Story-problems and Universal Design for Learning for Inclusive and Accessible Mathematics Education: A Study of Italian Preservice Special Education Teachers

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This article reports on a study that explored how narrative problem design and the Universal Design for Learning (UDL) framework support inclusive and accessible mathematics education. The research involved 269 Italian preservice secondary school special education teachers, with the goal of developing competencies in designing inclusive striped problems: mathematical story-problems structured according to Zan's Context and Question (C&Q) model and enriched through the use of multiple representations in line with UDL. Participants worked in groups to redesign mathematics problems and subsequently completed an individual questionnaire reflecting on inclusive educational design. Data were analysed through a combination of analysis of group designs and deductive qualitative content analysis. Results show that all groups incorporated multiple representations, over half successfully designed striped problems coherent with the C&Q model, and a majority included personalisation for specific disabilities. Questionnaire responses revealed participants' emerging awareness of narrative coherence, multimodality, and personalisation as interconnected dimensions of inclusive mathematics design. The results of this study suggest that inclusive striped problems are useful for designing inclusive learning activities in mathematics. The study highlights the potential of integrating the C&Q model and UDL in preservice teacher education to foster teachers' professional identity as designers of inclusive and accessible mathematics learning environments.

Keywords · pre-service teacher education · inclusive mathematics education · UDL · story-problems · · multimodality

Introduction

In recent years, inclusion has become a central concern in mathematics education research (Bertram & Scherer, 2022; Greenstein & Baglieri, 2018; Roos, 2023; Tan et al., 2019, 2022). Much of the existing literature focuses on instructional adaptations for specific disabilities (e.g., Fernandes & Healy, 2013; Lewis & Lynn, 2018), often addressing inclusion through a compensatory or case-based lens. While such approaches are valuable, they risk overlooking the broader diversity that characterises contemporary mathematics classrooms. Students differ not only in terms of disabilities, but also in language backgrounds, cultural experiences, prior knowledge, abilities, and learning preferences. From an inclusive perspective, mathematics education must therefore move beyond targeted accommodations and instead, adopt design principles capable of supporting all learners as a general condition of teaching (Bishop et al., 2015; Greenstein & Baglieri, 2018; Tan & Thorius, 2018, 2019).

At the same time, research highlights a persistent gap in teachers' preparation for inclusive mathematics teaching. Mathematics teachers, both pre-service and in service, often report limited training in designing activities that address heterogeneous educational needs (Bertram & Scherer, 2022). Teachers' beliefs and attitudes toward inclusion (Scherer & Bertram, 2024), as well as toward mathematics itself, play a crucial role in shaping their instructional choices and the success of inclusive practices (Bertram & Scherer, 2022; Coppola et al., 2012). Mathematics is frequently perceived as particularly difficult to teach inclusively, due to its abstract nature and the cumulative structure of mathematical content, which is often presented through tightly sequenced steps. It has been found that cognitively rich may fail to be inclusive if they are designed without careful attention to classroom diversity and accessibility (Seitz et al., 2020).

Within the Italian context, these issues have further relevance. Special education teachers are formally assigned to classes in which students with disabilities are present, yet their responsibility extends to the entire classroom. They actively contribute to the design of inclusive teaching activities across subject areas, including mathematics, with the aim of promoting participation and learning for all students (Taylor & Ringlaben, 2012; Zappaterra, 2014). Many special education teachers, however, do not have a strong disciplinary background in mathematics, as their training often emphasised pedagogical and educational dimensions rather than subject-specific knowledge.

From a pedagogical standpoint, traditional mathematics instruction has been dominated by text-based and auditory modalities, such as written problems and oral explanations (Lambert, 2021). These formats can create substantial barriers for students with dyslexia, visual impairments, hearing impairments, or difficulties in processing linguistic information. In response to these challenges, research has increasingly emphasised the role of multiple representations and multimodality in mathematics learning (Arzarello, 2006; Arzarello & Robutti, 2008; Ferrara, 2014). Providing access to mathematical content through diverse representational forms—such as visual, auditory, tactile, and embodied modalities—can foster participation and support understanding for a wide range of learners, including students with learning disabilities (Lambert & Sugita, 2016).

The Universal Design for Learning (UDL) framework offers a theoretical and methodological foundation for addressing these issues. In particular, the UDL principle of multiple means of representation emphasises the need to present information in flexible and varied ways so as to reduce barriers to learning and ensure accessibility for all students, not only those with formally identified special educational needs (Center for Applied Special Technology [CAST], 2018, 2024; Cottini, 2019; Meyer et al., 2014). From this perspective, inclusion is not achieved by adapting activities for a few, but by intentionally designing learning experiences that are accessible from the beginning of the planning process (Meyer & Rose, 2005).

Within mathematics education, storytelling and narrative-based problem posing have been shown to represent powerful tools for enhancing accessibility and meaning-making (Walters et al., 2018; Zazkis & Liljedahl, 2009). Narrative contexts can activate students' everyday knowledge and support comprehension by connecting mathematical structures to meaningful situations. Building on this idea, Zan's Context and Question (C&Q) model provides specific criteria for designing story-problems in which the narrative dimension and the mathematical question are coherently integrated (Zan, 2012). Problems structured according to this model are called *striped problems*. This is a translation of the Italian expression "problemi a righe" (i.e., Zan, 2012) used in other international scientific papers on mathematics education (e.g., Albano & Dello Iacono, 2019; Zanellato, 2024). Striped problems support the problem-solving process and can improve accessibility to mathematics (Zan, 2012; 2016).

