05).

> "So, I would say the PhET simulations have been really useful for teacher to ask: 'what if'? Because the students can test. But we usually… we go to the playground first, because they have to use their body, to experience it. So, we spent a lot of time in physics classes by going to the playground" (TCH04).

DV to encourage readiness to learn

Finally, DV was reported to be used for fostering a positive mindset in students to catch their attention. When explaining it, TCH04 said:

> "If I take care of choosing visualizations, I can get them into a mood quite fast in order to start a class, in order to collect their focus" (TCH04).

2.2. Tools

Six different types of DV-tools were reported by teachers. These can be grouped into three categories, according to the pedagogical purpose in the classroom. The first is tools for teaching data transformation and use. This group includes platforms for analysing global issues (e.g., demographic, global temperature), simulators, and 3D modelling. The second group also addresses this purpose but allows students to collect data and generate their own datasets. Tools in this group include programming languages and software for statistical analysis (in this case, Excel). The final group is related with image visualization. The tools included image search engines and tools for presenting content with images. This included videos and presentation programs, like PowerPoint. Even though these tools are more related to presenting general information. rather than quantitative data, it is important to note that for some teachers working with images is included in the notion of DV literacy.

Tools for teaching DV

Teachers reported the application of different DV digital tools for teaching. Six categories were found: 1) tools for analysing global issues (e.g., demographic, livelihoods); 2) simulators; 3) tools for 3D modelling; 4) programming languages; 5) image search engines; 6) tools for content presentation; and 7) tools for statistical analysis. An overview of these tools is provided in Figure 3.

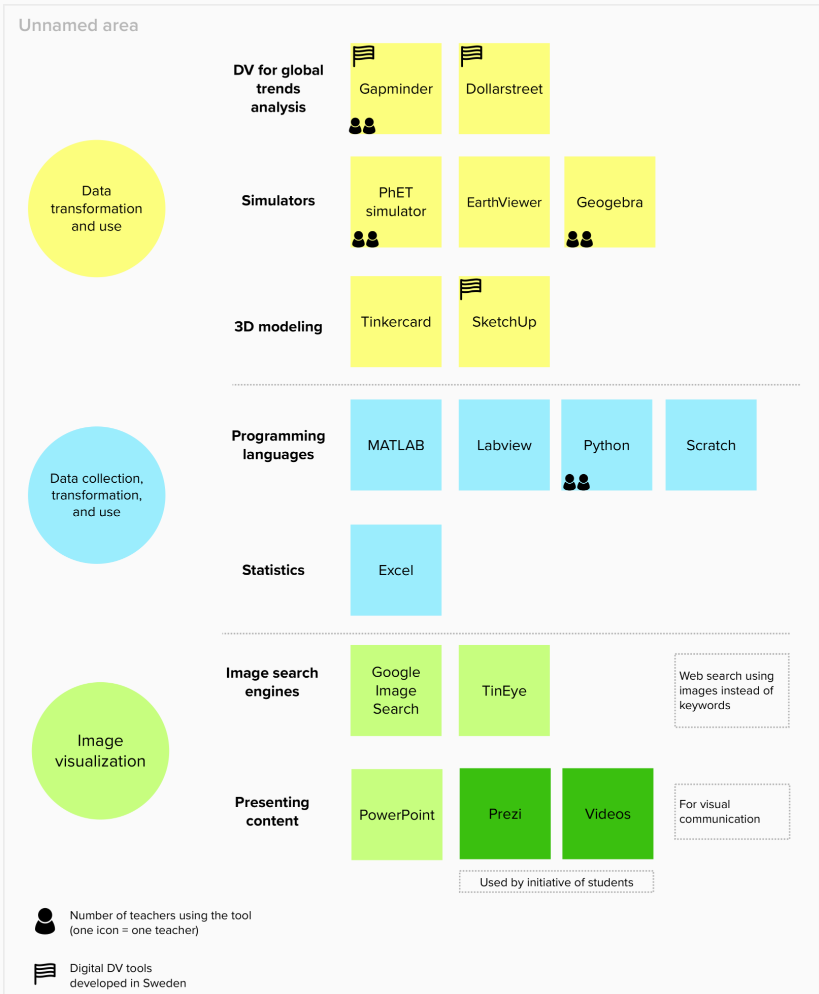

Figure 3. Digital DV tools used by teachers.

Closer inspection to Figure 3 reveals two interesting aspects. One is that most of the tools mentioned by teachers are meant for working with data sets provided by the correspondent platform. This means that the tool is not designed for a user to bring his/her own data sets, and use the tool to visualize them. The exceptions were Excel and programming languages. In this regard, one teacher highlighted the importance of integrating tools that allow students to work with large and complex data sets:

> "But as I said, until maybe two years ago, […] we just collected data for… maybe up to 1000 data points, and then you do some regression somewhere […] I mean there are so many tools and the basic tools that everyone use are Excel or Google Sheets […] It's hard to work with the data to really get what you want, but it's a good start" (TCH02).

Another intriguing aspect regarding DV-tools used by teachers is that working with images is included in the notion of data visualization literacy. Two visualization tasks that involved images were raised. One is the use of presentation programs (PowerPoint and Prezi) and videos for presenting information visually. In this regard, it is interesting to note that the latter two are tools used by students' initiative. The other task is web searching by using images [3] instead of keywords. The use of images to better understand data, and the ease to recognize what data is behind images, were found to be an important element when working with data visualizations. As TCH04 teacher puts it:

> "They also have an excellent site called Dollar Street, where students can compare how people live all around the world. So, what kind of toothbrushes are being used? How the toilets look like? I mean, it's quite close to their own world. So, it was actually that site I was thinking about when I wanted to have the students in a special mode for teaching, because if you have a picture into the kitchen of someone on the other side of the world, then you immediately transfer your mind to that kind of environment" (TCH04).

Interestingly, TCH06 also alluded to this notion, when elaborating on her impressions of her students' experience during the pilot test at Vislab:

> "[…] I think that the pictures helped a lot to make them interested, and if there wouldn't have been pictures, I don't think they would have been so interested in this. Because that really made them think and: 'oh, look at that! Let's see'. So that was a good move. To catch them and reel them in […]. So, I think when you combine physical models or pictures with this, it's like an enhanced reality. That really works well. Better than if it's just a screen" (TCH06).

It is important to note that the two aforementioned topics were also mentioned in the follow-up workshop at Vislab. These are: 1) the interest in bringing opportunities for students to work with their own datasets, and 2) the importance of recognizing the data behind images. A more detailed description will be provided in the second section of this chapter.

2.3. Perceived benefits for students on developing DV literacy

Overall, teachers' views indicate that they value DV for their teaching practice, as it provides benefits for their students in two spheres. One is that it supports their learning experience. The other is related to how properly understanding data visualizations can support students' critical thinking. Although the latter is described in terms of the difficulties to correctly understand the visualizations, it is included in this subtheme since during the interviews the teachers exemplified the benefits of DV by explaining the risks that the lack these skills presents for students. The examples included the importance of DV skills for making informed decisions and for becoming active members of society.

DV can enhance students' learning experience

In this case, TCH04 reported that DV can help students to focus. The comment below illustrates this view:

[3] Dollar Street, reported both by TCH04 and TCH06, is a tool that shows images from families around the world. Since it is possible to filter different topics (e.g., food, kitchens, house overview, among others), the tool allows to see 'who is behind these data'.

> "I think it can help them get a shortcut. Because there's so much information in the picture… you can embrace it in a very short time. If you have to go through a long time, figures or numbers, then you really have to concentrate quite a lot, and you can get lost. I mean, the cognitive load can be huge, and you can be distracted from other things. But if you have a picture –and the picture could a graph– […] and if the picture is well done, then the information is conveyed" (TCH04).

Commenting on this issue, TCH04 expressed the relevance of using DV with teenagers:

> "And if you are young, you don't have the patience to wait and read all information. You want to have it immediately. So, I think it works really well with teenagers, to work with pictures, because you're also getting them into a mood. The picture just not convey a sense of fact, it also conveys values […] And the same thing with data. What kind of data you choose to visualize: is not an objective. You always have an intention. So, it's a lot of power. You show a lot of power by what kind of visualizations you're making" (TCH04).

Properly understanding DV can foster critical thinking

This perceived benefit alluded to notion that DV allowed students to be critical when interpreting data. Thus, it helps them become citizens who make informed decisions. Interestingly, this view was shared by all participants when discussing DV-skills related topics. The comments below illustrate this view:

> "But scientific journal is normally more reliable than other sources. Other sources can be okay, but you have to teach them to be critical. […] For instance, that looks nice […] it's beautifully visualized, and you can see sort of all the things linked together. It may not be true" (TCH05).

> "[…] Because if you only see colourful pictures: it looks nice. […] But to really understand the data behind it, that's something that is very difficult, especially today, when you when you have this big flow of media. There's a lot of data behind. And how is that data looking? And how do you extract those data?" (TCH02).

