Data-Cards Drawagram: A Design Research Approach to Visualization Literacy

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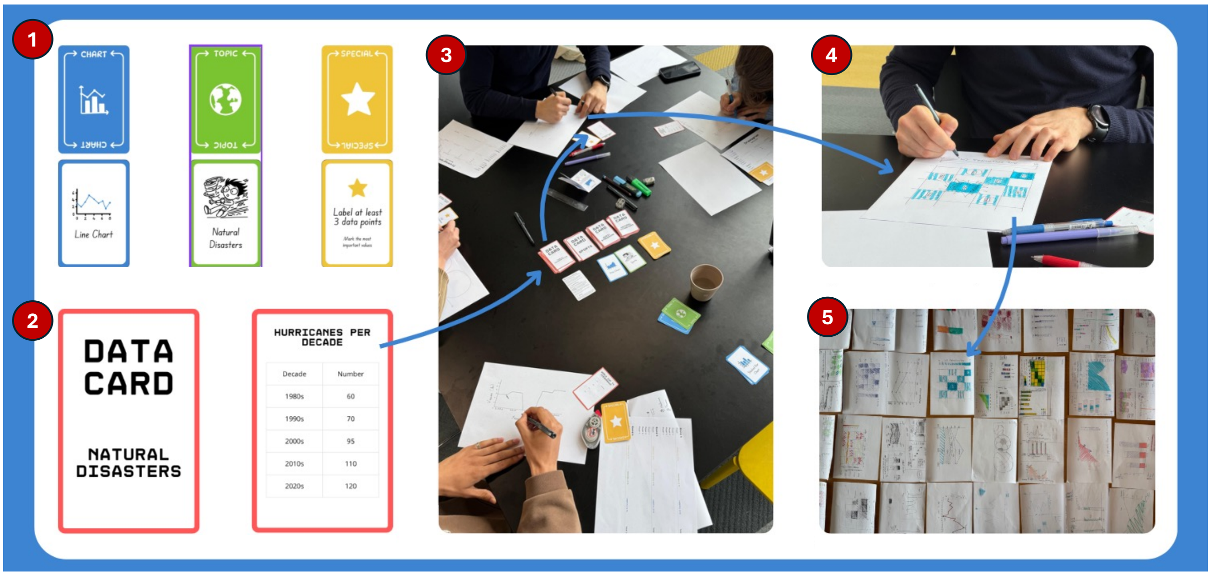


Figure 1: We performed a design intervention on the Drawagram [PS25] game (1) by introducing Data-Cards (2), structured prompts containing simple datasets that players must interpret and visualize during gameplay. We evaluated the effects of this intervention through comparative lab sessions (3), where players sketched visualizations based on the drawn cards (4, detail). We assessed player engagement, visualization literacy, and the quality of produced visualizations (5).

Abstract

Game-based learning offers a promising approach to developing visualization literacy, yet existing games often emphasize recognition over deeper reasoning about data representations. We present Data-Cards Drawagram, a structured variant of the drawing-based visualization game Drawagram, designed to encourage players to reason more deliberately about the relationship between data and visual form. Data-Cards are structured prompts containing simple datasets that players must interpret and visualize during gameplay. Our comparative study shows that the revised game yields stronger and more consistent literacy gains, while qualitative findings indicate deeper cognitive engagement and a more collaborative play experience.

CCS Concepts

• ***Human-centered computing*** → ***Visualization design and evaluation methods;*** *Information visualization;* • ***Applied computing*** → ***Interactive learning environments;***

1. Introduction

Data visualizations play an important role in how people understand the world. From news graphics to public dashboards, they shape opinions and guide decisions. But not everyone has the skills to interpret or create these visualizations correctly. This ability, known as visualization literacy, involves interpreting and reasoning about data presented visually [AGR21]. A lack of such literacy can make people more susceptible to misleading charts or poor data communication. Improving visualization literacy is, therefore, not only an educational goal but also an important means of promoting critical thinking in society.

