Inclusive Data Literacy: UDL and AI-Assisted Data Storytelling for BVI Students

Marina Buzzi[1] [0000-0003-1725-9433], Barbara Leporini[2] [0000-0003-2469-9648], Angelica Lo Duca[1] [0000-0002-5252-6966], Veronica Punzo[3] [0000-0002-5772-5593], and Daniela Rotelli[4] [0000-0002-0943-6922]

[1] IIT-CNR, Pisa, Italy {marina.buzzi,angelica.loduca}@iit.cnr.it
[2] University of Pisa & ISTI-CNR, Pisa, Italy barbara.leporini@unipi.it
[3] Scuola Superiore Sant'Anna, Pisa, Italy veronica.punzo@santannapisa.it
[4] Sorbonne Université, Paris, France daniela.rotelli@lip6.fr

Abstract. Blind and Visually Impaired (BVI) students face significant challenges in accessing and understanding data. Traditional educational resources often rely on visual aids, making it difficult for BVI students to develop data comprehension skills. This study proposes a new approach using Generative Artificial Intelligence, Universal Design for Learning, and Data Storytelling techniques to help BVI students understand data through narratives. By converting complex data concepts into interactive and adaptive narrative-based experiences, our aim is to reduce the accessibility gap and enhance cognitive engagement. Preliminary experiments suggest the feasibility of the proposed methodology. More testing with end users is needed to confirm its effectiveness.

Keywords: K-12 Data Storytelling · Blind and Visually Impaired Students · Generative AI · Data Literacy · Universal Design for Learning

1 Introduction

In today's digital society, data literacy - defined as the ability to articulate information needs, retrieve, evaluate, and manage data [12] is an essential skill, projected to be paramount by 2030 [10]. However, blind and visually impaired (BVI) students face unique challenges in developing these skills due to the significant reliance of traditional data education on visual representations [5]. In Italy, since the late 70s students with disabilities have attended common classes (from primary to high school) in which curricular teachers are assisted by support teachers [9]. In the 2023/2024 school year, more than 359,000 students with disabilities were enrolled in Italian schools, including around 12,000 BVI students [21]. Regrettably, despite progress in accessibility technologies, visually impaired students lack adequate educational resources to comprehend and engage with data.

Universal Design for Learning (UDL) addresses this need by promoting accessible learning through various representation, action, and expression methods, key elements of multimodal learning that support inclusion [30]. Storytelling has long been recognised as an effective pedagogical tool as it enhances engagement and comprehension by placing abstract concepts in a familiar and relatable context [36]. Like conventional storytelling, data storytelling (DS) employs narrative structures and visual representation to present data insights in an engaging and comprehensible manner [11]. Unfortunately, visual representation is not accessible to BVI students. One promising avenue is using GenAI to create accessible learning experiences by converting complex information into narrative-driven and multimodal experiences that align with the needs of BVI students.

Many works in the literature combine UDL and AI [33,17], UDL and storytelling [3], or AI and DS [43,24,23]. To our knowledge, no previous research has explored the integration of UDL, DS, and GenAI in a systematic methodology for BVI students. This paper explores the potential of UDL and AI-assisted DS to improve data literacy for BVI students. We propose a methodology that takes as input a general educational programme to introduce students to data literacy and leverages GenAI to convert the programme into data-driven stories for BVI students. The stories generated consider the educational needs of a specific BVI student and the available assistive technologies. Beyond generating narratives, our methodology also suggests the most effective modalities to communicate these stories, such as auditory, sonification, haptic feedback, or multisensory storytelling techniques. This adaptive approach ensures an engaging, understandable and tailored educational experience. Preliminary experiments have been carried out to verify the feasibility of the proposed approach.