Talking about this issue, TCH06 explained how developing critical thinking was crucial for making choices and be a part of current society:

> "I think if you don't understand the data, you won't be able to make choices that really reflect what you want to do. Because if you don't understand the data, you can't make a well educated choice. So, I think today, more than ever, you need to know what different choices there are, what the consequences are, and what goes on, and how it changes in the environment. And globally, if you don't understand the data, you're just not part of society" (TCH06).

Comments from TCH02 and TCH06 provide important insights into the relevance of DV literacy as a tool for navigating situations in current society. In this regard, the comments from participants seem to point out some aspects of media and current society: a big flow of information, and the responsibilities or expectations that come along with being a global citizen.

2.4. DV-related challenges faced by students

The comments presented on this section suggest that teachers perceive DV literacy as a set of skills, associated with different stages of the data life cycle. In this spectrum, teachers seem to agree that the main challenge for students is finding and assessing sources. In other words, to be sceptic about the sources they look up for or encounter. Three other challenges were raised. One of them is communicating by using DV. Interestingly, three teachers agree that even though they consider that students are proficient at making appealing visualizations, they often struggle to build it upon reliable data. Another challenge was related to interpreting information in a digital environment. Overall, comments suggest that a highly digital and visually saturated environment allows information to be accessible fast, in "bite-size" portions, and visually appealing. In the same vein, two teachers expressed that games and simulators can help students learn, but will only work if they are given guidance on how to use these tools. Finally, one teacher considered that working with large data sets poses a challenge both for students and teachers, since other skills, such as programming, are required to make sense of it.

Challenges for finding and assessing resources

Even though all teachers alluded to this challenge, three explicitly expose it as one of the main ones their students face. A variety of perspectives were expressed, but two participants seem to agree that students are proficient at creating visualizations, but lack the abilities to assess the reliability of resources. The comments from TCH01 and TCH05 exemplify this view:

> "They would not find the best sources. So that kind of literacy is not as advanced as some other literacies. They how to maybe do programming, but not find the relevant source" (TCH01).

> "They are good at visualizing data, but the quality of the data is not always there. So, it may look good. I mean they use the right colours, the fonts are easy to read and everything, but then, the actual data isn't good. They know how it should look like to be easy to read in most cases" (TCH05).

Likewise, when commenting about this challenge, TCH03 pointed out the difficulty that both high school students and adults have in questioning ones' own knowledge:

> "Students, like adults, you know, they want to believe what they have decided [...] You know… I've already decided, and then you won't listen to the arguments from the scientists. Maybe you want to listen to the people that are saying what do you want to hear?" (TCH03).

This view was echoed by TCH05, who elaborated on why we trust sources based on narratives that are familiar to oneself:

> "[…] And I think that's quite similar to all of us: when we go out on the internet, or when we find sources that we trust. Why do you trust that source? Is, well, because it tells you a story which is familiar to you, which you can relate to. If you encounter a source which is not familiar to you,

> and you don’t really understand it completely, you may stay away from it. Even though it might be correct. […] And we’re all guilty of that” (TCH05).

It is interesting to note that two teachers agree that finding and assessing resources is a challenge both for youngsters and adults. Therefore, these comments seem to reflect the importance of DV in settings beyond the classroom.

Challenges for communicating using DV

Another perceived challenge was communicating information by using visualizations. When discussing this issue, TCH01 and TCH06 expressed:

> “Because, that’s not just like being good at creating something smart and creative in the computer, but it’s about getting the message across to you. That is something you can learn, obviously, and it takes time to learn” (TCH01)

> “I think it goes… the extra mile. And just make them understand that their actions, what they share, what they spread, matters. Because even if they think they understand how it works, they don’t. So, if you share this picture, what could the consequences be?” (TCH06).

Challenges interpreting information in a digital environment

Concerns were expressed about students struggling reading long texts as a result of living in a highly digital environment, in which visuals play a significant role. Commenting on this topic, TCH01 explained:

> [...] we want to force them to do the good, old-fashioned reading as well. Yes. Not just look at short, fun video clips. Because they do tend to get into that as well. Because they’re so good at explaining things in a fast way. Right? (TCH01)

This concern was also raised by TCH04, who expressed:

> “[…] students are not so able to read long texts anymore. They want the shortcut. The visualization is really important, but you cannot jump over that text. So, we spend a lot of time with a text, together. You see, because usually when I had those students, 13 years old, they used to be better at reading […] It’s not about a particular… it’s about everyone, actually. So, I think it’s a trend not only in Sweden, as well, but we are living in a quite visual environment” (TCH04).

Moreover, three teachers commented about the challenges associated with the use of simulators in the classroom. Whilst acknowledging the benefits of these tools, they also pointed out that games or simulators do not necessarily support learning if students lack a proper guidance or purposeful use. The following comments illustrate this view:

> “I mean, you can play around with things and nothing really… It doesn’t give you anything, because you don’t know what you’re doing” (TCH05)

> […] earlier I said that the phones and computers distract them, but it has also made them very used to interpret visual data or simulations. So, I think it makes it easier for them, but often, the kind of games and what they're playing… is not at all that they develop an understanding for important things. So, most of the games, I think, are just numbing" (TCH06).

Challenge of working with large data sets

The difficulties associated with handling big and complex data sets, as opposed of doing so with simple and small ones, were also raised. Talking about this issue, TCH02 explained:

> "I think it's a big challenge. And I'm not I'm not sure. The problem is… all students can understand a simple *xy* graph, with 10 points, and some kind of regression. It seems intuitive. But when you have a lot of data, you usually don't see the data. The data is maybe a modified form. And you only see part of it, because it's so vast" (TCH02).

Interestingly, TCH02 also expressed that, for teaching science subjects, it is important to include big data. Thus, this expectation or requirement poses challenge both for students and for teachers.

2.5. Ways of supporting students to overcome DV-related challenges

Two themes arose when discussing about the methods teachers use to assist their students in overcoming the challenges associated with DV. When it comes to assessing sources, and sharing DV-related information, four teachers share the view that discussions around critical thinking were mainly used. As for helping students in working with simulators and large data sets, the reported activities seem to focus on making students active agents in their learning. These activities include: 1) providing guidance on using simulators, so students can further explore, experiment and make decisions; and 2) encourage them collect and plot their own data sets around topics that are familiar to them.

Discussing in class on ways to assess resources and share information

Four teachers highlighted that engaging students in this discussion was consider fundamental to support them in developing searching and fact-checking skills. The topics included: foster critical thinking when reading information, questioning the data behind the visualization, how to identify fake news, understand the ethics, and the implications of sharing information in social media. For assessing sources, TCH01, TCH03, TCH04 and THC05 share a similar approach. The comments below provide examples of this strategy:

> "Just talking about it all the time. And, you know, give good examples for right sources. This organization: you can trust" (TCH03).

> "Well, the traditional ways I would say. When you go on the website, your check for who's the creator and the editor. And we see there: can we trust them? When we go to images, I usually do like image searches to see: what kind of timestamps can we see on the image? Was it published before? Is it used in totally new circumstances?" (TCH04).

Support for working with data and/or using digital tools for that aim

Different approaches were explained in this topic. As for using simulators for DV, TCH05 explained:

> "I think they need the basics before they start. And then, you sort of need them to go through a set of operations. So, you show that they know what they're doing, and they can see that they get the expected results. And after that, if they want to try something different, sort of 'outside the box', that's fine. But if you don't know where that box is to start with, you don't know if you're inside or outside the box" (TCH05).

Moreover, TCH02 and TCH06 explained some activities they have conducted for engaging students in using digital tools for DV and working with large data sets:

> "It's hard, but this autumn, I did a project where I used data from Spotify, since all students use Spotify: more or less 99%, at least. So, all the students picked a number of songs, […] and students must select a few 100 songs […]. And then we try to do some simple artificial intelligence algorithm to see if you could do a program to see what kind of genre the song was. And it worked! […] But I think they thought: Oh, interesting! Because they see all this big data as just a lot of numbers. And they could see that this is really this is a rock song" (TCH02)

> "We've tried to visualize this PhET Lab to simulate different experiments and things you can't really do. And I've also tried to make it more local to them, because sometimes they care more if it's about your surroundings, than if it's just for the whole world. And they've made their own investigations and plotting their own data: that also makes it more interesting" (TCH06).

2.6. How teachers have learned about DV for their teaching practice

Three broad topics emerged when discussing teacher PL regarding DV. Firstly, two participants described the conditions that have characterized this process. On the one hand, the five STEM teachers reported that they have learned about this topic across their career, highlighting their teacher education or their background as researchers. However, none of them reported having a specific, formal training on integrating DV in their teaching practice. Secondly, three participants explicitly expressed that learning at the workplace has been an important element for integrating DV in the classroom. This includes learning both from colleagues (by collaborating and sharing information, methods, and tools); and from students (by delving into unknown topics together and being motivated to learn further as a result of their inquiries). Finally, two participants pointed out the that learning DV-skills was necessary for teachers to improve their practice. Programming for understanding data visualizations, and using visualizations to engage students, were provided as examples of this view.