One promising approach to building visualization literacy is game-based learning, in which game mechanics, such as game objectives, scores, and feedback mechanisms, are used to help players build practical skills in interpreting and creating data visualizations. Examples such as The Graphic Continuum: Match It Game [Sch20], Guess Vis? [AGR25], and Charty Party [KR19], use different types of game dynamics to help players identify, interpret, or reason about data visualizations. Games can create engaging environments that invite players to experiment, collaborate, and reflect. Studies have also shown that board and card games can help learners grasp complex visualization concepts through play [AGR25].

However, most of these games operate primarily on the recognition side of visualization literacy, asking players to identify, classify, or reason about predefined charts. Fewer games engage players in the construction of visualizations, i.e., the process of creating data representations from scratch. Drawagram [PS25] is a notable exception: it asks players to draw visual representations of (temporal) datasets under thematic constraints, shifting the focus from interpretation to creation. This constructive orientation makes Drawagram a particularly relevant candidate for investigating how design interventions can deepen reasoning about data-to-visual mappings. Yet, its open-ended format also introduces a limitation: without concrete data to work with, players may default to artistic expression at the expense of visualization principles. To address this tension, we introduce Data-Cards Drawagram, a structured variant of the original game. Data-Cards are prompts containing simple, self-contained datasets that players must interpret before visualizing them. This intervention targets two complementary aspects of visualization literacy: on the interpretive side, players must reason about data characteristics (e.g., trends, proportions, number of categories) to understand what the data conveys; on the constructive side, they must make deliberate decisions about how to map these characteristics to visual encodings within the assigned chart type. By grounding the creative process in concrete data, Data-Cards aim to bridge the gap between open-ended drawing and data-informed design.

In this study, we investigate whether Data-Cards Drawagram improves both learning outcomes and engagement compared to the original game. Specifically, we examine whether the added structure leads to greater visual literacy gains, as measured by the Mini-VLAT test [PO23], and whether it sustains or enhances player engagement during play. Given the exploratory nature of this work and the limited sample size, we focus on effect sizes and qualitative patterns rather than confirmatory statistical testing.

Our contribution is as follows: (1) we present a design-based intervention for augmenting open-ended visualization games with data-informed reasoning, instantiated through the Data-Cards artefact; (2) we provide empirical evidence from a comparative study on how such structure affects both learning and engagement in game-based visualization education; (3) we derive design implications for visualization literacy games grounded in a research-through-design approach—a perspective that remains underexplored in this context.

2. Related Work

In this section, we review related work on game-based approaches to visualization literacy as well as approaches for measuring it.

Several games have been developed to support visualization literacy through playful experiences. The Graphic Continuum: Match It Game [Sch20] is a card-matching game in which players pair data scenarios with appropriate chart types, reinforcing knowledge of visualization taxonomies. Guess Vis? [AGR25] challenges players to identify a hidden visualization through a series of (yes-or-no) questions, encouraging reasoning about visual properties and chart characteristics. Charty Party [KR19] takes a more informal approach, asking players to create humorous captions for existing charts, promoting engagement through humor while exposing players to a range of visualization types. Drawagram [PS25] stands apart by asking players to draw visual representations of temporal datasets under thematic constraints, shifting the focus from interpretation to creation. However, its original evaluation centered on engagement and self-reported confidence rather than objective knowledge gain.

Amabili et al. [AGR21] provide a useful framework for characterizing these games through six learning goals for visualization education, organized along two processes: deconstruction, i.e., analyzing existing visualizations by identifying (L1), associating (L2), and inferring their characteristics (L5); and construction, i.e., creating visualizations by defining (L3), comparing (L4), and evaluating design choices (L6). Viewed through this lens, most existing games operate primarily on the deconstruction side, asking players to recognize, classify, or reason about predefined charts. Drawagram is a notable exception in that it engages players in construction, but its open-ended format provides limited scaffolding to support deliberate reasoning about data-to-visual mappings.

To address this gap, we adopted a design research approach and developed Data-Cards Drawagram, a variant that introduces structured prompts to guide constructive reasoning about data representation while preserving the original game's creative and playful nature. More broadly, card-based tools have a rich tradition in design practice as means to structure creative processes and scaffold decision-making [WM13]. Our Data-Cards build on this by applying the card format specifically to ground visualization exercises in concrete data.