2 Universal Design for Learning for BVI Students

Based on the *Design for All* philosophy of the European Institute for Design and Disability [1], Universal Design for Learning (UDL) is a framework developed by CAST [40] that prioritises student-centred design and promotes educational diversity through the effective use of digital technology [14,4]. Introduced in 2008 and continuously updated in response to feedback from practitioners and new research, the UDL guidelines emphasise the importance of designing learning goals, methods, and materials that are valid for all students. With the aim of creating an inclusive learning environment that allows all students to reach their full potential, this framework acknowledges student differences by incorporating neuroscientific and pedagogical principles to provide multiple means of representation, action, expression, and engagement. Research by [6,30] demonstrates that UDL effectively improves accessibility and increases student participation in schools. UDL is based on the International Classification of Functioning, Disability, and Health (ICF) [13]. Although ICF focusses on barriers to learning and participation, UDL addresses curriculum-related barriers, highlighting the importance of context in achieving school inclusion and enabling teachers to effectively support BVI students by fostering cognitive potential [2,29]. Early interventions for BVI students should consider their observational skills while promoting the development of essential competencies for future learning [7] and prioritising hands-on experiences [16]. An inclusive approach emphasises communication through multiple sensory channels and adapts materials to meet individual needs . However, although in preschool BVI students develop sensory and motor skills through touch, hearing, taste, and smell, in primary school, reliance on visual and verbal communication can complicate understanding. Hence, the creation of teaching materials that are accessible and specialised to meet the individual needs of each student represents a critical challenge.

3 Data Storytelling for BVI Students

Data storytelling (DS) combines data, narrative and visualisation to communicate complex information in an accessible and engaging way [35]. For BVI students, DS offers a powerful alternative to traditional data literacy education, which frequently depends on visualisations such as charts and graphs [34] that represent barriers for BVI students, even when adapted through screen readers or tactile methods graphics [22]. In contrast, DS can leverage auditory and tactile modalities, enabling BVI students to engage with data through multisensory narratives. Research has shown that stories make data more relatable by providing context and emotional engagement, which fosters comprehension and retention [26]. For example, storytelling enables learners to connect data with personal experiences, make sense of complex patterns, and draw meaningful conclusions [27]. Explanatory visualisations, supported by narrative elements, can significantly improve accessibility by helping learners grasp key ideas without requiring advanced data interpretation skills [28]. AI potentially can enhance DS by tailoring the complexity of stories, adjusting sensory modalities, namely, providing sensory alternatives to BVI students for accessing content, and providing real-time feedback, creating context-aware narratives that optimise learning outcomes. AI-assisted tools can also automate storytelling processes, reducing the cognitive and logistical burden on educators [24].

We identify four types of data story: change over time, comparison between entities, zoom stories, and spatial change [35]. A data story relies on a clear narrative structure to guide the audience through complex information and insights. Several models from fiction and cinema have been adapted for DS, including the three-act structure, which organises the narrative into a setup, confrontation, and resolution [25]. Freytag's Pyramid extends this model by emphasising rising action, climax, and falling action to create narrative tension and highlight key insights [44]. Similarly, the Data Storytelling Arc simplifies Freytag's Pyramid by focussing on setting, rising insights, an "Aha!" moment, and actionable outcomes [8]. The Hero's Journey presents the data narrative as a transformative quest structured around the departure, initiation, and return phases [42].

4 The Proposed Methodology

The proposed early stage methodology is based on the expertise of one of the authors, who teaches Educational Technology for Inclusion at the university level within a Primary Teacher Education programme. This background ensures that the approach is informed by both pedagogical theory and practical experience in training future primary school teachers to address diverse learning needs.

Starting from these premises, in this work, we aim to tackle the issue of data literacy programmes for primary school BVI students in Italy by proposing a methodology that, combining UDL and DS, enables teachers to customise the general educational programme for the entire classroom to meet the unique needs of the BVI students, thereby creating an accessible and personalised learning path. As illustrated in Figure 1, this transformation is achieved through AI-driven automation.

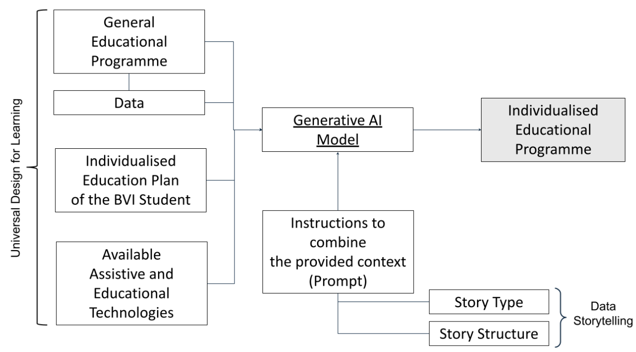

Fig. 1. The proposed methodology.