Where teachers have learned DV-related skills

STEM teachers reported this skill has been learned across their career, highlighting their teacher education (in higher education) or their background as researchers. However, none of the participants reported having a specific training (i.e., a formal course) focused on using DV for teaching. This was the case of TCH02, TCH04, TCH05 and TCH06. For instance, TCH02 and TCH04 describe their experience in this regard:

> "I really don't know how. I mean, with my background research… to visualize your data. That's what you do. But I have not reflected that side. And I don't know where I learned it. It's also a skill that takes a lot of time. And I have never heard of teachers taking a course in data visualization" (TCH02).

> "No, I've just had it when I studied to become a Math teacher, they showed us different tools, which was very good. Because it's difficult to find them. Oh! I think we have had that kind of… we show each other? We've had a few of those days. And we show: 'this is a good one, you should try it'. Yeah. But then, it's difficult to really find the time to explore it and learn it yourself (TCH04).

Informal workplace learning

Learning at the workplace (i.e., the school) was mentioned by all participants. Interestingly, examples include learning from colleagues (peer learning) and from students. The following comments illustrate these views:

> "There's always some… you hear somebody: 'oh, last year I tried to have my Mathematic course in the computer'. 'Oh, you did? How? Is it working? I can try it!'. We talk a lot about what is your experience with that. Yeah. So, we're sharing tools. I think it's more fun when you really feel you are a part of the group that is working together. (TCH03).

> "[colleagues name] has taught me a lot, since she's a teacher for teachers. She is very into the latest… she's very, very updated in that area. I'm new" (TCH04).

Two teachers reported having learned DV-related knowledge from their interactions with students. As TCH04 and TCH05 put it:

> "No, I think the computers have changed that a lot. Because earlier, I was the one who was supposed to have all the answers. But now we can find out together. And I really enjoy that. Yeah. I don't have all the answers. I don't know. We have to find out. So, I think it's a good thing that has changed" (TCH04).

> "Questions from students, mostly, I would say. Because they can challenge you. They can ask you things… and you sit down and figure out: how can I show that? Is there a way I can visualize this as an experiment? Because if they ask you something, and it's something you don't explain properly… it needs better visualization" (TCH05).

However, one participant pointed out one that trying to fit training in their schedule might be a challenge for teachers:

> "But I think one of the big challenges in school is to have the time to do this in a proper way, because we have so many things we have to do" (TCH01).

DV-skills educators need to improve their teaching practice

Two participants shared their perceptions about the DV skills they consider important for educators to develop. On the one hand, TCH02 pointed out the need to develop programming skills to be able to integrate big and complex data sets in any subject:

> "And it's particularly hard to involve the teachers… the language teachers, social science teachers. But the data visualization is something that they understand, […] and that could be a really good connection to use. But then data visualization would be to make everyone understand why programming skills are important" (TCH02).

On the other hand, TCH06 alluded to the notion of developing DV-skills to engage students, as described in the subtheme *2.1. Uses in the classroom.*

RQ2 – How can Vislab support in-service teacher PL regarding DV literacy?

Follow-up workshop at Vislab

The table below presents the topics brought by teachers in the discussion during the workshop at Vislab, and the summary of the suggestions that emerged from each topic.

Table 5. Compilation of ideas from teachers at follow-up workshop.

Question	Topic that emerged	Summary of suggestions
Q2. What would you like to learn/explore for supporting your students in developing DV literacy?	Develop DV literacy skills as a teacher.	**Teachers' training** Provide DV course Teachers' training at Vislab focused on DV for teaching practice.
Q3. How can Vislab support this process?	Development of a teachers' guide for the Vislab exhibition, by Universeum.	**Guides for teachers** Vislab guides designed for teachers. This can help teachers to learn how to approach the exhibition, and the possibilities it can provide.
	Provide guidance (by Universeum staff) before, during, and after the experience at Vislab. That is, not only limited to the visit to the exhibition.	**Activities organization and structure**

	More interactive structure for students when visiting Vislab (*comment from teacher who participated in the first pilot test at Vislab*).	Recommendations for enhancing the learning experience at Vislab (both for teachers and students). Recommendations for structuring the visit at Vislab.
Q4. How should that training be organized?	Format: formal training Opportunity to explore the exhibition before conducting the visit with students.	**Teachers' training** Format: formal training Include time to explore and understand the exhibition.

As Table 5 shows, the topics that dominated the discussion revolved around the last three guide questions. Few comments were about students' core skills to improve their DV skills. Instead, students' learning needs were discussed in terms of the experience at Vislab (i.e., suggestions about the structure of the activities), rather than specific knowledge or content they should acquire. Finally, the topics brought by teachers –presented in the table above– were grouped in three categories. The suggestions made by teachers were then analysed and interpreted as elements to be considered in designing a DV-teacher PL learning programme at Vislab, as explained in the following section.

According to participants' suggestions, there seems to be three topics that Vislab can consider for supporting teacher PL on DV.

1. **Provide formal training on DV**. The preferred format is formal. It should support teachers in developing DV skills, and understanding how to integrate it in their teaching practice.
2. **Create guides for teachers**. Vislab guides designed for teachers. This can help teachers to learn how to approach the exhibition, and the possibilities it can provide. For instance, to understand each module of the exhibition, or how DV and the exhibition can be related to the Sustainable Development Goals.
3. **Provide guidance and support with activities during the whole experience**. Refers to suggested activities for improving the learning at Vislab. It includes: 1) providing guidance before, during, and after the visit to the exhibition; 2) and structuring the visit in more interactive way.

RQ3 – What are the key elements for designing an effective in-service teacher PL programme regarding DV literacy in a science centre?

The discussion on how the findings from the interviews and the main indeas from the brainstorming session are related to the design elements proposed in the *Effective teacher PL model,* by Darling-Hammond et al. (2017), is presented in the following chapter.

Analysis of results and Discussion

This chapter is divided into five sections. The first trhee sections present an analysis and discussion of the findings of each research question. The fourht section discusses how the findings could contribute to the existing knowledge on teachers' DV literacy training. The fourht section discusses the limitations of the study, and the fifth and final one provides suggestions for future research.

RQ1. What are in-service teachers' considerations regarding DV (associated concepts, perceived value for their teaching, challenges for their students)?

Teachers' considerations regarding DV involved two main themes: associated concepts and skills regarding DV (i.e., how is conceptualized), and aspects related to DV in the teaching practice. For this study, participants' understanding of DV and their related experiences with it in the classroom were analysed from a teacher PL perspective. That is, by inquiring about their students' learning needs in order to explore their reflections regarding their own learning needs for their profession.

How do teachers understand DV?

It was found that participants' conceptualization of DV included elements of both IV and DV, according to the definitions suggested by Kim et al. (2016). However, it is important to point out that the distinction between these terms was not profoundly discussed during the interviews with participants. Therefore, a deeper inquiry into this topic might have revealed different views. Interestingly, the elements related to IV seemed to dominate teachers' descriptions. The features related to processing and displaying numeral or statistical data (DV) were: DV as visual representations, such as graphs, diagrams, and numbers; and DV as a process of transforming numbers into visual representations. The features that were more in line with IV were: the associated attributes (dynamic, complex, and effective), DV as a pedagogical method (e.g., to evoke emotions, capture students' attention), associated events (how information is displayed in news by using visualization). Thus, consistent with the literature, this research found that teachers' concepts on DV support the idea that IV and DV are often seen as similar domains (Kim et al., 2016). Nevertheless, it is important to note that this distinction seem very clear for some participants when describing their accounts of how they use DV in the classroom.

Moreover, a theme predominantly present in teachers' description of their ideas on DV was Hans Rosling and his work on. Some factors may contribute to the relevance of this idea for the participants. One of the most important is that he was Swedish doctor and became famous worldwide by offering speeches and TED-Talks in which he advocated for the use of data to investigate global issues. Timing-related factors may also explain this relevance. These include the fact that Rosling recently passed away (in 2016), and statistics were frequently used in media and relevant to the general public during the Covid-19 pandemic that started in 2020. Therefore, the relevance of this topic could be considered as an important element of a teacher PL design at Vislab, as it will be discussed in the following section.

As for the DV-associated skills, participants expressed those that they consider crucial for students to develop where critical thinking for finding and assessing sources, and skills for data processing. Comparison of these results with the literature on DV literacy and the skills that constitute it, suggests that participants describe DV-skills in a broader perspective that reflect the abilities necessary to handle both types of data: either abstract and non-spatial, as well as numerical or statistical inputs. Even though examples of both IV and DV representations were mentioned by all participants throughout the interviews, we did not dive in specific cognitive tasks associated with certain visualizations and datasets. For instance, the task of finding correlations in a scatterplot. Therefore, the eight associated cognitive tasks that are included in Lee et al. (2017) Visualization Literacy Assessment Test were not explicitly reflected in participants' ideas. However, this finding was expected, as the questions during the interviews were focused on inquiring about the overall students' learning needs from the teacher perspective, rather than focusing on students' experience in working with specific DV representations.

