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Narrativity and Climate Change Education: Design of an Operative Approach

Emma D'Orto * and Giulia Tasquier

Department of Physics and Astronomy "A. Righi", Alma Mater Studiorum—University of Bologna, 40127 Bologna, Italy; giulia.tasquier2@unibo.it

* Correspondence: emma.dorto2@unibo.it

Abstract: Narratives are intrinsic to how humans make sense of the world, helping us structure experiences, interpret complex phenomena, and construct meaning. This sensemaking capacity makes narratives particularly relevant for climate change education (CCE), where learners must navigate global challenges, engage with uncertainty and envision sustainable futures. Yet the characterisation of narratives remains conceptually ambiguous, presenting challenges for leveraging their educational potential. This study addresses this research problem by posing the question: *How can we develop an operational definition of narratives for CCE that effectively unpacks the complexity of narrative as a way of thinking and enables analysis and comparison of narrative features for educational purposes?* Grounded in Bruner's theory of paradigmatic and narrative modes of thought, this paper introduces a four-layer framework for categorising narratives based on their "narrativity". By demonstrating its practical application through an example, this study offers a tool for recognising, selecting, and/or designing narrative forms that align with diverse educational purposes, laying the ground for future research and practices in CCE.

Keywords: climate change education; narratives; narrative thinking; operative approach; literary studies; narrative analysis

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1. Introduction

The climate change (CC) crisis represents one of the most pressing global challenges of our time, demanding not only scientific and technological solutions but also transformative shifts in education, policy, and societal attitudes [1]. The sheer complexity and uncertainty of CC require individuals and communities to make sense of intricate scientific data, navigate ethical dilemmas, and envision sustainable futures. In this context, marked by the impelling need to develop innovative approaches to address the complexity of the issue, narratives emerge as a valuable tool, offering a means to structure experiences, interpret complexities, and connect abstract phenomena with human values and emotions. Indeed, in recent decades, narratives have garnered increasing attention as instruments for conceptualising and engaging with climate-related issues across a wide range of fields. Despite this, considerable ambiguity persists regarding the definition and use of the term "narratives", which is applied inconsistently across disciplines, encompassing a spectrum of concepts and artefacts. This ambiguity risks diluting the educational value of narratives, particularly when it comes in the context of Climate Change Education (CCE). Indeed, while narratives are frequently heralded for their capacity to engage audiences, foster empathy, and bridge knowledge gaps, their application in educational contexts often lacks a systematic framework to capture their potential in contributing a cognitive dimension,

such as their recognised effectiveness in contributing to CC scientific inquiry by framing data in ways that elucidate causal relationships and implications [2,3].

As Ryan [4] argued, the recent popularity of "narrative" risks diluting its meaning, conflating it with broad notions like "belief", "experience", or "human perspective". Identifying a space of definition for "narratives" as well as highlighting narrative elements—such as temporality, causality, and events—is essential in order to prevent such dilution and to point out the multifaceted role of narratives in CCE, such as sensemaking, fostering imagination and agency, and framing CC as a temporal and causal challenge [5,6]. Many scholars have already attempted to define essential narrative features, but rigidly delineating these criteria risks excluding narrative forms that hold educational value. Conversely, adopting an overly inclusive definition risks portraying all narrative artefacts as equivalent, which may overlook the unique capacities that certain features hold for representing climate complexities and guiding CCE initiatives [7].

The hypothesis underlying this study is that the role of narratives within CCE could be informed and clarified by moving the focus from their significance as representation and communication tools to their status as artefacts connected to a specific kind of thinking, with its own strengths and limitations. This study aligns with Bruner's theory of dual modes of thought [8], which theorises narrative and logico-scientific thinking as irreducible and complementary cognitive processes, both indispensable and rich ways in which people "know" and "describe" the world around them: narrative thinking emphasises action, temporality, and verisimilitude of human experience, while paradigmatic thinking focuses on logic, abstraction, and verifiability [8]. In Bruner's conception, narrative mode can be operatively defined as the capacity to create or critically evaluate narrative artefacts, such as scientific thinking which can produce and evaluate 'well-formed scientific arguments' [8].