The integration of the C&Q model with the UDL principle of representation opens up new possibilities for inclusive mathematics design. Story-problems can be enriched through multiple representational forms (e.g., visual supports, audio narration, tactile materials, digital tools, text-to-speech software, automatic voicing with digital mathematical notation), allowing students to access the same mathematical content through different modalities. Such an approach aligns with a broader conception of inclusion, in which accessibility, personalisation, and participation are embedded in the design of learning activities.

Against this background, a workshop for Italian prospective middle and high school special education teachers aimed at developing competencies in designing inclusive mathematics learning environments was designed. During the workshop, participants were asked to design *inclusive striped problems*, that is, story-problems structured according to Zan's C&Q model and enriched through the UDL principle of representation, considering forms of personalisation for hypothetical-specific disabilities. At the end of the workshop, participants completed an anonymous questionnaire intended to explore their perceptions and awareness related to inclusive educational design in mathematics.

The study reported in this article investigated the extent to which participants' designs reflected the key components of inclusive striped problems: in particular, coherence with the C&Q model, and the use of multiple representations with attention to personalisation for specific educational needs, in accordance with the UDL approach. Examining these aspects is crucial, as teachers' design choices play a central role in shaping accessibility and reducing epistemological and didactic obstacles to learning mathematics (Brousseau, 1983; D'Amore et al., 2008).

Based on these considerations, the study addressed the following research question:

> *To what extent do prospective special education teachers refer to aspects of the C&Q model, multiple representations, and personalisation when designing inclusive striped problems and reflecting on inclusive educational design in mathematics?*

Conceptual Background

There is a relationship between the UDL framework (CAST, 2018, 2024; Meyer et al., 2014) and mathematical story-problems and C&Q model (Zan, 2011, 2012). On the one hand, multimodal mathematical problem formulation (in accordance with the UDL principle of representation) enhances the inclusive character of striped problems. On the other hand, the C&Q model can be a specification and an implementation of the UDL principle of representation. This synergy allows the text formulation of a mathematical problem to be more accessible.

The UDL Framework

Universal Design for Learning (UDL) is an educational approach based on universal design principles applied to educational issues (Meyer et al., 2014). The idea stemmed from Universal Design, developed in the mid-1980s in the United States by architect Ronald Mace of the University of North Carolina (Harris, 2004). The goal of Universal Design was to study and design buildings and products in order to make them maximally accessible to all people, including those with special needs and address peculiar disability situations. According to Universal Design the design of products and environments can be usable by all, to the greatest extent possible, without the need for special adaptations or aids (Mace, 1997; Story et al., 1998).

The UDL approach is similar to Universal Design; however, UDL addresses the teaching/learning process. The aim is to provide for adjustments to teaching curricula (Pisha & Coyne, 2001) so that learning activities turn out to be, on the one hand, more responsive to the needs of individual students who may have special needs and, on the other hand, end up constituting qualitative opportunities for all (Cottini, 2019). The challenge, therefore, is not to modify or adapt curricula for a special few, but to do so effectively from the beginning of the planning process for all, thus ensuring accessibility to all aspects of learning.

The UDL methodology aims to provide flexibility in how information is presented and in the way students demonstrate their knowledge and skills. This approach reduces barriers in education, provides adaptations, appropriate support, and maintains high achievement expectations for all students, including students with disabilities (CAST, 2018, 2024). The three main principles are as follows:

- *Multiple means of representation*, to provide learners with different ways of acquiring information, thereby providing a plurality of approaches to accommodate students' varying ways of making sense of information. It can be effective to act on: the physical characteristics of the information (e.g., text size, background-figure contrast, color, audio volume, etc.); the provision of alternatives so as not to be limited to the use of single mediums (visual, auditory, textual); the preliminary explanation of terms, symbols, and concepts; supports to facilitate understanding, such as diagrams, concept maps, artifacts, text-to-speech software, automatic voicing with digital mathematical notation, and concretisations of various kinds.
- *Multiple means of action and expression*, to ensure that students have multiple ways in which to demonstrate and reflect on their learning. Students can use graphic organisers, such as story webs, outlining tools, or concept mapping tools; compose in multiple media, such as text,

speech, drawing, illustration, comics, storyboards, design, film, music, storytelling, dance/movement, visual art, sculpture, or video; or use physical manipulatives (e.g., building blocks, 3D models, base-10 blocks). From this perspective, students can solve problems using a variety of strategies.

- *Multiple means of engagement*, to enhance students' motivation and engagement in learning. It promotes the use of tasks that allow for active participation, exploration and experimentation, and that link learning to meaningful experiences. From this perspective, engagement can be fostered through strategies such as cooperative learning, inquiry-based learning, gamification of activities, or by giving students the opportunity to make choices that enhance their sense of personal relevance.

It would be limiting to conceive of UDL methodology as an approach to be followed passively, as a list of options and flexible strategies. It should be understood as an intentional design process aimed at reducing cultural, cognitive, behavioral, and physical barriers (Craig et al., 2022), in order to make learning accessible to all students, including students with disabilities. As Lambert pointed out, "mathematics education must include disability in calls for equity" (Lambert, 2015, p. 15). To consider people with disabilities as a sum of their deficits or dysfunctions, as "non-thinkers", means to "dehumanize" them (Lambert et al., 2018) and not allow them "to engage in rich content and research" (Lambert & Tan, 2020, p. 29). The inclusive perspective of UDL considers the needs of specific students, for whom activities should be designed with differentiations even if not coherent with those of others in the class (Lambert et al., 2021).