Moreover, the DV-skills that were brought by teachers do reflect the five key process steps involved in DV construction and interpretation proposed by Börner et al. (2019). These steps are: data collection, analysis, visualization, deployment and interpretation. It is interesting to note that the alignment with these steps also reflect teachers' accounts of students not only as users or consumers of data visualizations, but also as producers of those representations. This view was reflected in two ideas that were brought by teachers. One was raised by highlights of the importance of students gathering data to build their own data sets, and their strength in creating appealing data visualizations. Interestingly, this finding supports the work of Wise (2020), who notes that the line between what data scientist and data literate citizens should know is narrowing. For instance, comments from all teachers reflected their concern of how data can manipulate students' views and decision-making. This unanimous view supports Wise (2020) ideas on the need for citizens to develop the data literacies to understand, question and problematize the processes of generating, analysing, and using data: skills that were previously regarded mainly to data scientist.

The need to develop programming skills for handling big and complex data sets was also raised by two teachers. These results seem to be in agreement with observations in other studies regarding the unique characteristics of data in the current society. This means that, on the one hand, larger and complex data sets require new computational tools –and skills–, to analyse them (Wise, 2020; Wolff et al., 2016). On the other hand, data is now open to the scrutiny of those with many different types of expertise –not exclusive to scientist or experts– (Wise, 2020). The accounts on activities they did in the classroom to engage students in collecting data using digital tools, and using programming skills to analyse data collected from online platforms reflect this view.

Finally, teachers seem to agree that, despite seeing a range of DV skills among students, they had a positive assessment of their students' level of DV literacy. In this regard, programming skills, creating appealing visualizations (such as posters and videos) and 3D models using online tools were highlighted by three teachers as the strongest DV abilities of students. Interestingly enough, this seems to suggest that teachers see a blurry line between digital skills, DV skills and IV skills. This view, therefore, also supports the IV definition proposed by Kim et al. (2016), in which representations of information refer specifically to those that interactive and computer-generated. This finding also reveals the key role that digital tools play for teachers' experience when teaching DV in the classroom, especially when working with large and complex data sets that requires new computational tools for their analysis (e.g., programming languages) (Wise, 2020).

Interestingly, teachers' accounts on their impression of students' DV literacy level prompted reflections in their own level. From a teacher PL perspective, this finding supports the idea that teacher learning is motivated by reflecting on their own teaching in the school context, and that it is mainly driven to support students' learning (Postholm, 2012; Timperley et al., 2007). For instance, one participant suggested the need for teachers of any subject, to develop basic programming skills. Two other participants mentioned that they considered their students to be more proficient in using digital tools for creating visual representations than them. Even though these representations were more related to those of IV, the comments were relevant in the sense that they reflect an interesting relationship of students-teachers. For instance, in the context of DV, how teachers can learn not only from colleagues or through formal training, but also from their students. This finding has important implications for designing teacher PL programmes, as will be discussed in the next section.

What are teachers' experiences with DV in the classroom?

Concerning the aspects related to DV in the teaching practice (second theme), another important finding was regarding the similarities and differences of participants' accounts with findings from previous studies about teachers' beliefs and experiences on DV. This included three major topics: teachers' perceived value of DV, challenges that students face when learning DV, and teachers' reflections on how they have learned about DV for their teaching practice.

Teachers' views on the perceived value of DV for their students

Regarding participants' ideas and experiences of integrating DV in their teaching practice, the most obvious finding to emerge from the analysis is that accounts from all teachers reflect a positive view and experience with DV in this regard. Most importantly, it was found that all teachers involved in this study agreed on the view that DV is a crucial skill to teach, and one that benefit students. This outcome differs to that of Shreiner and Dykes (2021), who found that only 58% of all participants considered that DV was an important skill to teach.

There are several reasons that may explain participants' positive attitude towards DV. The most important to consider is the recruitment base I used for this study. All teachers that agreed in participating in the study had already an interest in DV-related topics, since all of them were contacted through a list of teachers who expressed an interest in taking part in Vislab and STEM education pilot experiments. Other factors may have also played a role in the positive views of teachers towards DV. One of them is access to resources to teach DV. All teachers showed they have knowledge and/or access to these tools. Most importantly, none of the participants reported feeling limited by lack of access to digital tools to teach about DV. In fact, four STEM teachers expressed that they have to decide, among all available options, which online resources they integrate in the classroom to master them and take the most out of them. This finding is different Shreiner and Dykes (2021) study, who suggested that one reason why educators may view DV as unimportant was that they considered there are not enough resources to teach DV: only 62% of participants reported the have access to online tools for this purpose. Moreover, 56% agreed that, if given more resources, they would teach more DV-related tasks.

Furthermore, participants' knowledge and familiarity with Hans Rosling and his work might have also influenced their positive view of DV. His relevance to all participants' view on DV may be to various factors: same cultural background, the focus of his work (facilitating fact-based knowledge everyone could understand), free access to teaching material and tools that his foundation provides, and the multiple ways to know about his work (a book, free online tools, a TED talk available in YouTube). Therefore, this suggests that it is an important reference for both experts and non-experts on the field. This is an interesting aspect to consider when designing teacher PL programmes on DV, as will be discussed in the following section.

In sum, all participants from this study agree that DV was valuable for their teaching practice and for their students. It is encouraging to compare this finding with the reviewed literature, which highlights that DV literacy is an important skill that students should develop throughout their education (Börner et al., 2019; Kdra, 2018; Lee et al., 2017; Shreiner & Dykes, 2021; Wolff et al., 2016). The factors that may contribute to this view is a resourceful environment which offers access to online tools to teach and integrate DV, a perceived positive experience in integrating DV in the classroom, both for students and teachers. From a teacher PL perspective, this finding has important implications. First, because it represents the starting point of teacher PL: if educators recognize it as a learning need of their students, it can motivate teachers to reflect and define what they need to learn to support their students in achieving this goal (Timperley et al., 2007). Second, this finding is relevant for suggesting content design elements to develop PL programmes regarding DV at Vislab. This issue will be discussed in the next section.

Teachers' views on the challenges students face when learning DV

Results showed that the main DV-related challenges for students are associated to stages of data lifecycle in general. Hence, discussions around specific DV cognitive tasks, such as difficulties in interpreting data from a specific type of graph, or on building certain types of data visualizations, were not raised by any teacher during the interviews. This finding also accords with our earlier observations, which showed that teachers view DV and IV skills as similar. Moreover, when comparing the challenges raised by teachers with those presented by Shreiner and Dykes (2021) in their review, some similarities and differences were found.

First, all teachers seem to agree that the main challenge for students is finding and assessing sources. In other words, to be sceptic about the sources they find. This result reflects arguments from Shreiner and Dykes (2021) who identified that understanding the intentionality with which a data visualization is created may be a difficulty for students. In this vein, teachers pointed out that one of the factors that contributes to this challenge is assessing sources in a digital environment. For instance, the challenge of being critical about data visualizations –regardless of how appealing they are presented–, and those posed by DV-online tools, with interactive elements that may become numbing and distracting without proper guidance. This challenge was not described by Shreiner and Dykes (2021).

Moreover, it is interesting to compare comments on how data visualizations can affect the cognitive load of students –either in a positive or negative way–. On the one hand, Shreiner and Dykes (2021) referred that irrelevant tasks or information within a visualization increased the cognitive load of the task. Similarly, results from this study suggest that all teachers agree on the view that DV helps students understand information. One teacher pointed out that if data visualizations are properly constructed, they can enhance students' learning experience by reducing the cognitive load that huge data sets may imply. This result, and the challenges of using digital tools to teach DV, suggest that participants are aware of the benefits that DV representations and tools provide, but also understand the conditions that should be present for the objectives to be fulfilled. From a teacher PL perspective, this is an important element to consider for the design element of instructional models proposed by Darling-Hammond et al. (2017), and for understanding the challenges associated with the available resources that educators have for teaching DV. This will be further discussed in the following section.

Finally, there are two DV-related challenges for students that participants reflected on, but were not found in the reviewed literature. One is communicating by using DV. Interestingly, three teachers agree that even though they consider that students are proficient at making appealing visualizations, they often struggle to build them upon reliable data. This result corroborates the ideas of Kędra (2018), who suggested that even though students of today are constantly exposed to cutting-edge technology, they may not always exhibit the abilities required to understand data visualizations and successfully communicate through visual methods. However, it is important to point out that the *type* of visualizations for conveying a message was not discussed during the interviews. Therefore, this might have included both DV and IV representations. When comparing this outcome with the reviewed literature on DV literacy, it is interesting to note that the DV associates skills are mainly proposed from the user's point of view. For instance, Lee et al. (2017) and Shreiner and Dykes (2021) focused on the tasks and challenges related to identifying and interpreting data visualizations. From a teacher PL standpoint, this seems to be a relevant factor to take into account for content and instructional models design elements. For instance, to consider what kind of activities should be integrated in an instructional model to support students in developing DV-skills, both as users and producers of visualizations.

Teachers' reflections on how they have learned about DV for their teaching practice

Although five of the participants (all STEM teachers) reported they have learned about DV during their teacher preparation in higher education and/or during their experience as researchers, the study found that none of the participants reported having a specific, formal course or learning programme on how to teach about DV. This finding is consistent with that of Shreiner and Dykes (2021), who showed that 97% of all respondents from their study expressed that they did not have PL courses focused on DV.