The UDL's emphasis on flexibility and inclusion is reflected in the integration of three key components: *i)* the General Education Programme (GEP) with the specific data used as examples; *ii)* the Individualised Education Plan (IEP) of the BVI student; *iii)* the Available Assistive and Educational Technologies (AAET). GenAI intervenes to combine UDL and DS principles, hence personalising the educational programme to meet each student's individual needs.
GEP. According to the International Standard Classification of Education [20], educational programmes are intended to improve the general knowledge, skills, and competencies of learners to establish a foundation for lifelong learning. Primary education programmes are generally structured to provide students with key reading, writing, and mathematics abilities while creating a solid foundation to learn and understand core knowledge areas [41]. The GEP includes data, which refers to information provided as input to the system for the purpose of generating a narrative. For example, students' preferences or event details, such as the number of animals, colour, and type of food.
IEP. Student's IEP, created for each student with special educational needs, examines key environmental and personal factors such as relationships, socialisation, communication and autonomy to promote inclusive intervention [18]. Taking into account various classroom dynamics, it enables effective pedagogical planning that respects different ways of expression and interaction.

AAET. Within the framework of educational technologies, understood as digital tools and resources designed to improve and transform teaching and learning processes [15], assistive technologies are specifically designed to support individuals with disabilities or special needs to promote their health, well-being, inclusion, and participation [39]. Braille displays and speech synthesis software allow BVI students to access learning materials [32].

GenAI integrates UDL and DS: by analysing UDL content, including the GEP, the BVI student's IEP, and the AAETs, GenAI creates a personalised educational programme tailored to the needs of BVI students. UDL personalises content and methods for individual learning requirements, while DS transforms material into engaging narrative-based lessons that enhance data literacy. In addition, GenAI recommends suitable assistive technologies to improve accessibility and personalised learning experiences.

5 Preliminary Experiments

To test the feasibility of the proposed methodology, we performed two preliminary experiments using OpenAI ChatGPT Plus in versions 4.0 and 4.5 as GenAI models. We supplied each model with various context parameters (Sect. 4) using the specific functionality offered by ChatGPT for document uploads. Initially, we also attempted to use Microsoft Copilot Pro; however, its limitation on simultaneous document uploads led us to concentrate solely on ChatGPT. We conducted a case study on a first-grade class in a primary school in Italy. All context documents are available on GitHub [38]. The GEP includes three progressive lessons: (1) observation and data collection, (2) organisation and visual representation of the data, and (3) interpretation of the data and its use to build a narrative. The BVI student's profile was derived from the IEP, appropriately anonymized, which establishes personalised learning objectives and competencies. The IEP concerns a 6-year-old completely blind girl named Cecilia (nickname for privacy issues). As assistive and didactic technologies, we included a screen reader, a rubber board (tactile writing board), clay, and an accessible tablet. As data, we used data related to animals (as specified in the GEP), and the goal was to make children able to classify animals based on colour, size, and diet. Starting from this context, students had to build stories of the comparison between entity types following the three-act structure (Sect. 3). We used the following prompt to instruct ChatGPT to generate the adapted programme:

Adapt the attached programme, titled Data Literacy Programme, for Grade 1 to the attached profile of the Blind and Visually Impaired student, titled IEP Cecilia, using the assistive and didactic technologies specified in the attached file, titled Available Technologies. In adapting the programme, generate a data-driven story that uses the data provided in CSV format, is based on entity comparison, and follows a three-act structure.

The generated programmes, whose results are discussed in the following section, are available on GitHub [38].