Mathematical Story-problems

Storytelling is a very effective tool in mathematics education (Walters et al., 2018), and in mathematics special education (Albano & Iacono, 2019). It achieves several purposes, such as, creating problem situations, outlining a framework for problem solving, and asking questions, for example, questions that arise within the context of the story (Zazkis & Liljedahl, 2009). Demattè (2011) emphasised the potential of storytelling to present mathematics in a different way from the arid and uncreative subject it represents for many students.

There is a strong connection between the solving process and the representation of a mathematical problem (Mayer, 1982; Mayer & Hegarty, 2012). A properly described contextualised problem situation can enable the student to recall knowledge of the world and facilitate the representation of the problem and thus enable the problem-solving process. So, when problems are situated in a narrative context, students activate narrative thinking (Bruner, 1986) and are able to relate to people, their intentions and feelings. Narrative thinking is central to daily life and can support logical thinking. For Bruner, the two thoughts are complementary. However, to make the synergy of these two types of thinking effective in problem solving, the narrative and logical dimensions should be connected properly.

In the process of representation, when the context takes the form of a story (even a short one), there must be an event taking place in time, characters who perform actions aimed at a purpose, and the parts of the story are linked by causal relationships. Often, the expressions "word problems" and "story-problems" are used as synonyms. This association does not always apply because many problems do not present a real story, either because the time dimension is missing or because the characters of the story are missing, that is, the protagonists of the story are not mentioned. Zan (2012) observed that if the context describes a story (an event taking place in time, with animated characters), the text may be badly structured narratively (e.g., narrative links between different parts of the text are not obvious). In these cases, the context of the story could hinder the understanding and the resolution of the problem because it presents *narrative breaks* in its formulation. Indeed, story-problems can present narrative breaks when there are fractures between the mathematical dimension (problem structure) and narrative dimension.

Zan (2011, 2012) introduced the C&Q (Context and Question) model, which emphasises the characteristics that a story-problem should have to evoke students' knowledge and foster the problem-solving process. According to the C&Q model the information presented in a story-problem should make sense in a narrative framework; there should be a temporal dimension in which the story takes place; there should be at least one character (protagonist) who acts to achieve one or more purposes, which have not yet been achieved; and the story should provide for a continuum that the answer to the question suggests. Continuity with the story is lost if the question is not asked in context and does not refer to the character's purposes. As Zan observed, "If the final question does not emerge narratively from the story, students who approach the problem with a narrative approach will tend to answer a question suggested by the story or, in the absence of a natural question, try to complete it" (Zan, 2012, p. 441, authors' translation). The mathematical problem, therefore, must be verisimilar and arise spontaneously from the story. An example of (re)formulating a story-problem into a striped problem is described by Zan (2012) and is shown in Table 1.

Table 1
An Example of (Re)formulation of a Striped Problem (Zan, 2012).

Original version of the story-problem (Zan, 2012, p. 447, authors' translation)	Reformulation (Zan, 2012, p. 449, authors' translation)
To prepare a peach marmalade, grandmother used 10 kg of peaches and 5 kg of sugar. The resulting marmalade (removing the scraps and taking into account the cooking) is 3/5 of the initial weight of peaches and sugar. How many jars with a capacity of 250 grams did grandmother use?	Also, this year grandmother wants to make jam together with her granddaughter Martina with the fruit from her garden that she likes so much: they have harvested as many as 10 kg of peaches, and to make the jam it is necessary to add 5 kg of sugar, as the recipe says. Martina is all happy: "Grandma, can you imagine? So much jam just for me!" and Grandma says to her, "See that you don't eat it all in a month! Anyway, when we take out the scraps and bake everything, we will have about 3/5 of the total initial weight of peaches and sugar left! In fact, do a favor. Go get the jars from the basement so I can wash them thoroughly before I put the jam in them; get the ones on the bottom shelf, 250 grams." Martina is happy to do her grandmother a favor, but she doesn't feel like making unnecessary trips. She needs to find a way to figure out how many jars she needs. Can you help her?

The first column of Table 1 shows the original version of the problem (Zan, 2012, p. 447). In the context, a character ("the grandmother") who has a purpose ("to prepare a peach jam") is described. However, this is not a striped problem in Zan's sense since answering the question, "How many jars with a capacity of 250 grams did grandmother use?" is not useful for the character to achieve her purpose, which has already been achieved in the narrated context. To make it a striped problem, it needed to be reformulated. The second column of Table 1 shows a possible reformulation proposed by Zan (2012, p. 449): the character is no longer grandmother but "granddaughter Martina", whose purpose is to get the necessary jars, "to do her grandmother a favor" but without making "unnecessary trips"; narrative details were added (e.g., jars to be taken "from the basement") with the aim of calling out the student's knowledge of the world and making the character's purpose and the story more understandable and shareable; the narrative tenses were changed from past to future so that answering the question is useful for the character's purpose. In a striped problem, there is a close connection between the question and the story. Thus, students' understanding of the story will be fostered, as well as the problem-solving process.