Consistent with the literature, this research found that learning at the workplace has been an important element for learning about DV (Havnes & Smeby, 2014; Lo, 2021; Postholm, 2012; Timperley et al., 2007). Participants reported they have done so by collaborating and sharing information, methods, and tools with colleagues. An interesting finding is related to their learning experience during their teaching practice. Three participants reported that learning by interacting with students has helped them in their learning process. This has been by jointly exploring unknown topics (such as using certain functions in simulators) and becoming inspired to learn more as a result of their inquiries. However, this result has not previously been described in findings from the reviewed literature. Although Shreiner and Dykes (2021) found that the years of practice seemed to be the main opportunity for teachers to develop competencies to teach DV, the study did not reveal details of the conditions and elements involved.

Finally, one teacher considered that working with large data sets poses a challenge both for students and teachers, since other skills, such as programming, are required to make sense of it. This view seems to be consistent with findings from Shreiner and Dykes (2021), which showed that programming languages for creating visualizations was part of participants' competencies. From a teacher PL perspective, this finding poses an interesting aspect to consider for the collaboration design element proposed by Darling-Hammond et al. (2017). The implications of this finding will be discussed in the following section.

RQ2. How can a science centre exhibition of data visualisation support in-service teacher PL regarding DV literacy?

One of the topics that emerged from the discussion at the follow-up workshop was that teachers suggested that training at Vislab should be organized as a formal training programme. This type of learning is characterized by being structured, it happens off-the-job and outside the working environment, usually in a classroom-based educational setting, and based on a didactic interaction. Moreover, it mostly involves endorsed and sponsored programs from external institutions. Therefore, training happens in a context intended specifically for learning (Manuti et al., 2015).

Based on teachers' suggestions and the learning affordances offered by Vislab, formal learning seems the best approach to develop a teacher PL programme on DV, as it supports teachers in improving their DV literacy in the following ways:

- The facilities are specifically intended to develop DV skills
- Facilities in the exhibition allow:
    - peer collaboration with other teachers
    - an off-work safe space for reflection and practice
    - methods, tools, and resources to transfer the knowledge and skills gained on this experience to their classroom or daily practice.
    - the opportunity to communicate with peers after completing the workshop.

RQ3. What are the key elements for designing an effective in-service teacher PL programme regarding DV literacy in a science centre?

Moreover, drawing on the results from this study, the findings from Lo (2021) and the framework of Darling-Hammond et al. (2017), this section develops and suggest a set of 10 principles for effective teacher PL on DV at Vislab.

1. ***Content focus***

- Principle 1. Understand teachers' views on the value of DV and highlight the benefits for their students

Results from this study suggest that a way to motivate teachers on developing DV skills for their teaching practice is by highlighting how this will benefit their students. Findings from interviews also suggest that a way to encourage engagement in this practice is by providing resources that teachers can use both at Vislab and in their classroom. Moreover, findings from the interview suggest that Hans Rosling and his work seem to have a positive influence on teachers' knowledge and ideas on DV. This suggests that providing teachers with references of experts in the field, or with examples of current initiatives in education can be helpful for a PL programme.

- Principle 2. Develop a 'key concepts' guide on DV and related concepts

Findings from the interviews suggest that teachers' ideas on DV include elements of both DV and IV. Therefore, the inclusion of content knowledge that focuses on explaining the similarities and differences between the two fields can help teachers understand how they are related, but also the differences between them. Moreover, teachers' accounts o their experiences in teaching DV revealed a close link between digital tools and DV. Consequently, digital literacy should also be considered for the key concepts guide. Concept maps can be used to facilitate this process (Lo, 2021). For instance, by showing how each concept is related to different modules of the exhibition. It can also be valuable to provide teachers with concept mapping experience, by encouraging them to develop their own concept map and establish connections among the Vislab exhibition and the concepts related to DV (Lo, 2021).

Lo (2021) asserts that it is crucial for teacher PL programs to incorporate both content knowledge and pedagogical content knowledge. Therefore, developing a connected foundation of content knowledge and pedagogical content knowledge should also be considered when designing a DV teacher PL programme at Vislab. This can be facilitated by including easy-to-follow instructional models, as explained in the following principle.

2. ***Use of instructional models***

- Principle 3. Develop guides to approach the exhibition

Suggestions from teachers during the follow-up workshop focused mainly on the development of guides to understand the exhibition and familiarize with it. They considered this would greatly help them in understanding how to approach it, and the affordances that it offers for a learning experience for students. It is interesting to compare this finding with that of Lo (2021), who observed that content focus was the most frequently design element in the studies from his review. This does not appear to be the case in this study. Instead, instructional models seem to dominate teachers' suggestions. A possible explanation for this might be that all teachers were familiar and interested in DV before the interviews and the workshop, two of them had participated in a pilot test at Vislab, and all reported having integrated DV in their classroom. Therefore, all participants were familiar with the topic.

Besides providing basic information about the exhibition, these guides can include instructional models such as lesson plans and model activities that teachers can implement when visiting the exhibition(Lo, 2021). Teachers pointed out two topics in this regard: 1) how each module of the exhibition is related to one another, and 2) how cross-sectional topics can be approached and integrated. For instance, participants raised the question: how can Sustainable Development Goals be integrated in different modules of the exhibition? An instructional model can address this issue by suggesting activities in which students need to use data from the exhibition in order to solve a specific problem or to complete a task. Following on the example provided before, the instructional model would suggest students to calculate their carbon footprint based on their diet. The model would inform the teacher to which Sustainable Development Goals this activity is related.

One important aspect to consider in this design element is student-related challenges. This is one of the major challenges to integrated STEM education that Lo (2021) identified from the 37 teacher PL programs from his review. Thus, findings on students' DV-related challenges from the present study offer the opportunity to inform the design of lesson plans and activities to tackle these challenges. One of the main challenges reported by teachers was that of interpreting information in a digital or visually saturated environment. In this regard, two teachers that participated in the pilot test with their students revealed that age seemed to influence the level of engagement with different modules. Therefore, instructional models should suggest activities for each module based on students' age and interests. This would ensure that they have a clear goal in mind, and that the cognitive load is appropriate for their learning.

The challenge of working with large data sets was also raised during the follow-up workshop. In this regard, one teacher suggested the possibility for students to bring their own data sets and using Vislab facilities to create visualizations for further analysis. However, as for the current state of the exhibition, this suggestion is not feasible to implement, since the modules only offer the option of visualizing information from a fixed data set. Yet, this is an option that could be considered and explored by Vislab staff for future projects. Nevertheless, this challenge, and those of finding and assessing sources, and creating visualizations upon reliable data can be addressed by providing coaching and expert support before and after the visit, as explained in the following section.

- Principle 4. Allocate time for teachers to develop their own instructional materials

Besides providing instructional models, Lo (2021) found that teacher PL facilitators should allocate time for participants to develop those of their own. According to the author, this is an important element for teachers to take ownership of the materials developed by PL facilitators. This is because teachers understand their students' abilities and the realities of their classroom (Lo, 2021). This finding resonates with a comment during the interview with a teacher who participated in the pilot test at Vislab:

> "It's really important what the students know before they come to the Vislab. And the teacher knows that. Therefore, I think it's important to have a program that's tailor-made for what this class knows beforehand" (TCH04).

This finding suggests that it is important that during the PL programme, teachers have the time to reflect about their students' DV competencies, challenges, and conditions in the classroom. This would better inform the instructional models they design during training, and can improve the learning experience of students when visiting the exhibition.

3. Active learning

- Principle 5. Allocate time to conduct a teaching pilot test

Participants suggested that the PL programme at Vislab should include the opportunity for teachers to explore the exhibition before conducting a visit with students. This view was shared by all participants during the workshop. This result corroborates the findings of Lo (2021), which showed that teachers who participated in the learning process as students increased their understanding and self-efficacy in using the instructional models. Another benefit of this endeavour is that Vislab provides learning opportunities for teachers to practice teaching DV in a resourceful and safe environment, outside their own classroom (Adams & Gupta, 2017; Avraamidou, 2014). This element is crucial to consider in a teacher PL programme, as Shreiner and Dykes (2021) found that for most teachers from their study, the classroom was the only opportunity to learn to teach DV.

A way to facilitate this element is to allocate time for teacher participants to pilot their instructional models with a small group. Lo's (2021) review suggests doing it with a group of graduate student volunteers. It can also be considered to conduct this pilot lesson among participants in the PL programme. Research suggest that this practice is fundamental for bridging the gap between planning and implementation (Lo, 2021). Moreover, it provides an opportunity for teachers to practice teaching DV: one of the crucial elements that is needed for teachers to feel effective and confident in supporting their students to develop DV skills (Shreiner & Dykes, 2021).

4. Collaboration

- Principle 6. Encourage multidisciplinary collaboration

Results from the interviews revealed that three teachers expressed learning from their colleagues at the workplace as an important element for learning about teaching DV. This implies practices like sharing information, methods, and tools to integrate DV in the classroom. These results corroborate the ideas of Postholm (2012), who found that collaboration with peers is an important element of how experienced teachers learn.