This study aims to initiate investigation into how this operates within the context of CC. It does so by proposing a new theoretical characterisation of CC narratives, grounded both in science education research literature and literary studies, constituting the first phase of a larger project. This specific research forms part of a larger initiative—situated within the EU-funded project CLIMADEMY (https://climademy.eu/ (accessed on 11 November 2024))—which investigates how a narrative approach can cultivate consciousness, imagination, and attitudes necessary to navigate the uncertainties surrounding CC.

This study has been especially informed by the literary concept of "narrativity", employed to build a framework that unpacks the complexity of CC narrative features in four hierarchical but interconnected layers, and clarifies their positioning in regard to a paradigmatic/narrative thinking spectrum. The framework has been adapted as a tool with the aim of informing the design of narrative-thinking-enhanced CC courses and the selection of those narrative artefacts that best address CC's specific educational challenges.

Grounded in Bruner's perspective, throughout the paper we will mostly use the terms "narrative" and "narrative thinking" rather than their synonyms "story" and "storytelling", because the latter (within narrative theory) carry more restrictive and specific literary technical meanings [9]. Additionally, in common discourse, storytelling is often associated with practices aimed at crafting argumentations in the form of a story for engagement boosting or persuasion, while we are concerned with "narrative" as that "type of discourse characteristic of stories", and "narrative thinking" as a mode of thought with a distinctive form [8,9].

The article is organised as follows: the first part of the article (Section 2) presents the theoretical foundation of the study, it contextualises the second part of the article, where we present the design of our new definition in the form of an operative theoretical tool (Section 3) and present a selection of artefacts positioned through it (Section 4). To

conclude, we discuss potentialities, limitations and possible future research directions (Sections 5 and 6).

2. Theoretical Framework

This chapter lays the theoretical foundation for our exploration of narratives in CCE, examining how narrative thinking can enrich educational practices and foster deeper engagement with climate issues. Section 2.1 delves into the established and emerging roles of narratives within CCE, highlighting their ability to humanize science, challenge stereotypes, and stimulate ethical discourse. Section 2.2 offers a comprehensive examination of the various definitions and frameworks of "narrative" drawn from science education and literary studies, underscoring the multifaceted nature of narrative as both a cognitive tool and a communicative device. Finally, Section 2.3 articulates our research question, setting the stage for developing an operational definition of narratives that can effectively capture their complexity and utility in CCE.

2.1. Narratives in Climate Change Education

Narratives are well-established tools in science education and communication, especially known for their potential to engage and convey complex issues in accessible and emotional ways [3,10]. Common approaches in science education, such as the use of storytelling techniques to foster students' engagement and historical narratives with the objective of humanising science, counteracting stereotypes, and fostering ethical discourse [11–16], all translate effectively when dealing with wicked problems or socio-scientific issues, like climate change, sustainability and artificial intelligence (https://iseeproject.eu/ (accessed on 11 November 2024)). For example, illustrating CC science development, the environmental impact of humanity, or CC policy changes over time could help students in recognising climate change as a multidimensional issue encompassing scientific, social, and political perspectives. Developing from that hypothesis, some recent literature [16–19] has investigated and shown how narratives hold a broader potential in the fields of CC, uniquely engaging with the urgency of imagining sustainable futures and rethinking humanity's role within a complex, interconnected and uncertain world. In the arts and literature, particularly through the science fiction genre, narratives have revealed great power in envisioning alternative futures [19,20]. Yet, this imaginative power now collides with the pressing need to render these futures more tangible and to transcend the dystopian stereotypes often associated with the genre [20,21]. To address CC in a realistic way, as Indian writer Amitav Ghosh points out [20], the novel (today's most influential literary form) faces inherent challenges, struggling to depict key elements such as non-human agents, long-term processes, and extreme events. While other authors are investigating the potential of various traditional and emerging genres [21], for CCE purposes it could be interesting to notice that within climate change hard sciences, narratives are increasingly used to address these very challenges Ghosh highlighted. The storyline approach, for instance, unlike a risk-based approach, emphasises narrative-based explanations to analyse past events, such as extreme weather impacts, and construct long-term future scenarios, while an educational approach has recently been investigated in regard to the possibility of developing sustainability skills [22]. Unlike literary narratives, which often grapple with representing complexity, scientific narratives leverage on that to explore temporal and causal relationships and provide actionable insights to support decision-making processes. This use of narratives highlights their role as cognitive tools for understanding and generating knowledge within scientific domains and as a form of scientific inquiry suited to adaptation for educational purposes To clarify and expand the potential of narratives in CCE, we can look at narrative as a complex and stratified concept that shows different potential and limits for CC representation and