Finally, standardized instruments, such as the Visualization Literacy Assessment Test (VLAT) [LKK16], provide a means to objectively assess learning outcomes. We adopt its shorter variant, the Mini-VLAT [PO23], as a pre- and post-test measure to assess whether our design intervention yields measurable literacy gains.

3. Design Intervention: Data-Cards Drawagram

The original Drawagram: In the original Drawagram game [PS25], multiple players (typically 3 or 4) begin each round by taking a shared Chart Card (e.g., spline chart) and Topic Card (e.g., water usage), while each player also receives an individual Special

Card imposing a constraint such as "label at least 3 data points" or "use at least 2 colors." The players then have 5 minutes to sketch a visualization on paper. Once the time is up, each player presents their sketch and explains their design choices. The group discusses the results, and a voting phase follows in which players rate each other's work on creativity, accuracy, and legibility. Learning, therefore, emerges from the interplay of creating, presenting, and reflecting on visualizations rather than from interpreting predefined charts.

Pilot Study: In addition to learning the game rules and gaining a better understanding of Drawagram's mechanics, we conducted an initial pilot study, which consisted of multiple self-facilitated sessions (e.g., playing with uncovered cards or thinking aloud in a group) conducted by the five members of the research team, all of whom had backgrounds in Industrial Design and varying levels of familiarity with data visualization. In these sessions, the team observed how the game encourages creativity and collaboration but relies heavily on players' imagination rather than on actual data. While this freedom made the experience enjoyable and open-ended, it also revealed a limitation: players often created assumption-based visualizations disconnected from realistic datasets.

These insights raised multiple design questions, among which: • How can one accurately visualize data when no actual data is provided? • What kind of learning process takes place when players try to visualize imagined data? • How does this creative freedom influence engagement and reasoning about data visualizations?

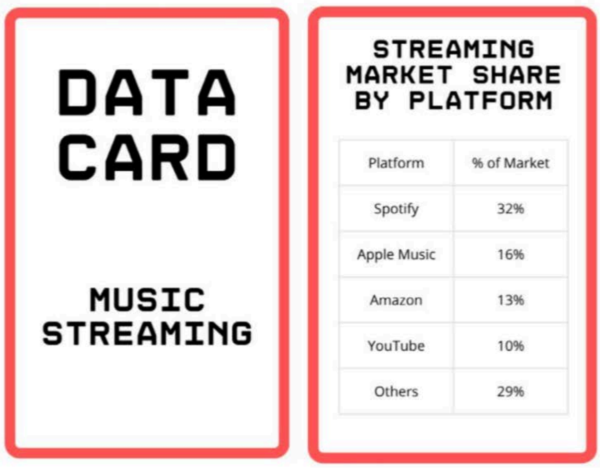
This first-person perspective served as a reflective step within the design process. It helped us recognize that the original game's openness allows for considerable creativity, but not necessarily for data reasoning. This insight became the foundation for our subsequent design intervention.

Data-Cards: To address the observed issues from the pilot study, a new artefact was designed: Data-Cards. These cards introduce short, structured datasets linked directly to each topic in Drawagram (see Figure 2a). Each new card has two sides: the front displays the card type and the associated topic (e.g., Music Streaming), while the back presents a small, self-contained dataset in tabular form, such as streaming market share percentages broken down by platform (see Figure 2b). During gameplay, players select a topic and a chart card as usual, but, as an additional step, they are asked to select a corresponding Data-Card containing simple numerical data (e.g., in tabular form) or trends to visualize. Players remain free to interpret and visualize the data as they wish, but the card ensures that their work is grounded in real data.

This approach aligns with the Data-Users-Tasks Design Triangle [MA14], which states that effective visualization design must balance the characteristics of the data, the needs of the users, and the nature of their tasks. Our Data-Cards further strengthen Drawagram's alignment with the design triangle by addressing all three dimensions:

- **Data:** Data-Cards add concrete datasets to ground the visualizations in reality.
- **Users:** Data-Cards support non-expert players in engaging with data without requiring technical expertise.