An interesting finding was the experience shared by two teachers regarding a collaboration in an interdisciplinary project at school. The project aimed at teaching students about data life cycle, focusing on the topic of climate change. Students would be encouraged to explore the origin and transformations of data: from raw data to data visualizations available into public media. Teachers from various subjects –both STEM and non-STEM– are involved, so the DV analysis includes different skills, knowledge, and perspectives. It is encouraging to compare this initiative with findings from Lo (2021), who found that in-school multidisciplinary collaboration was a frequently mentioned element of effective teacher PL programmes.

Evidence from the literature reviewed by Lo (2021) revealed that multidisciplinary collaboration facilitated in the implementation of integrated STEM education in both the classroom and extracurricular settings (Lo, 2021). This finding suggests that a similar approach would be effective in a DV teacher PL programme at Vislab, since it is a topic that it is relevant for various subjects, such as Social Studies, Math, and Biology. An implication of this is the possibility of attracting educators from different subjects, and foster collaboration between them. According to Darling-Hammond et al. (2017) and Lo (2021), these conditions would facilitate sharing information and practices, understand the meaning and relevance of DV for each subject, and build consensus on key DV-related concepts.

5. ***Coaching and expert support***

- Principle 7. Provide guidance and support with subject knowledge and instructional strategies during the whole experience at Vislab

During the workshop, all participants agreed on the view that guidance and support from staff during all stages of the would help them in their PL process. This finding supports that of Lo (2021), who found that coaching and expert support regarding knowledge of STEM practice and instructional methods for teaching STEM were a crucial element of effective teacher PL programmes. It is important to note that the guidance that teachers suggested was not a one-time event that should happen during the training at Vislab. Instead, they highlighted that it should be present during all stages of the visit with students. This means, before, during, and after attending the exhibition. One participant suggested to develop guides that are available for teachers, with recommended activities during these stages. However, the content of these guides was not discussed during the workshop. It is therefore suggested that these activities follow the activity design principles described by Beetham and Sharpe (2019):

- the purpose of the activity
- the role of the tutor
- how the interaction between learners will take place, and how dialogues are structured
- the product or outcome of the activity (reflect, co-create, inform, communicate)
- how feedback will be given to learners on their progress

- how assessment and review will be conducted

Furthermore, some strategies can be used to ensure the relevance and effectiveness of the coaching process. Lo’s (2021) review suggests a co-design approach, in which participants and facilitators create a common vision, including common goals and contextual factors. This finding also accords with our earlier observation, which showed how important it is for teachers to be able to adapt the Vislab visit according to each group. For instance, according to age or specific topics the classroom is working on. In fact, the two teachers who participated in the pilot test at Vislab explicitly highlighted how students from different grades engaged in different modules at the exhibition, probably due to their age and interests. This finding also reflects the relevance of teacher participation in co-designing this experience with facilitators and experts, since they are the ones who best know the circumstances and context of their students and the school. This outcome is also consistent with that of Sgouros and Stavrou (2019), who showed that the collaboration between teachers and researchers on curriculum design in a science center context appeared to be beneficial for teacher PL, particularly for growing their pedagogical repertoire and developing the competencies needed to introduce current science topics in the classroom.

6. Feedback and reflection

- Principle 8. Facilitate teacher reflection on their understanding of DV literacy

Prior studies have noted that reflection on the teaching practice is essential in the teacher PL process (Darling-Hammond et al., 2017; Lo, 2021; Postholm, 2012; Timperley et al., 2007). In the context of this study, this design element is especially relevant, as reflecting on their own teaching practice in the school context and in collaboration with colleagues is one of the ways that experienced teachers learn –as opposed to pre-service teachers– (Postholm, 2012). Findings from the interviews and the workshop showed that exploring teachers’ ideas and experiences on DV opened up a space for teachers to reflect on their own concepts, and learning needs of both their students and them. Thus, a similar approach may help facilitators at Vislab to gain a deeper understanding of teachers’ needs and expectations regarding their PL process.

- Principle 9. Provide feedback on DV integration in the teaching practice

Even though this element was not discussed during interviews with teachers or in the workshop, research suggests that a reflective coaching model approach has been valued by teacher participants from PL programmes, and has improved their teaching practice (Lo, 2021). Likewise, several reports have shown the importance of feedback for improving self-efficacy in their teaching practice. For instance, Shreiner and Dykes (2021) suggest that a teacher's sense of self-assurance is enhanced when they receive positive feedback, when they feel a sense of mastery over the material they are teaching, and when they can draw on past experiences to inform their current teaching practice. This process can be facilitated by following considerations on how feedback should be delivered so that it promotes effective learning (Beetham & Sharpe, 2019):

- Ensure tutor feedback at timely points. Drawing from teachers' suggestions during the workshop, this feedback can be provided in two instances: during the training session at Vislab, and after their experience in the exhibition with students.
- Design tasks to give intrinsic feedback if possible. For instance, by encouraging participants to express their experience while interacting with tools and modules in the exhibition.
- Consider peer feedback as an alternative to tutor feedback. Could be implemented after conducting the teacher pilot test suggested in the Active learning design element.
- Foster skills of self-evaluation. Allow time for self-reflection, as in the design element described above.
- Ensure learners have examples of successful student work to compare against their own efforts. Can be facilitated by providing successful instructional models, as suggested for the second design element in this study.

7. ***Sustained duration***

- Principle 10. Provide ongoing support across several years

When asked about teachers' experience in learning about DV, two teachers mentioned that time constraints could hinder a deeper exploration of this topic. This is an important element to consider when designing a PL programme. Lo (2021) found that this was one of the main challenges related to integrated STEM education in almost half of the 37 teacher PL programmes from this review. His findings revealed that using a time in which teachers were relatively less occupied by their teaching load – for instance, during summer– was a common practice in more than half of the reviewed programmes (Lo, 2021).

Moreover, consecutive participation and ongoing support from experts over more than one year was found to be beneficial for developing teachers' confidence and ability to teach STEM (Lo, 2021). This finding resonates with teachers' suggestion on providing ongoing support, beyond a one-time guidance during the visit with students, which was previously discussed. Considering the time constraints that teachers may face, this might be facilitated by using approaches with more flexibility and sustainability. Lo (2021) suggests virtual meetings and online asynchronous coaching. In the context of Vislab, an online platform can be used to make this content available. Follow-up surveys can also allow teachers to share their experiences at Vislab, and how it has helped them to integrate or improve their DV teaching practice.

Limitations

It is hoped that the insights gained from help to understand teachers' ideas on DV that can provide guidance for designing effective teacher PL programme at Vislab. This may be of special interest for in-service teachers PL around this topic, since research suggest that little is known about it (Shreiner & Dykes, 2021). Moreover, it can inform both Vislab and science centres about design elements to consider when planning teacher PL programmes. However, it is important to interpret these results considering the limitations of the study.

First, it could be argued that the positive views of teachers towards DV were due to their prior interest in the topic, as all of them were recruited from a list of teachers from who were interested in participating in pilot tests related to Vislab and STEM education. Moreover, two of the participants had the pilot experience with their students at Vislab before interviews were conducted. It could therefore be argued that these factors may have influenced participants' level of knowledge about the topic and how they perceive their experiences of teaching DV in the classroom. Likewise, the study only included the view of one teacher from a non-STEM subject. Although teachers from other contexts and subjects were invited to participate in this study, it was not possible to include them in the study for the reasons described in the Recruitment section of the Method chapter. Therefore, the findings may be somehow limited to the context of STEM subjects, which include data and DV as part of their curriculum. For instance, Technology includes developing programming skills to visualize data.

It is also important to bear in mind that even though results show that the participants from this study hold particular ideas regarding teaching DV, they do not offer insights into the prevalence of these views among teachers as a whole. It is important to highlight that this was not the aim of the study (rather, to explore individuals' ideas on DV), but discussing it can provide some ideas for future research, as it will be discussed in the next section. There are other limitations regarding the sample. On the one hand, with a small sample size, caution must be applied, as the findings might not be generalizable to the experience of in-service teachers. However, results were not meant to be representative of a population. On the other hand, only Swedish participants were interviewed. Therefore, results do not denote the ideas and experiences of international teachers.

As for the follow-up workshop, one of the main limitations was that the time allocated for the brainstorming session was very short. Overall, the workshop lasted one hour, which included other activities as described in the Method chapter. Thus, even though in this study I attempted to suggest the design principles by combining the results from the interviews and the suggestions discussed at the workshop, these are based on small sample and a short-term collaborative ideation process. A possible method could have been to use an iterative co-design approach in order to develop the PL design principles over time. However, time constrictions and the opportunity to meet with all the participants on one-time event was considered to outperform these approaches. Finally, two of the interviews were conducted online. This made it harder to elaborate and review the transcripts. Therefore, this condition, plus mine as a non-native speaker of English or Swedish, made it more difficult for me to be confident that the interpretation of participants' responses was correctly.