Inclusive Striped Problems

An inclusive striped problem (Figure 1) is a story-problem structured in accordance with Zan's C&Q model, with regard to the narrative aspect, and in accordance with the first principle of UDL (multiple means of representation), with regard to the inclusion aspect (Dello Iacono & Vivarelli, 2023).

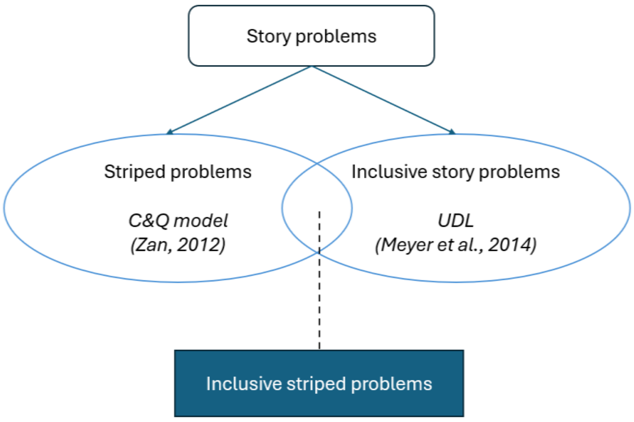

Figure 1. Inclusive striped problems model.

It is possible to create inclusive striped problems, either by starting with a narrative problem and then making it inclusive according to the UDL framework, or vice versa (see Figure 1). For the purposes of this research, it is proposed that the first possibility is the most effective one because the narrative form of the inclusive problem can itself be seen as a different representation of the problem, in accordance with the UDL framework (CAST, 2024). From this point of view, the UDL framework can be understood as a broader framework, within which Zan's C&Q model can fit. The use of the C&Q model can be seen as the first (but essential) step toward the development of an inclusive mathematical problem.

In implementing multiple means of representation, the teacher may propose the text of a mathematical problem by providing different options for perception (e.g., intervening on the font or size of the text, images, graphs, and other visual content; contrast between background and text or image; color used for information or intensity; volume or speed of speech or sound speed or synchronisation of video, animation, sound, simulations, speech synthesis software); or multiple options for mathematical expressions and symbols (e.g., a chart, map, hyperlinks, illustrations, translations); include supports for unfamiliar references within the text (e.g., specific symbols, properties and theorems, figurative language, mathematical language). Then, in the presence of specific disabilities, the teacher may provide a compensatory representation of the mathematical problem with respect to the specific disability. For example, in the case of low vision or blindness the teacher may provide alternatives such as Braille texts to support verbal communication; haptic equivalents that simulate touch; or typhlo-didactic tools that support tactile exploration.

In the case of reformulation as a striped problem in Table 1, other forms of representation could be provided to introduce the striped problem in a multimodal way according to the UDL principle of representation, thereby creating an inclusive striped problem. For example, comic strips could be used to replace part of the text, such as data and problem information. The comics could be accompanied by a speech synthesiser that can read the content. This can help, for example, dyslexic or visually impaired students. In addition, if there is a foreign student in the class, a translation of the text can also be provided. Also, this type of layout can capture students' attention and can be useful for students diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD). There are many possibilities for the multi-presentation of the mathematics problem.

Methodology

The research methodology employed was design-based research (Design-based Research Collective, 2003) with a focus on Task Design (Canogullari & Radmehr, 2026; Watson & Ohtani, 2015). Task Design methods are based on the idea that mathematical tasks represent the primary mediator between teaching and learning. From this perspective, Task Design emerges as a particularly effective approach for investigating pre-service teachers' thinking, as it allows for an integrated analysis of the product (the tasks designed) and the process (the underlying decisions and rationales). Within this framework, pre-service teachers take on the role of designers of mathematical activity, mobilising both disciplinary and pedagogical knowledge, and developing the ability to anticipate students' strategies and to create meaningful learning opportunities. As evidence, researchers collect data in the form of tasks, lesson plans, materials, questionnaires, and interviews, and analyse them according to specific analytical criteria.

Research Context and Participants

The study involved prospective special education teachers attending the "Laboratory of Special Education: Codes of logical and mathematical language" (workshop below) as part of the "TFA Sostegno" program (specialisation course for prospective special education teachers), held at the University of Molise (Italy). The "TFA Sostegno" program lasted approximately 8 months and consisted of a total of about 800 hours, including 180 hours of workshops. The workshop described in this article was part of the regular program. All prospective special education teachers involved in the program were divided into groups based on their grade level. The participants in this study were prospective secondary (middle and high) school special education teachers (approximately half of the participants in the program). They took part in the workshop described below. All participants gave their consent to take part in the study.

By the time the workshop was held, the participants had already completed most of the hours required by the program. A total of 278 participants were involved in the workshop. Almost half of the participants had experience as special education teachers, and more than 30% had experience as discipline teachers. The participants were divided into two main groups: the first group was comprised of prospective middle school teachers, and the second group was comprised of prospective high school teachers. Both groups of participants took part in the same workshop. The first author of this article was the instructor of the high school teacher group, while the second author was the instructor of the middle school teacher group.

The Workshop

The workshop lasted 20 hours, divided into four sessions of 5 hours each. Each session took place over the course of a week. Therefore, the total duration of the workshop was one month. The aim of the workshop was, on the one hand, to help participants develop their skills in designing inclusive mathematics activities and, on the other hand, to encourage them to reflect on the importance of designing inclusive mathematics learning activities. The workshop consisted of four phases.