(a)



(b)

Figure 2: Overview of the Data Cards used in the study. (a) Example of a Data Card design for the topic "Music Streaming." (b) A hand of Data-Cards, each covering a different topic.

- **Tasks:** Data-Cards maintain Drawagram's original creative goal while introducing an authentic data interpretation challenge.

By introducing such principles in a game-based learning context, the Data-Cards merge creative play with structure, turning visualization design from an abstract exercise into a more meaningful and data-informed experience.

Based on this design intervention, we hypothesize that the addition of Data-Cards will improve players' ability to identify and interpret data visualizations while minimizing the loss of engagement caused by the trade-off between freedom and structure. The hypothesis would be accepted if Data-Cards Drawagram produced higher knowledge gain and equal or higher engagement than the original Drawagram.

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4. Methodology and Study Design

Our study combines a design research intervention with a controlled evaluation. In this section, we describe the methodological framework guiding our research and the structure of our study.

Koskinen et al. [KZB*13] identify three approaches to constructive design research. The Field approach draws on design ethnography, studying how designed artefacts are used in real-world contexts. The Showroom approach is rooted in art and design practice, using provocative artefacts to generate discourse and reflection. The Lab approach borrows from experimental traditions, placing design artefacts in controlled settings to isolate specific variables and observe their effects on participants. In this study, we adopt the Lab approach to design research, as it allows us to compare two versions of the same game under identical conditions and to measure the effect of a single design variable, i.e., the introduction of Data-Cards, on visualization literacy and engagement.

The study consisted of structured Lab sessions comparing the original Drawagram and the Data-Cards Drawagram under identical conditions. A total of 32 participants (aged 18+), primarily Industrial Design students with a few with Engineering backgrounds, were recruited through personal networks. None reported formal training in data visualization, making them a close approximation to novice users. Participants were randomly assigned to one of two conditions: original Drawagram or Data-Cards Drawagram, and played in groups of four. Members of the research team joined the groups as facilitators i.e., supervising and leading each game session. Each facilitator also hosted two sessions — one per condition — resulting in a total of eight sessions. This setup ensured that each facilitator ran both conditions (i.e., original vs Data-Cards), helping to control for facilitator effects. Each session lasted approximately one hour and included four rounds of gameplay.

All sessions followed the same structure. Participants first completed a test to assess skills such as identifying and interpreting data visualizations. To measure visualization literacy, we adopted the Mini-VLAT [PO23], a validated 12-item short form of the VLAT [LKK16]. Its brevity made it practical within a one-hour session, and its prior use in game-based visualization research supports comparability. The same instrument was administered as pre- and post-test. Participants then played four rounds of the assigned game version, during which facilitators recorded observations of gameplay behavior and engagement (see Figure 3). After play, participants completed a Mini-VLAT post-test, followed by the VisEngage survey [HP17], a standardized instrument assessing engagement across multiple dimensions, and a final short semi-structured interview: Interview questions focused on what players liked or disliked about the game, the perceived balance between creativity and data accuracy, and suggestions for improvement.

Mini-VLAT score differences were used to measure knowledge gain, while observations and interview responses were analyzed thematically, focusing on three key aspects that emerged from participants' reflections: the relationship between data and visualization, confidence and motivation in expressing visualization ideas, and engagement with the game's competitive mechanics.

5. Results and Findings

In this section, we present the results of our comparative study. We first report quantitative findings based on Mini-VLAT scores, followed by qualitative insights from observations and post-game interviews.

5.1. Quantitative Analysis

To assess the effect of the design intervention on visualization literacy, we compared Mini-VLAT scores before and after gameplay for both conditions. Pre-test scores were comparable between conditions (Mpre = 13.21 vs. 13.06), suggesting that randomization produced balanced groups in terms of baseline literacy.

The post-tests show that visualization literacy improved across all participants, indicating that both game versions supported learning (see Table 1). The original Drawagram improved from a mean pre-test score of $M_{pre} = 13.21$ to $M_{post} = 13.73$, yielding an average gain of $\Delta M = 0.52$ ($SD = 0.74$), while Data-Cards Drawagram increased from $M_{pre} = 13.06$ to $M_{post} = 14.00$, yielding a higher average gain of $\Delta M = 0.94$ ($SD = 0.23$). All scores are reported on a 0–16 scale.