6 Discussion and Future Work

The generations of stories through ChatGPT differed according to the model used. The 4.0 model generated four lessons, where only the fourth was a data story; the 4.5 model instead generated three lessons already organised as a data story following the three-act structure. The two versions of the programme adapted for Cecilia have similar approaches but significant differences in the tools used. The GPT4.5 version focusses on a three-act structured narrative and uses mainly digital technologies such as the accessible tablet with screen reader and voice dictation function, the tactile tablet for raised line graphs and clay models for animal classification. In contrast, the GPT4.0 version takes a more sensory and spatial approach, employing stackable blocks to build tactile bar graphs, symbols, and textures to represent data, haptic feedback on the tablet, and voice recording as the final form of expression. While the former focusses on the shared construction of a data-driven story, the latter emphasises autonomous, physical space exploration, and personal recorded narration. Thus, GPT 4.5 seems to be more suitable and effective. From a practical and educational perspective, the proposed methodology contributes to inclusive classroom practices by providing teachers with customised tools and adaptive strategies. In particular, combining UDL with AI-assisted data storytelling can allow educators to tailor the learning experiences of BVI students without isolating them from their peers. This approach also improves early data literacy by encouraging essential skills such as critical thinking and problem solving, thereby promoting long-term academic growth of BVI students and increasing their independence in daily life. However, the study presents some limitations that require consideration in future research. The preliminary experiments should be validated in real-world classroom scenarios that include UDL factors of increasing complexity. To ensure equitable and secure learning environments, ethical implications, such as the inherent biases of GenAI models and privacy concerns about personal data, must be further investigated [37,31]. To mitigate risks related to biassed or overly simplified content generation, teachers will review all AI-produced stories before use. The system is designed as a co-creative assistant rather than an autonomous generator, ensuring human oversight in every step. Field testing is planned for summer 2025 in collaboration with the Italian Association of Blind and Visually Impaired [19]. During these summer camps, we aim to evaluate the effectiveness of DS in improving data literacy with about 12-16 K-12 BVI students. To this end, we will define some evaluation metrics and conduct a comparative study involving two groups of students: the first group will follow a traditional educational path without using DS. In contrast, the second group will engage with the AI-assisted DS approach. Both groups will complete pre- and post-programme questionnaires to assess learning outcomes and measure any improvements in data literacy. In this paper, we used a generic GenAI model. We plan to apply retrieval-augmented generation techniques and multi-agent architectures to improve performance. This preliminary study suggests the feasibility of combining UDL, DS, and GenAI for inclusive education. If confirmed, the proposed approach could become a replicable methodology in other contexts.

Acknowledgements

This study is part of the PRIN project 2022HXLH47 “STEMMA -Science, Technology, Engineering, Mathematics, Motivation and Accessibility” (funded by the European Union - Next Generation EU, Mission 4 Component C2 CUP B53D23019500006).

References

1. The EIDD Stockholm Declaration 2004: `https://tinyurl.com/2jtt3hsc`
2. Ainscow, M.: Promoting inclusion and equity in education: lessons from international experiences. Nordic journal of studies in educational policy **6**(1), 7–16 (2020)
3. Alharbi, S., Newbury, P.: Improving student engagement and satisfaction using universal design for learning and storytelling. In: European Conference on E-Learning. pp. 559–XIII. Academic Conferences International Limited (2021)
4. Aral, S.: The hype machine: How social media disrupts our elections, our economy, and our health–and how we must adapt. Crown Currency (2021)
5. Bhat, S.A., Alyahya, S.: Infographics in educational settings: A literature review. IEEE Access **12**, 1633–1649 (2023)
6. Cook, S.C., Rao, K.: Systematically applying udl to effective practices for students with learning disabilities. Learning disability quarterly **41**(3), 179–191 (2018)
7. Diasse, M.D., Kawai, N.: Evidence-based practices for students with visual impairments in regular settings. International Journal of Special Education (2024)
8. Dykes, B.: Effective data storytelling: how to drive change with data, narrative and visuals. John Wiley & Sons (2019)
9. Teacher education for inclusive education: `https://tinyurl.com/3wfeh3j5`
10. Data Literacy: The Upskilling Evolution: `https://tinyurl.com/yfna2729`
11. Few, S.: Show me the numbers: Designing tables and graphs to enlighten/
12. DigComp Framework: `https://tinyurl.com/2s3e6p2b`
13. International Classification of Functioning, D., Health (ICF): `https://tinyurl.com/45b7wvvb`
14. Gardou, C.: La société inclusive, parlons-en! Érès (2012)
15. Granić, A.: Educational technology adoption: A systematic review. Education and Information Technologies **27**(7), 9725–9744 (2022)
16. Hunaepi, H., Suma, I.K., Subagia, I.W.: Curiosity in science learning: A systematic literature review. Journal of Essential Competencies in Education (2024)
17. Hyatt, S.E., Owenz, M.B.: Using universal design for learning and artificial intelligence to support students with disabilities. College Teaching pp. 1–8 (2024)
18. Il Decreto interministeriale: `https://tinyurl.com/b2s2zesc`
19. Unione Italiana dei Ciechi e degli Ipovedenti: `https://www.uiciechi.it/`
20. International Standard Classification of Education (ISCED): `https://tinyurl.com/3w5hydc6`
21. ISTAT: `https://shorturl.at/WAeAH`
22. Kakehi, B., Iwamura, M., Minatani, K., Kise, K.: Grouping effect for bar graph summarization for people with visual impairments. In: Proceedings of the 26th International ACM SIGACCESS Conference on Computers and Accessibility (2024)
23. Li, H., Wang, Y., Liao, Q.V., Qu, H.: Why is ai not a panacea for data workers? an interview study on human-ai collaboration in data storytelling. IEEE Transactions on Visualization and Computer Graphics (2025)