Finally, before applying the design principles from this study, it should also be acknowledged that the reviewed studies on teacher PL have been conducted in the United States, included teachers from both elementary and secondary school, and the PL programmes were not conducted in science centres. Therefore, it is important to consider specific conditions for the Swedish context.

Future research

To develop a full picture of teachers' ideas regarding teaching DV, it is suggested that additional studies include participants from both STEM and other subjects. This could shed some light in understanding their perceived value for students' learning, and which skills they considered they should develop in order support their students in this process. An example of this was discussed with one of the participants, who suggested that it would be beneficial for teachers of all subjects to develop basic programming skills in order to understand how data visualizations are constructed. Hints from this study, and findings from Shreiner and Dykes (2021) suggests that it could be an interesting area to explore for designing teacher PL programmes on DV.

Another area of research could be to explore how teachers' PL happen when interacting with students. Results from this thesis already contain some elements that contribute to this type of learning. Examples from teachers included: questions from students and digital skills that students develop with tools for DV –especially when they have the role of producers rather than consumers of data and information–. This can be used to explore and inform, from a different perspective, teachers' learning needs. Finally, future research regarding teacher PL on DV could also include views from stakeholders other than school teachers. For instance, teacher educators, facilitators at science centers or school principals, who are also part of the education system.

Conclusion

One of the aims of the present study was to explore in-service teachers' considerations regarding DV, which included associated concepts, perceived value of DV, and related challenges that students face. Findings from the interviews conducted with teacher participants suggest that their ideas on DV include elements of both DV and IV definitions. As for the associated DV-skills, results showed that those considered by teachers as are more related to the steps involved in DV construction and interpretation, rather than specific cognitive tasks involved in processing and displaying numeral or statistical input. Moreover, participants' accounts of their experiences with DV in the classroom and the challenges that students face, reflect the close relationship between DV literacy and digital literacy. Results also reflect that participants have positive beliefs and experiences around DV, and consider that it is valuable for their students. Teachers' experiences of teaching DV in the classroom also revealed some circumstances, reasons, and processes surrounding teacher PL. In this case, interaction with colleagues and teachers' background in research, were identified as the main elements of how teachers have learned. Most importantly, the study found that none of the participants reported having a specific, formal course or learning programme on how to teach about DV. Findings also suggest that in-service teacher PL on DV is motivated by reflecting on their own teaching in the school context in order to improve their students' learning outcomes. Taken together, these results confirm what is previously known about teacher PL on DV.

The study also aimed at understanding how a science centre exhibition of DV can support teacher PL on this topic, and at suggesting the key elements for designing this learning experience. Based on the analysis of findings from interviews and from the discussion with teachers during the follow-up workshop at Vislab, this study suggests a set of 10 design principles for teacher PL on DV that can take place in this exhibition. These are: 1) Understand teachers' views on the value of DV and highlight the benefits for their students; 2) Develop a 'key concepts' guide on DV and related concepts; 3) Develop guides to approach the exhibition; 4) Allocate time for teachers to develop their own instructional materials; 5) Allocate time to conduct a teaching pilot test; 6) Encourage multidisciplinary collaboration; 7) Provide guidance and support with subject knowledge and instructional strategies during the whole experience at Vislab; 8) Facilitate teacher reflection on their understanding of DV literacy; 9) Provide feedback on DV integration in the teaching practice; and 10) Provide ongoing support across several years.

This study contributes to our understanding of in-service teachers' ideas and experiences of teaching DV. Moreover, the insights gained from this study may be of assistance to design an effective teacher PL programme at Vislab. In the long run, it is hoped that this study will offer some insight into the DV learning needs of teachers and the most effective techniques for creating training programs that address these needs outside of the classroom.

Reference list

Adams, J. D., & Gupta, P. (2017). Informal science institutions and learning to teach: An examination of identity, agency, and affordances. *Journal of Research in Science Teaching*, *54*(1), 121–138. https://doi.org/10.1002/tea.21270

Avraamidou, L. (2014). Developing a Reform-Minded Science Teaching Identity: The Role of Informal Science Environments. *Journal of Science Teacher Education*, *25*(7), 823–843. https://doi.org/10.1007/s10972-014-9395-y

Beetham, H., & Sharpe, R. (2019). Learning Activity and Activity Systems. In *Rethinking Pedagogy for a Digital Age* (pp. 32–48). https://www-taylorfrancis-com.ezproxy.ub.gu.se/books/edit/10.4324/9781351252805/rethinking-pedagogy-digital-age-helen-beetham-rhona-sharpe

Börner, K., Bueckle, A., & Ginda, M. (2019). Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(6), 1857–1864. https://doi.org/10.1073/pnas.1807180116

Börner, K., Maltese, A., Balliet, R. N., & Heimlich, J. (2016). Investigating aspects of data visualization literacy using 20 information visualizations and 273 science museum visitors. *Information Visualization*, *15*(3), 198–213. https://doi.org/10.1177/1473871615594652

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). *Effective Teacher Professional Development* (Issue June).

Gapminder. (2022). *Gapminder*. https://www.gapminder.org/

Gill, P., Stewart, K., Treasure, E., & Chadwick, B. (2008). Methods of data collection in qualitative research: Interviews and focus groups. *British Dental Journal*, *204*(6), 291–295. https://doi.org/10.1038/bdj.2008.192

Havnes, A., & Smeby, J.-C. (2014). Professional development and the professions. In *International handbook of research in professional and practice-based learning* (pp. 915–954). Springer International Handbooks of Education For further.

Kędra, J. (2018). What does it mean to be visually literate? Examination of visual literacy definitions in a context of higher education. *Journal of Visual Literacy*, *37*(2), 67–84. https://doi.org/10.1080/1051144X.2018.1492234

Kim, M. C., Zhu, Y., & Chen, C. (2016). How are they different? A quantitative domain comparison of information visualization and data visualization (2000–2014). *Scientometrics*, *107*(1), 123–165. https://doi.org/10.1007/s11192-015-1830-0

Lee, S., Kim, S. H., & Kwon, B. C. (2017). VLAT: Development of a Visualization Literacy Assessment Test. *IEEE Transactions on Visualization and Computer Graphics*, *23*(1), 551–560. https://doi.org/10.1109/TVCG.2016.2598920

Lindfors, M., Pettersson, F., & Olofsson, A. D. (2021). Conditions for professional digital competence: the teacher educators' view. *Education Inquiry*, *12*(4), 390–409. https://doi.org/10.1080/20004508.2021.1890936

Lo, C. K. (2021). Design Principles for Effective Teacher Professional Development in Integrated STEM Education : A Systematic Review. *Educational Technology & Society*, *24*(4), 136–152.

Mandinach, E. B., & Gummer, E. S. (2016). What does it mean for teachers to be data literate: Laying out the skills, knowledge, and dispositions. *Teaching and Teacher Education*, *60*, 366–376. https://doi.org/10.1016/j.tate.2016.07.011

Manuti, A., Pastore, S., Scardigno, A. F., Giancaspro, M. L., & Morciano, D. (2015). Formal and informal learning in the workplace: A research review. *International Journal of Training and Development*, *19*(1), 1–17. https://doi.org/10.1111/ijtd.12044

McKinnon, M., & Lamberts, R. (2014). Influencing Science Teaching Self-Efficacy Beliefs of Primary School Teachers: A longitudinal case study. *International Journal of Science Education, Part B: Communication and Public Engagement*, *4*(2), 172–194. https://doi.org/10.1080/21548455.2013.793432

Nasiopoulou, P., Williams, P., & Lantz-Andersson, A. (2021). Preschool Teachers' Work with Curriculum Content Areas in Relation to Their Professional Competence and Group Size in Preschool: A Mixed-methods Analysis. *Scandinavian Journal of Educational Research*, *0*(0), 1–16. https://doi.org/10.1080/00313831.2021.1897875

Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of Educational Research*, *81*(3), 376–407. https://doi.org/10.3102/0034654311413609

Postholm, M. B. (2012). Teachers' professional development: A theoretical review. *Educational Research*, *54*(4), 405–429. https://doi.org/10.1080/00131881.2012.734725

Sgouros, G., & Stavrou, D. (2019). Teachers' professional development in Nanoscience and nanotechnology in the context of a Community of Learners. *International Journal of Science Education*, *41*(15), 2070–2093. https://doi.org/10.1080/09500693.2019.1659521

Shreiner, T. L., & Dykes, B. M. (2021). Visualizing the teaching of data visualizations in social studies: A study of teachers' data literacy practices, beliefs, and knowledge. *Theory and Research in Social Education*, *49*(2), 262–306. https://doi.org/10.1080/00933104.2020.1850382

Swedish Research Council. (2017). *Sweden 2017: GOOD RESEARCH PRACTICE*.

Thomas, G. (2013). *How to do your research project. A guide for students in Education and Applied Social Sciences* (Second). SAGE Publications Ltd.

Thorén W., A. (2021). *Look around! What can you discover? The science center - a critical space for science student teachers' development*. University of Gothenburg.

Timperley, H. (2011). *Realizing The Power Of Professional Learning*. Open University Press.