In Phase 1, participants were introduced to the theoretical content that inspired the workshop, namely story-problems and the C&Q model (Zan, 2011; 2012) and the UDL approach (CAST, 2018, 2024; Meyer et al., 2014), with particular reference to the principle of representation to design inclusive striped problems.

In Phase 2, participants were divided into groups of 5–6 members each. A total of 47 groups were created. Each group was given a few INVALSI mathematical problems (Italian national standardised tests administered by Istituto Nazionale per la Valutazione del Sistema Educativo di Istruzione e di Formazione). Each group was assigned a specific content area (Numbers, Space and Figures, Relations and Functions, Data and Predictions) and the task, for each group, was as follows:

- select an INVALSI problem related to your assigned content area;
- make it a striped problem in accordance with Zan's C&Q model;
- make the striped problem "accessible to all students" and provide for personalisation for specific disabilities, in accordance with the UDL approach;
- prepare a pptx or docx file that includes: the INVALSI problem you started with; the striped problem based on Zan's C&Q model; and the striped problem "accessible to all students," with any necessary personalisation for specific disabilities, in accordance with the UDL approach.

In Phase 3, each participant responded individually to a questionnaire administered anonymously through an online form. It was designed with the purpose of investigating the level of awareness gained by each participant during the workshop regarding inclusive educational design. The following were the questions from the questionnaire:

- To what extent did designing a striped problem offer you a new perspective on educational design? Justify your answer.
- To what extent did designing a mathematical problem according to the UDL approach offer you a new perspective on instructional design? Justify your answer.
- To what extent did the proposed activity raise your awareness of the importance of inclusive instructional design in mathematics? Justify your answer.
- How much did the proposed activity help you recognise the importance of the teacher as a "designer" of inclusive activities in mathematics education? Justify your answer.
- How might this course impact your work as a prospective support teacher? Justify your answer.

Each question required participants to first express a numerical value (Likert-type scale) from 1 to 5 and then justify their response. Open-ended questions were included because:

> … it is open-ended responses that might contain the "germs" of information that otherwise might not have been caught in the questionnaire (…). An open-ended question can capture the authenticity, richness, depth of response, honesty and candor, which are the hallmarks of qualitative data. (Cohen et al., 2007, p. 249).

The anonymous individual feedback questionnaire was administered before the presentation of the group work in Phase 4 to prevent discussion of each person's work from influencing others' ideas. In Phase 4, each group had about 10 minutes to present their work to all participants in a plenary session, showing the file they had created in Phase 2.

Data Collection and Analysis Criteria

In order to answer the research question, both the final designs of the groups carried out in Phase 2 and the responses to the questionnaire administered in the Phase 3 of the workshop were analysed. In particular, we analysed the extent to which groups, in their designs considering specific items:

a) Item a: referred to the C&Q model, that is, (i) the information presented in the story-problem makes sense in a narrative framework, (ii) there is a time dimension in which the story takes place, (iii) there is at least one character who acts to achieve a purpose, and (iv) answering the question serves the character's purpose;
b) Item b: included multiple means of representation to facilitate access to information about the problem; and
c) Item c: provided for elements of personalisation for specific disabilities.

For each of the three items, the designs of each group were coded by assigning a value of 1 to designs that met the characteristics of that specific item, and 0 otherwise. This provided codes in the form of triples, where the first value referred to item a), the second value to item b) and the third to item c). For example, the triple (1,1,1) identifies a design that is an inclusive striped problem, i.e., a project that simultaneously satisfies all the characteristics of striped problems a), includes multiple means of representation b), and includes personalisation elements c). The triplet (0,1,0) identifies a design that does not meet all the characteristics of striped problems (i.e., it is not a striped problem), includes multiple representations, and does not include personalisation elements. The triplet (1,0,0) identifies a design that meets all the characteristics of striped problems, does not include multiple means of representation, and does not include personalisation elements, and so on.

In addition, the participants' responses to the questionnaire were analysed using deductive content analysis (Mayring, 2015). The deductive application of categories operates through analytical dimensions formulated *a priori* and systematically derived from theoretical frameworks, which are subsequently related to the text. In this approach, the qualitative phase of the analysis comprised of a methodologically controlled assignment of these categories to specific textual passages. Specifically, we collected all the participants' answers to the five questions in the questionnaire administered in the Phase 3 in a spreadsheet. We analysed these answers, scanning texts for explicit or implicit references to: the C&Q model (narrative aspects such as story, characters, context, purpose); multiple representations (multimodality, visual/audio channels, alternative forms of representation); personalisation related to specific disabilities. Each participant's responses across all questionnaire items were considered as a single textual unit.

Results

In this section, the results from the analysis of the groups' designs completed in Phase 2 of the workshop are presented. This is followed by the deductive content analysis of the participants' responses to the anonymous questionnaire administered in Phase 3 of the workshop.

Results of the Analysis of Group Designs

The groups of participants (47 groups) created story problems covering different content areas (Numbers, Space and Figures, Relations and Functions, Data and Predictions). Most of the story problems fell under the Numbers content area: 19 groups in Numbers, 12 groups in Data and Predictions; 10 groups in Relations and Functions; only 6 groups in Space and Figures.

Some of the problems created were not striped problems; but many were. A striped problem non-example is the following story-problem proposed by Group 1. In the story-problem there are two characters, Antonio and Giada, who seem to have a purpose, namely, "win the title of math champions." However, answering the questions, "What is the score that Antonio gets? What is the score that Giada gets?" in the problem does not serve the characters to achieve that purpose. Therefore, it is not a striped problem according to Zan's C&Q model.