investigation depending on the aspects we leverage. This aligns with the literature review of Soares et al. [15], arguing that rather than a simplistic "narrative effect", learning from science narrative texts should be approached as a multitude of narrative effects that capture the interactions between the different elements of narrative and learning. The hypothesis at the basis of this study is that narratives' strengths and limitations for climate change education (CCE) could be clarified and handled by aligning with Bruner's theory of dual modes of thought [8], which theorises narrative and logico-scientific thinking as irreducible and complementary cognitive processes, both indispensable and rich ways in which people 'know' and 'describe' the world around them. The existing definitions of narratives often lack the theoretical tools to systematically characterise narratives based on their capacity to function as modes of thinking.

Our study addresses this by proposing a novel framework that links narrative artefacts to narrative thinking, individuating key narrative elements and aligning them with specific educational roles and objectives. Drawing on insights from the humanities and social sciences, we conceptualise narratives both as cognitive tools for "making sense" of experience [7,8,16,23] and as literary devices that organise events into meaningful patterns [16]. By integrating these perspectives, we aim to provide a tool to leverage narratives in ways that balance Bruner's paradigmatic and narrative modes of thought, fostering multidimensional sensemaking of climate change.

2.2. Framing and Defining Narratives

Within the areas of social sciences and humanities, disciplines such as linguistics and narratology have developed nuanced definitions of narratives, which science education and communication have both integrated and adapted while also creating their own field-specific interpretations. Those definitions range from well-structured frameworks to very vague or brief descriptions.

One of the most comprehensive frameworks is the Text Linguistic framework (TL) developed by Adam [24,25] and adapted within science education by Soares et al. [15]. This framework helps recognise and distinguish a narrative text from other text types (such as argumentative or expository). According to TL, texts are social objects shaped by the expectations and practices of their socio-cultural context. This means they are structured according to genres such as fable, scientific report, or cookbook, which are abstract models of what is to be expected and adopted in specific communicative situations [24]. Those genres influence both the so-called textual and pragmatic components of a text, which respectively refer to the internal structures that organise a text and the text's communicative purpose. [25]. In narrative texts, the content (an example of pragmatic components) includes elements such as settings, characters, plot (sequence of actions), conflicts, and theme. The textual and pragmatic components interact, making texts inherently variable and often "mixed". Materials only containing prototypical narrative features have likely been extracted from larger heterogeneous texts or carefully constructed that way for a specific pedagogical or experimental purpose. The TL framework shows the complex and inherent hybrid nature of texts, contextualising the existence of artefacts such as storyline scenarios, which incorporate narrative features even though they might not have an overall narrative structure and could not be perceived generally as narratives [15,24].

An alternative approach defines narratives by highlighting the key features typically associated with them. For example, Jerome Bruner [26] (p. 77) specifies four essential elements required for a text to be recognised as a narrative:

> "*Narrative requires, as mentioned in the preceding chapter, four crucial grammatical constituents if it is to be effectively carried out. It requires, first, a means for emphasizing human action or "agentivity"—action directed toward goals controlled by agents. It*

> *requires, secondly, that a sequential order be established and maintained—that events and states be "linearized" in a standard way. Narrative, thirdly, also requires a sensitivity to what is canonical and what violates canonicality in human interaction. Finally, narrative requires something approximating a narrator's perspective: it cannot, in the jargon of narratology, be "voiceless"*".