Timperley, H., Wilson, A., Barrar, H., & Fung, I. (2007). *Teacher Professional Learning and Development*. http://www.educationcounts.govt.nz/publications/series/2515/15341

Universeum. (2021a). *New Vislabs: "Here you get the tools to save the world."* https://www.universeum.se/nyheter/nya-vislabs-har-far-du-verktygen-att-radda-varlden/

Universeum. (2021b). *Teacher programme - Universeum*. https://www.universeum.se/utbildning/lararprogram/#3

Universeum. (2021c). *With the earth in focus - now the new Vislab is emerging*. https://www.universeum.se/nyheter/med-jorden-i-fokus-nu-vaxer-nya-vislab-fram/

Wise, A. F. (2020). Educating Data Scientists and Data Literate Citizens for a New Generation of Data. *Journal of the Learning Sciences*, *29*(1), 165–181. https://doi.org/10.1080/10508406.2019.1705678

Wolff, A., Gooch, D., Cavero Montaner, J. J., Rashid, U., & Kortuem, G. (2016). Creating an Understanding of Data Literacy for a Data-driven Society. *The Journal of Community Informatics*, *12*(3), 9–26. https://doi.org/10.15353/joci.v12i3.3275

Appendices

Appendix 1 – Information letter and Informed consent

Information letter

Dear [participant's name]

You are invited to participate in a research study about teachers' views around data visualization for their teaching practice. Your participation in the study would consist of an interview that will take approximately one hour, followed by an opportunity to participate in a workshop at Universeum. During the interview, you will be asked to share your views on data visualization, the value you perceive on using it in the classroom, and if you have used it. It is your experience and knowledge as a teacher that I would be enthusiastic if you would like to share with me, so no preparation is needed from your side.

Why is this study done?
Nowadays, we constantly see data visualized in different ways. For instance, when checking the news, we see graphs showing how Covid-19 cases have changed over time, or how global temperature has changed over the years. Therefore, this information may help us to make decisions or take a stance on a certain situation. However, sometimes we might find it difficult to understand the information or to evaluate the reliability of sources. Trying to find the answers to these questions might be difficult in everyday life. In this scenario, your viewpoint as a teacher can be very valuable to better understand the situations that students and educators encounter at school when learning and teaching about data visualization. To sum up, your perspective can contribute to understanding how we can learn to interpret data visualizations and become citizens who make informed decisions.

What is the study about?
This study is conducted as a Master's Thesis at Vislabs. This is the newest exhibition at Universeum, a Science Center in Gothenburg. The purpose of Vislabs is to respond to the challenge of interpreting research data, so high school students and adults can understand sustainability-related topics and act accordingly. Since the exhibition opened in January 2022, working with data visualizations as a non-expert is still not clear. Thus, the aim of my thesis, which is part of the Master's program of Information Technology and Learning (ITLGU) at the University of Gothenburg (GU), is to explore teachers' views on data visualization and understand what kind of competencies are needed for working and interpreting the research data used at Vislabs. Any opinions and experiences you would like to share in the interview will help answer these questions. There will be also an opportunity to participate in a follow-up workshop in which your teacher's expertise will contribute to designing a teacher-training program at Vislabs.

How will it work?
Your participation is voluntary. During the interview, you may skip any question you do not want to answer. The views and experiences you share are important for the study, therefore, I would ask if I can audio-record our conversation (or video-record if it is held online). However, we can omit the recording if you prefer so. Your participation will be anonymous - your name and the name of the school you teach at will not be used in any reports resulting from the study. You can find more information on how data will be handled in the Informed Consent.

Feel free to contact me via email if you would like to know more about this research study (gusanagsa@student.gu.se). Lena Pareto, my thesis supervisor and Professor of Pedagogy at Universeum, can also provide further information regarding the Vislabs exhibition in general (lena.pareto@gu.se).

I look forward to working with you and thank you in advance for your time and contribution.

Kind regards,
Ana Gabriela Santos

Informed consent

Research topic: Teachers' view on the use of data visualization for teaching
Researcher: Ana Gabriela Santos Guzmán
Master's Programme in Information Technology and Learning
University of Gothenburg
Email address: gusanagsa@student.gu.se
Contact phone number: +46 0729490143
Supervisor: Lena Pareto

Declaration by Respondent:

I have read and understood the information provided by Ana Gabriela Santos in her introductory information letter concerning the referred study, and I have had the opportunity to ask questions and to obtain any additional information I requested about this research. I hereby offer my informed consent to participate in this study under the following conditions:

- I grant permission for the interview to be audio or video recorded and transcribed to facilitate data analysis (please select your decision:
    - Yes
    - No
- I may decline to answer any of the questions asked.
- The data collected will only be used for the purposes of this research and will not be shared with any third parties.
- Confidentiality will be guaranteed, and data presented in the research will be anonymized.
- All digital files, transcripts (if applicable) and summaries will be given codes and stored separately from any names or other direct identification of participants.
- I may withdraw from all or part of this research at any time.

Participant's Name:

Participant's Signature:

Date:

Appendix 2 – Interview guide

Topic	Possible questions	Possible follow-up questions	Probes
Concepts/Knowledge	Can you tell me about what comes to your mind when you hear the term "visualization"?	Maybe you have seen data that is presented visually, e.g., Covid statistics, election, sport scores, migration, climate change, or any other situation?	Maybe a recent event? Let me give you an example…
	Do you have any visualization in mind that you have recently seen?	Can you walk me through the context in which you saw it, and what was it about?	How do you think it helped you?
Perceived value	What do you think about the level of students' ability to "decipher" data from visualizations? For instance, in news or social media.	What kind of behaviors/attitudes/beliefs/skills do they have that reflect this?	Would you mind sharing an anecdote? Can you tell me more?
	In which situations or current topics do you think data visualization skills can benefit students or help them navigate situations or challenges in everyday life?	In which topics/matters of everyday life do you think it would have the most benefit for them? Is there any experience would you like to share?	Can you tell me more about your students' experience with that?
	Are there any topics you for which you find especially valuable the use of graphs, infographics, charts, tables?	Can you give an example of current topics or any given subject you discuss/teach by using data visualization?	Can you tell me more about your students' reactions?
What are the challenges/experiences of students and teachers?	Have you find useful to teach using data visualizations? ◦	If not Why don't you find it useful? What do you use instead? What do you think would be useful, or is there something you would like to explore further? How do you think this can help you and your students?	Why would you like to explore that?
		If so In your experience, what would you say is the greatest challenge for students when learning and representing data/information in a visual way? (e.g., collecting, transforming, representing, interpreting, communicating, assessing... is this reliable? is it accurate?) What strategies/tools/methods have you found useful to help them overcome these challenges?	Can you share an experience or an example?

Appendix 3 – Framework for coding

Theme	Subtheme	Description	Quote examples
Associated concepts and skills regarding DV	DV associated concepts	Ideas that come to mind when asked about the term 'data visualization'.	"Well, I have associated with having long sheets of numbers and someone has transformed them for a graphical representation for diagrams or for well…more, more graphical way easier to understand" (TCH04).
	DV-associated skills	Skills students need to use in the classroom for DV-related tasks. It also includes teachers' overall impressions of students' DV literacy level.	"Everyone was sort of very used to there being large data sets. Not having create them themselves. And I think one thing that could be useful is actually to make the students curate a data set, so they get a feeling for that" (TCH05).
Aspects related to DV in the teaching practice	Uses in the classroom	Reasons to integrate DV in teaching practice.	"And if you are using pictures on visualizations that really concentrate on the dangers then the students get into the danger mode. But if you are using visualization that conveys possibilities and conveys how you can save the world, or… then they get into that mode. So as a teacher, I can choose what kind of mode -mental mode- I want this teaching moment to be" (TCH06).
	Tools	Digital tools teachers use in the classroom for DV-related tasks.	"They're working a lot with Geoagebra in math, because it's a good tool for manipulating geometry when you can just move around thing" (TCH02).
	Perceived benefits for students on developing DV literacy	Teachers' perceived value for students to develop DV literacy	"I think they are quite good at making graphics using… I am not sure what programs they use. But they sort of make very snazzy pictures, and overlays and things… so they're quite good at making stuff look good" (TCH05).
	DV-related challenges faced by students	Main difficulties students face in the classroom with DV-related tasks, and ways teachers help students overcome them.	"They would not find the best sources or so when that kind of literacy is not as advanced as some literacy. They would, they wouldn't know how to maybe do programming but not find the relevant source" (TCH01).
	Ways of supporting students to overcome DV-related challenges	Methods used by teachers in the classroom to help students in the perceived DV-challenges.	"Just talking about it all the time. And you know, give good examples for right sources… you know? This organization you can trust. Maybe this organization if you don't know where that information came from" (TCH03).
	How teachers have learned about DV for their teaching practice	Highlights from teachers on ways in which they have learned about DV for their teaching practice.	"I really don't know how I mean… with background research, to visualize your data. That's, that's what you do. But I have not reflected that side. And I don't know where I learned it. It's, it's also a skill that takes a lot of time. And I have never heard of teachers taking a course in data visualization" (TCH02)