Antonio and Giada, two secondary school students from Campobasso, leave for Rome for the finals of the math Olympiad. Since they turned out to be the best in their school they will compete against other kids from the school in Florence, Italy, to win the title of math champions. The competition involves solving closed-ended math questions. Two points are awarded for each correct answer, and one point is deducted for each incorrect answer. Antonio answers eleven questions correctly and gets the other nine wrong; Giada answers six questions correctly and gets the other fourteen wrong. What is the score that Antonio gets? What is the score that Giada gets?"

Figure 2. Story-problem proposed by Group 1.

Group 2 created a striped problem (see Figure 3). Indeed, all the requirements in Zan's C&Q model were met. Moreover, a group member stated,

> *There is a severely visually impaired student in the class and therefore it is planned to make the problem accessible, to her and all her other classmates, with the use of alternative forms so as to make it understandable through the use of different channels: auditory, visual, etc.*

Therefore, the group provided multiple problem representations and personalisation for the student with disabilities. First, the group planned "a podcast so to be listened to by the visually impaired student and all her classmates." In addition, "the text of the problem is translated into Braille to facilitate the visually impaired student present in the class; this further makes the understanding of the problem accessible, and the student can choose the mode he prefers." Moreover, the group planned:

> *to create a three-dimensional model representing the physical elements of the problem. This provided further accessibility to the student and her peers, through tactile reading of the space and figures. In addition, it is possible to provide a class activity for the making of the model that is useful for improving and increasing inclusiveness and improving the classroom climate through a common activity. The*

student and her classmates can factually provide for the placement of the sunbeds under the umbrellas so as to solve the problem with elements of a concrete nature.

In this way, an inclusive striped problem was created by the group, with different representations and personalisation (podcast, Braille, artefact "with elements of a concrete nature").

Off on vacation!!!

Cristian left for vacation with his family and joined his cousin Michael, who works as a lifeguard at the Hotel "Il Gabbiano" in Rimini. As soon as he arrived, he arranged his things in his room and looked out onto the beautiful terrace from which he could see the sea and the beach. The beach is tiny, there are a total of 5 rows of umbrellas: 3 rows have 6 umbrellas and the other 2 rows have 5 umbrellas. This can also be seen in the photo Cristian took from the terrace.

From the terrace, Cristian looks at the beach and sees his cousin Michael working and waves for him to join him. Cristian goes down to the beach and finds Michael setting up the sunbeds under the umbrellas. Cristian wants to help his cousin. There is room under each umbrella for a maximum of 2 sunbeds.

Michael and Cristian together manage to place a total of 38 sunbeds. At the end of the day, to organise the next day's work, Michael asks Cristian under how many umbrellas they placed 2 sunbeds. He helps Cristian answer his cousin's question.

Figure 3. Story-problem proposed by Group 2.

Table 2 below shows the extent (percentage) to which groups referred to the C&Q model, multiple representations and aspects of personalisation in their design, according to the analysis criteria above. The table shows that multiple means of representation reached a 100% success rate at value 1, indicating that all participating groups were able to effectively implement multimodal strategies (such as visual or audio channels) to convey mathematical information. This suggests that the concept of multimodality was well-internalised by participants as a fundamental pillar of accessible design.

Table 2

The Extent (Percentage) to Which Groups Referred to the C&Q Model, Multiple Representations and Personalisation in Designs.

Value	C&Q model	Multiple representations	Personalisation
0	44.7%	0%	37%
1	55.3%	100%	63%

Regarding the C&Q model, more than half of the groups (55.3%) succeeded in designing striped problems by satisfying all the characteristics of the C&Q model (e.g., Group 2, see Figure 3). Approximately 45% of groups created story problems at value 0 that did not meet all the criteria for a striped problem. This means that nearly half of the groups (21 out of a total of 47) did not create striped problems. Their greatest difficulty was not in creating a narrative (all groups imagined characters and a story with a time dimension in which the story takes place), but they had difficulty connecting the question to the purpose of the characters (e.g., Group 1, see Figure 2).

Regarding multiple means of representation, all groups (see Table 2) provided at least two representations of the data. The most frequently used representations were text with pictures, comics, and audio files. In addition, most groups (63%) provided personalisation for specific disabilities. Examples include the Braille language for visually impaired students and material artifacts (e.g., sticks, straws, tiles). The results relating to personalisation reflect a solid, if not general, ability to adapt projects to specific disabilities.

Table 3 shows the percentages for each of the eight possible groupings (see section "Data collection and analysis criteria"). The data included show that the groupings (1,0,0) and (1,0,1) are empty. This means that all groups that designed problems of value 1 with respect to the C&Q model (Item a, first value of the triplet) also included multiple means of representations (Item b, second value of the triplet). Thus, there were no groups that created story problems according to the C&Q model without multiple representations. In addition, only 12.8% of the designs were in the grouping (1,1,0). This means that six groups designed problems according to the C&Q model (Item a, first value of the triplet) and included multiple means of representation (Item b, second value of the triplet) but did not address personalisation. The grouping with the highest frequency is (1,1,1) which reached 42.5%. This grouping (1,1,1) designed inclusive striped problems, which are value 1 with respect to each item (C&Q model, multiple means of representation, and personalisation).