Data-Cards Drawagram consistently showed stronger gains, particularly in the identification subscore ($\approx$ +0.8 vs. $\approx$ +0.5 for the original). While the small sample size warrants cautious interpretation, this pattern is consistent with the idea that structured data prompts may encourage more deliberate reasoning about data-to-visual mappings.

To quantify the learning difference between conditions, effect sizes were calculated based on the group mean gains and pooled standard deviation. The resulting Cohen's $d = 0.76$ and Hedges' $g = 0.66$ both indicate a moderate learning advantage for Data-Cards Drawagram. Given the relatively small sample size ($n = 16$ per condition), we focus on effect sizes rather than null-hypothesis significance testing and the results should be interpreted as indicative rather than confirmatory. Notably, the standard deviation of gains was considerably lower in the Data-Cards condition

Figure 3: A participant sketches a line chart of World Cup TV viewership data based on a provided Data-Card during a study session.

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($SD = 0.23$) compared to the original ($SD = 0.74$), suggesting that the structured format produced more consistent learning outcomes across participants.

Table 1: Mini-VLAT score summary by condition.

Condition	M_{pre}	M_{post}	ΔM	SD
Original Drawagram	13.21	13.73	0.52	0.74
Data-Cards Drawagram	13.06	14.00	0.94	0.23

5.2. Qualitative Analysis

To complement the quantitative findings, we analyzed facilitator observations and post-game interview responses. Three themes emerged from this analysis: (1) the relationship between data and visual representation, (2) confidence and motivation in expressing visualization ideas, and (3) engagement with the game's competitive mechanics.

Data and visual representation. Enjoyment was primarily derived from the novelty of the activity and gamified mechanics in the original Drawagram. Data-Cards prompted participants to reflect on the relationship between data and visual representation while creating charts. Rather than sketching from imagination alone, players had to interpret the provided data and reason about how its specific characteristics—such as trends, proportions, or number of categories—could be effectively represented within the assigned chart type. Facilitators observed that this led to more deliberate design choices and richer discussions during the presentation phase — a pattern consistent with the stronger identification gains found in the quantitative analysis.

Confidence and motivation. Data-Cards Drawagram appeared to strengthen participants' cognitive engagement and intrinsic motivation, thereby promoting the transition from passive gameplay to active learning in the field of data visualization. Players in the Data-Cards condition engaged in self-reflection on their use of the provided data, and several noted that the cards provided a clearer starting point for their designs. Moreover, some participants reported that the possibility of interpreting the same data in multiple ways challenged them to think more critically about how to encode it visually, suggesting that the structured yet open-ended nature of Data-Cards strikes a productive balance between guidance and creative freedom. Finally, the introduction of more structure sustained attention and engagement, as noticed during both game versions, but was more pronounced in the Data-Cards sessions.

Competitive and collaborative dynamics. From the open questions, we noted how the Data-Cards shifted the purpose of game competition, transforming it from comparing visual alternatives into a shared challenge. Participants described their experience with phrases like "engaged competition" and "playful matches". This reflects a collaborative atmosphere within the competitive elements and fosters a more constructive environment. Facilitators noted that players provided one another with feedback on data interpretation rather than solely on aesthetic quality.

Overall, the incorporation of Data-Cards improved players' engagement in terms of game enjoyment, motivation, and competitive responses. Data-Cards Drawagram led to more sustained interest in the game, as participants noted that added cards made them relate more to a specific context.

6. Discussion

The results of our study indicate that both game versions supported learning, but that the addition of Data-Cards led to stronger and more consistent gains in visualization literacy. In this section, we reflect on the design implications of these findings, discuss limitations of our study, and outline directions for future research.

6.1. Design Implications

The findings of this study highlight that small, simple design interventions can influence both learning outcomes and player experience in educational visualization games. The addition of Data-Cards strengthened visualization literacy gains, particularly in identification tasks, while maintaining player engagement during gameplay. This suggests that introducing structured data elements can support learning without diminishing the activity's playful nature.