24. Li, H., Wang, Y., Qu, H.: Where are we so far? understanding data storytelling tools from the perspective of human-ai collaboration. In: Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (2024)
25. Lo Duca, A.: Become a Great Data Storyteller: Learn How You Can Drive Change with Data. John Wiley & Sons (2025)
26. Matuk, C., Amato, A., Davidesco, I., Rubel, L., Stornaiuolo, A., Bumbacher, E., Chance, B., DesPortes, K., Eloy, A., Fagan, E., et al.: Data storytelling in the classroom. In: Proceedings of the 16th International ICLS 2022. International Society of the Learning Sciences (2022)
27. Matuk, C., Hurwich, T., Spiegel, A., Diamond, J.: How do teachers use comics to promote engagement, equity, and diversity in science classrooms? Research in Science Education **51**, 685–732 (2021)
28. Milesi, M.E., Martinez-Maldonado, R.: Data storytelling in learning analytics? a qualitative investigation into educators' perceptions of benefits and risks. In: Proceedings of the 14th LAK Conference (2024)
29. Mitchell, D., Sutherland, D.: What really works in special and inclusive education: Using evidence-based teaching strategies. Routledge (2020)
30. Rose, D.H., Meyer, A.: Teaching every student in the digital age: Universal design for learning. ERIC (2002)
31. Roselli, D., Matthews, J., Talagala, N.: Managing bias in ai. In: Companion Proceedings of the 2019 World Wide Web Conference. pp. 539–544. ACM (2019)
32. Russomanno, A., O'Modhrain, S., Gillespie, R.B., Rodger, M.W.: Refreshing refreshable braille displays. IEEE transactions on haptics **8**(3), 287–297 (2015)
33. Saborío-Taylor, S., Rojas-Ramírez, F.: Universal design for learning and artificial intelligence in the digital era: Fostering inclusion and autonomous learning. International Journal of Professional Development, Learners and Learning **6**(2) (2024)
34. Sarica, H.C., Yildirim, D.: Data storytelling in education: a systematic review. INTED2024 Proceedings pp. 6990–6997 (2024)
35. Segel, E., Heer, J.: Narrative visualization: Telling stories with data. IEEE transactions on visualization and computer graphics **16**(6), 1139–1148 (2010)
36. Shao, H., Martinez-Maldonado, R., Echeverria, V., Yan, L., Gasevic, D.: Data storytelling in data visualisation: Does it enhance the efficiency and effectiveness of information retrieval and insights comprehension? In: Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems. pp. 1–21 (2024)
37. Stahl, B.C., Eke, D.: The ethics of chatgpt–exploring the ethical issues of an emerging technology. International Journal of Information Management (2024)
38. Supplementary Material: `https://github.com/alod83/AIED2025`
39. Assistive technology: `https://tinyurl.com/2jrvvw6f`
40. The UDL Guidelines: `https://udlguidelines.cast.org`
41. UNESCO: `https://tinyurl.com/3w5hydc6`
42. Wei, Z., Qu, H., Xu, X.: Telling data stories with the hero's journey: Design guidance for creating data videos. IEEE Transactions on Visualization and Computer Graphics (2024)
43. Yan, L., Martinez-Maldonado, R., Jin, Y., Echeverria, V., Milesi, M., Fan, J., Zhao, L., Alfredo, R., Li, X., Gašević, D.: From data stories to dialogues: A randomised controlled trial of generative ai agents and data storytelling in enhancing data visualisation comprehension. arXiv preprint arXiv:2409.11645 (2024)
44. Yang, L., Xu, X., Lan, X., Liu, Z., Guo, S., Shi, Y., Qu, H., Cao, N.: A design space for applying the freytag's pyramid structure to data stories. IEEE Transactions on Visualization and Computer Graphics **28**(1), 922–932 (2022)