Table 3
The Percentage for Each of the Eight Possible Design Types

(0,0,0)	(0,0,1)	(0,1,0)	(0,1,1)	(1,0,0)	(1,0,1)	(1,1,0)	(1,1,1)
0% *0 groups*	0% *0 groups*	23.4%, *11 groups*	21.3% *10 groups*	0% *0 groups*	0% *0 groups*	12.8% *6 groups*	42.5% *20 groups*

Results of Deductive Content Analysis

Table 4 provides a quantitative overview of the deductive content analysis conducted in accordance with the analysis criteria described in section, "Data collection and analysis criteria." The results in Table 4 show that a substantial proportion of participants referred explicitly to key dimensions of inclusive mathematics design in their written responses. References to the narrative dimension of problems, associated with the C&Q model, were the most frequent, suggesting that story, context, and characters were particularly salient for participants when reflecting on accessibility and meaning in mathematics. A similar number of participants referred to multiple representations and to personalisation for specific disabilities, indicating an emerging awareness of accessibility both at a universal level (through multimodality) and at a more targeted level (through adaptations for specific needs). Although these references were not present in all responses, the analysis of the percentages shown in the Table 4 highlights that core elements of the theoretical framework were spontaneously taken up by a substantial subset of participants, supporting the relevance of these constructs in participants' reflective discourse.

Table 4

Frequency of Participant References to Inclusive Striped Problems Dimensions in Written Responses

Reference to C&Q Model (story, narrative, characters, context)	Reference to multiple representations	Reference to personalisation for specific disabilities
64 participants (23%)	57 participants (21%)	56 participants (20%)

Narrative dimension and references to the C&Q Model

A substantial number of participants explicitly referred to the narrative dimension of mathematical problems, emphasising the role of stories, characters, and meaningful contexts in fostering understanding. Several responses stressed that transforming a mathematical problem into a story makes mathematics more accessible and comprehensible, particularly for students who struggle with abstraction. For instance, one participant wrote:

> *Transforming a mathematical problem from school into a real-life problem allows us to look at the problem from a different perspective. In my opinion, this means giving it time, space, a story, protagonists - in short, bringing it to life. This allows us to make sense of the problematic situation, which becomes an experience to be lived and faced.*

Another participant similarly observed that:

> *Through this new method, I was able to understand how important it is, in problem solving, to contextualise the problem in tangible, narrative situations, with events described in temporal dimensions, where we find the causal links between the subject and personal purposes.*

These excerpts point to an implicit understanding of key aspects of Zan's C&Q model. Although the model is not always explicitly named, participants' references to characters with intentions and to the meaningful emergence of the question from the story reflect core C&Q principles. The emphasis on "*an experience to be lived and faced*" suggests that participants recognised narrative coherence as a mediator between everyday experience and mathematical reasoning, supporting students' sense-making processes rather than merely guiding them toward a numerical result. The importance of "*contextualising the problem in tangible, narrative situations*" resonates with the principle that when a mathematical question is coherently embedded within a narrative, students are encouraged to engage deeply with the situational context of the problem. Rather than approaching the task as a purely procedural exercise, this narrative alignment fosters a more authentic connection to the problem-solving process, transforming the mathematical challenge into a meaningful goal for students.

Multiple representations and multimodality

Participants also frequently referred to the importance of presenting mathematical content through multiple representations. These references often highlighted multimodality as a means of enhancing accessibility and supporting different learners. Visual, auditory, and alternative symbolic representations were described as complementary tools that allow students to access the same content through different channels. Such responses align closely with the UDL principle of multiple means of representation. Participants did not frame multimodality as a remedial strategy aimed solely at students with difficulties, but rather as a general design principle that benefits the whole class. This was evident in comments such as:

> *Ways of presenting information that can be implemented can be helpful for all students, not just those with disabilities.*

For example, one participant wrote that:

> *According to the UDL approach, the problem becomes accessible to everyone and allows different options to be provided to all students for learning information, acting on different perceptual channels.*

Another participant emphasised that multimodality helps to:

> *Understand and reflect on all aspects to be taken into account in order to design content that is accessible to everyone, reducing barriers to learning, adapting content, and providing multiple presentations and forms of engagement that encourage motivation to learn.*

Analytically, these statements suggest that participants were beginning to conceptualise representation as a central component of inclusive design. By acknowledging that mathematical meaning can be accessed through diverse modes, participants implicitly challenged the dominance of text-based and symbolic representations traditionally associated with mathematics instruction. In doing so, they articulated a view of accessibility that is consistent with UDL's emphasis on flexibility and proactive design.

Personalisation for specific disabilities

In addition to general representational strategies and in accordance with the UDL approach, many participants explicitly addressed the need for personalisation in the presence of specific disabilities. References to students with special educational needs were common, and participants often mentioned concrete tools and adaptations designed to meet these learners' needs. One participant wrote that personalisation is:

> *An excellent solution for simplifying the understanding of mathematical problems, which are sometimes difficult for students with SEN* [Special Educational Need]*, SLD* [Specific Learning Disorders]*, or H* [students with disabilities] *to understand.*

Another noted that:

> *UDL enables the implementation of the principle of personalization in curriculum design and aims to respect individual differences and eliminate the labeling of students (H, DSA, ADHD, BES, etc.).*

This emphasised how UDL enhances personalisation, the concept of inclusion, and every individual's right to education. These examples illustrate that participants viewed personalisation as a necessary extension of inclusive design rather than as an afterthought. Importantly, several responses linked personalisation to professional responsibility. For instance, one participant stated that:

> *The teacher must be able to design inclusive activities adapted to the specific needs of all students in the class.*

This comment highlights an emerging awareness of the teacher's role as a designer who must anticipate and respond to different educational needs. From an analytical point of view, these reflections indicate that participants understood personalisation as an integral part of the UDL framework, which aims to encourage the design of activities that are accessible to all, combining universal and individualised approaches, while also taking into account the presence of special educational needs.