A simpler definition of the same kind could focus on just one feature of narratives, such as their typical beginning–middle–end structure. Costantino and Weber [18], for example, describe narratives as "stories about how the world works, what the future will look like, and our own role in this process", and Bushell et al. [27] argued that "at its basic level, a narrative can explain the situation, define a problem that disrupts the order of the initial situation and then provide a resolution to that same problem, which re-establishes order". Broad definitions of this kind have the potentiality to frame the climate crisis, the issue as a whole, in a structure that evokes a narrative but, at the same time, are so vague that they dilute the meaning of narrative into concepts like "worldview", "interpretation", "belief", or "attitude".

While providing valuable and useful insight into the typical features and roles of narrative, the definition of narrative discussed so far fails to encapsulate the potential of narratives as artefacts capable of fostering a specific way of thinking, such as individuating typical thinking skills that we employ to craft a narrative (or critically analyse one) as a way to make sense of a situation or a problem and thus to inform our future actions. An example of those skills is described by Fletcher in his book "Storythinking" [28] and includes, for example, "prioritizing the exceptional", "perspective shifting", which refer respectively to the analysis of (and speculation on) the role of contingencies and to imagine what it is like to be someone else in order to identify root causes of their behaviour [28].

A framework that avoids either overly strict or excessively broad definitions of narrative and, at the same time, describes narrative as a specific kind of "explanation" which is a product of a specific kind of scientific way of thinking, is offered by Norris et al. [11]. It identifies eight narrative features—narrator, narratee, events, past time, narrative appetite, structure, agency, and purpose—yet, unlike Bruner, does not treat these elements as necessary conditions. Instead, it suggests that there are degrees of "narrativity", emphasising events, past time, and agency as the core elements.

The concept of narrativity has been explored within literary studies in a more structured framework developed by Ryan in her "Theoretical Foundations of Transmedial Narratology" [4]. She proposes the following: "we can make a distinction between 'being a narrative' and 'possessing narrativity'. The property of 'being a narrative' can be assigned to any semiotic object produced with the intent of evoking a narrative script in the mind of the audience. (. . .) 'Having narrativity', on the other hand, means being able to evoke such a script, whether or not the author of the text/object intended to do so, and whether or not there is an author" [4] (pp. 6, 7). She then goes on to define this cognitive template through the following features, understood as conditions where each implies the preceding one [4]:

1. Narrative involves the construction of a mental image of a world populated with identified agents (characters) and objects (spatial dimension).
2. This world must undergo non-entirely predictable changes in state that are caused by non-habitual physical events: either accidents (happenings) or deliberate actions by intelligent agents (temporal dimension).
3. In addition to being linked to physical states by causal relations, physical events must be associated with mental states and events (goals, plans, and emotions). This network of connections gives events coherence, motivation, closure, and intelligibility and turns them into a plot (logical, mental, and formal dimension).

As illustrated in Figure 1, Ryan establishes a hierarchy among narrative elements, describing a narrative as an artefact that can be composed and elaborated by progressively adding layers of significance and meaning. That means that adopting her concept of narrativity not only blurs the line between what is or is not a narrative, but also traces a path that shows how some elements depend on others for their significance and how (as the level of narrativity increases) the complexity of the narrative structure also increases, progressively moving away from the possibility of explaining, interpreting, or representing a phenomenon through pure quantitative methods such as data and mathematical modelling. This is why Ryan's approach is particularly well-suited to being paired with Bruner's theory of **two modes of thought**, as it allows for a nuanced representation of **climate change (CC) narrative artefacts** along a spectrum between **paradigmatic and narrative reasoning**. At lower levels of narrativity, where temporality and causality remain closely tied to structured scientific reasoning, phenomena can still be interpreted and represented through **quantitative methods**, such as data analysis and mathematical modelling. However, as narrativity increases—incorporating more complex characterisation, subjective perspectives, and open-ended plot structures—representation progressively shifts toward **qualitative meaning-making**, where narrative thinking (rather than empirical abstraction) becomes the primary mode of understanding. This transition illustrates why CC narratives, when viewed through Ryan's framework, are not merely communication tools but also **modes of thinking** that complement scientific reasoning by enabling engagement with **uncertainty, ethical dimensions, and human experience**, aspects often resistant to purely paradigmatic approaches.