One implication is that structured constraints can redirect creativity rather than restrict it. While the original Drawagram allowed players complete freedom to imagine data, the Data-Cards grounded visualizations in actual datasets. This prompted players to think more deliberately about how to represent trends and patterns, encouraging reflection on the relationship between data and visual representation. The lower variance in learning gains observed in the Data-Cards condition further suggests that this intervention produced more consistent learning outcomes, reducing the dependence on individual players' prior experience or imagination.

A second implication concerns the relationship between our intervention and the deconstruction/construction framework proposed by Amabili et al. [AGR21]. The original Drawagram is primarily a construction-based game in which players compose visualizations from scratch. The Data-Cards introduced a form of deconstruction into this process, requiring players to first reason about the data characteristics before creating their visual representation. This combination of both processes within a single game may explain the stronger identification gains, as players were prompted to engage with visualization components at a more analytical level before and during the creative act of drawing.

It is worth noting that both conditions began with relatively high pre-test scores ($M_{pre} > 13$ on a 0–16 scale), suggesting that participants already had a baseline level of familiarity with visualization concepts. This likely produced a ceiling effect, limiting the magnitude of observable gains. The positive trend in favor of Data-Cards Drawagram is, therefore, particularly encouraging, as it suggests that the intervention has the potential to achieve even greater impact with less-experienced audiences.

6.2. Limitations

The scope of this study was limited by a relatively small sample size ($n = 16$ per condition), with participants drawn from a similar demographic, i.e., primarily Industrial Design students. This restricts the generalizability of the findings. Furthermore, while the Lab approach enabled controlled comparisons and systematic observation, it may have limited ecological validity, as the research setting might not fully reflect how players would play and learn in real-world environments, such as a classroom. Moreover, long-term retention of visualization literacy improvements remains untested. Finally, the observed gains in engagement and learning may partially reflect novelty bias, i.e., participants may have been more attentive and receptive simply because the Data-Cards format was unfamiliar. Longitudinal studies would be needed to disentangle genuine literacy development from such short-term effects and to assess whether the benefits persist over repeated play.

Additionally, we did not collect detailed demographic data (e.g., precise age or gender distributions), which limits our ability to fully characterize the sample. The Mini-VLAT, while practical and validated, primarily measures interpretive visualization literacy and may not capture gains in constructive skills that the Data-Cards intervention specifically targets.

6.3. Future Work

Future research could explore how the integration of Data-Cards functions over extended periods and within more diverse participant groups, including different age ranges and levels of data literacy. Implementing the game in real-life classroom contexts or informal learning settings could reveal how social and contextual factors influence learning outcomes outside of the Lab setting. Additionally, exploring variations in Data-Cards, such as incomplete-data or conflicting-trend cards, could further show how varying levels of structure influence reasoning and engagement. Developments such as these could help achieve a better balance among structure, creativity, and engagement in fostering data visualization literacy. From a methodological perspective, complementary assessment methods, such as rubric-based evaluation of participants' sketches, could provide a fuller picture of learning outcomes, particularly regarding constructive visualization skills that standardized tests like the Mini-VLAT do not address.

7. Conclusions

Through a Lab-based Research-through-Design approach, this study demonstrated that the addition of Data-Cards can enhance learning outcomes in Drawagram. The quantitative results showed consistently higher gains in visualization literacy for the Data-Cards version, with a moderate effect size, while qualitative insights confirmed that engagement was maintained and, in several dimensions, deepened. By introducing Data-Cards, we took a step toward bridging the gap between playful experimentation and data-informed reasoning, showing that minimal structure can guide constructive thinking about data representation without diminishing enjoyment.

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AI Usage

Due to the limited scope and time constraints of this study, we employed a Large Language Model (ChatGPT 4.0) to generate synthetic numerical values for the Data-Cards. Even though the generated data may not have been directly based on any existing sources, it still provided a believable set of Data-Cards that can be effectively used to play Drawagram. Importantly, the use of synthetic rather than real-world data does not affect the validity of our findings, as the study assessed participants' ability to visually represent a given dataset, irrespective of its origin or factual accuracy. Finally, AI enabled the rapid production of a large set of Data-Cards, increasing variety across gameplay sessions.

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