Discussion and Conclusions

This study investigated the following research question:

> *To what extent do prospective special education teachers refer to aspects of the C&Q model, multiple representations, and personalisation when designing inclusive striped problems and reflecting on inclusive educational design in mathematics?*

By integrating narrative problem design with the Universal Design for Learning (UDL) framework (CAST, 2018, 2024), the study aimed to explore how preservice teachers engage with inclusive mathematics design as an intentional and reflective process.

The findings showed that all participating groups incorporated multimodal strategies in their designs, and a substantial proportion of individual participants explicitly referred to multimodality in their reflective responses. This suggests that the idea of accessibility through diverse representational modes was readily appropriated by participants and perceived as a central component of inclusive mathematics education. Such findings align with previous research highlighting the relative accessibility of UDL principles for teachers and their effectiveness in fostering inclusive instructional practices (Craig et al., 2022; Lambert, 2021).

In contrast, engagement with the narrative dimension of mathematical problems, as formalised in Zan's C&Q model, proved more challenging. Although all groups were able to construct story-based problems with characters and contexts, only just over half (55%) succeeded in designing striped problems in which the mathematical question coherently emerged from the characters' purposes. This difficulty was also reflected in participants' reflections, where narrative elements were often emphasised in intuitive or experiential terms, but not always translated into structurally coherent problem formulations.

Personalisation for specific disabilities occupied an intermediate position. A majority of groups included targeted adaptations, and many participants explicitly referred to personalisation in their reflections. Importantly, personalisation was often framed as a part of universal design. This indicates that participants were beginning to articulate an inclusive perspective in which multimodality provides a general architecture for access, while personalisation addresses specific needs within that architecture. Such a view is consistent with contemporary inclusive mathematics education literature, which emphasises the integration of universal and individualised approaches (Lambert et al., 2021).

Taken together, these findings suggest that participants developed an emerging awareness of inclusive mathematics education as a design-oriented practice, in which narrative coherence, multimodal access, and personalisation are interconnected. This awareness was evident not only in the design products but also in participants' reflective discourse, supporting the idea that engaging preservice teachers in design tasks can foster professional learning beyond procedural competence (Scherer & Bertram, 2024).

The study contributes to the literature in several ways. First, it provides empirical evidence of how the C&Q model and UDL can be meaningfully integrated in preservice teacher mathematics education, offering a concrete operationalisation of inclusive mathematics design through the notion of inclusive striped problems. While previous research has separately documented the benefits of narrative problem solving (Zazkis & Liljedahl, 2009) and multimodality (Arzarello, 2006; Arzarello & Robutti, 2008; Ferrara, 2014), this study highlights the productive interplay between these approaches within a unified design framework. Second, the study extends research on teacher education for inclusion by focusing on special education teachers' role as designers of mathematics learning environments, rather than as providers of compensatory support (Padilla et al., 2024; Tan et al., 2022).

At the same time, the results also point to important directions for future research. The fact that only just over half of the participants (55%) were able to complete the task satisfactorily with respect to the C&Q model indicates that narrative coherence cannot be taken for granted. Designing mathematically meaningful stories that align characters' purposes with the problem question appears to be a demanding cognitive and pedagogical task. While storytelling is considered by participants to be a pedagogical resource (Zazkis & Liljedahl, 2009), the results show that the critical use of the C&Q model requires more consistent and explicit support. This suggests the need for further research into instructional approaches that more explicitly support teachers in developing narrative competence in mathematics, possibly through extended training, iterative design cycles, or explicit analysis of "narrative breaks" that hinder problem understanding (Zan, 2011; 2012).

From an educational perspective, the findings have several implications. Teacher education programs should explicitly address narrative structure as an epistemological dimension of mathematical problems, not merely as an engagement strategy (Walters et al., 2018). Moreover, integrating UDL principles into mathematics teacher education can help future teachers move beyond reactive accommodations toward proactive, inclusive design (Cottini, 2019; Lambert, 2021). For special education teachers in particular, developing confidence and competence in mathematical design is crucial, given their central role in promoting accessibility for all students (Baccaglini-Frank, 2022; Lambert, 2020; Morselli & Robotti, 2023; Scherer, 2021).

In conclusion, this study shows that engaging preservice special education teachers in the design of inclusive striped problems can foster awareness of inclusive and accessible mathematics education grounded in narrative coherence, multimodality, and personalisation. While the results are promising, they also highlight the need for further research and professional development focused on the narrative foundations of mathematical problem solving.

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Ethical approval

Ethical approval was granted by the University of Campania "L. Vanvitelli" Department of Mathematics and Physics Ethics Research Committee for the data to be reported. Human subject research approval was obtained as protocol RP-01-01-2023. Participants consented to collecting and processing data for research purposes.

Competing interests

The authors declare there are no competing interests.

Data availability statement

The data that supports the findings of this study are available from the corresponding author, upon request.

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