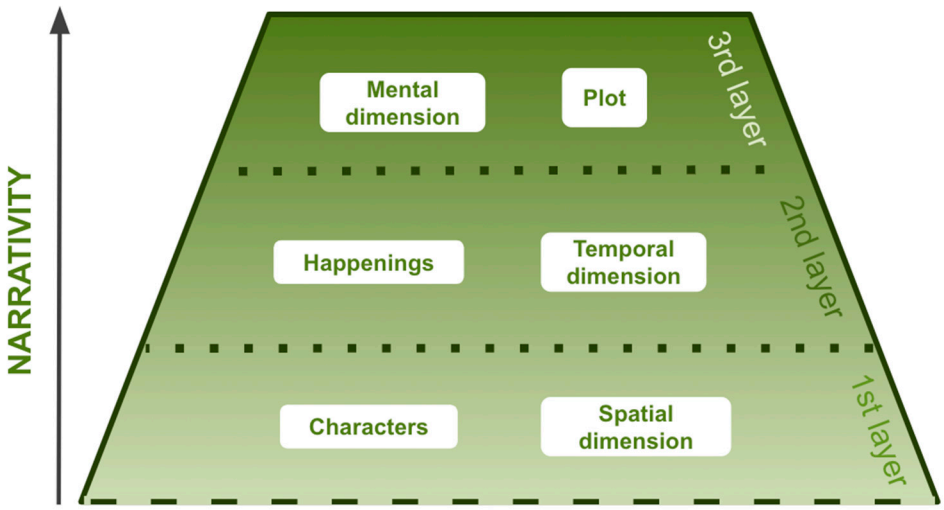

Figure 1. Ryan's narrativity framework. This figure illustrates Ryan's framework for characterising transmedial narratives through the concept of narrativity. Each layer is defined by two narrativity features and implies the ones below.

A final strength of the framework relies on its transmedial perspective, where "language" is understood broadly as any system of symbols—textual, visual, auditory, cinematic, or other—capable of representing and communicating meaning. This adaptability aligns with Claude Bremond's [4,29] view that narrative is independent from the media, since it may be transposed from one to another without losing its essential properties. The "cognitive template" linked to each narrativity layer highlights the connections between artefacts and the cognitive processes that are involved with working with it, making it suitable to describe narrative as a way of thinking [8,26]. On a more practical side, the value of the transmedial perspective lies in its capacity to include non-textual educational

materials frequently used in climate education, such as videos, graphic novels, games, infographics, scenarios, storylines, and mixed-media artefacts.

2.3. Research Question

In light of what was discussed in Sections 2.1 and 2.2, in this study we address the following research question (RQ):

> *How can we develop an operational definition of narratives for CCE that effectively un-packs the complexity of narrative as a way of thinking and enables analysis and comparison of narrative features for educational purposes?*

To address this RQ, the following two chapters aim to streamline this multifaceted debate by operatively summarising the different frameworks adopted in this paper, and to develop a theoretical tool. Specifically, the tool is designed to reveal CC artefacts' narrative complexity based on their narrative features and the related narrative thinking that is possible to foster through their use. This tool provides a structured method for analysing and organising narratives, especially by identifying their levels of narrativity, helping educators integrate diverse narrative forms and ways of thinking.

3. Design of a Narrativity Tool for CCE

The design process that led to the creation of our theoretical tool (Figure 2) is the result of pairing Bruner's perspective and Ryan's framework [4] to analyse the CC narratives landscape and achieve a new categorisation that highlights four different aspects of narratives and their significance as a way of thinking to balance paradigmatic thinking.

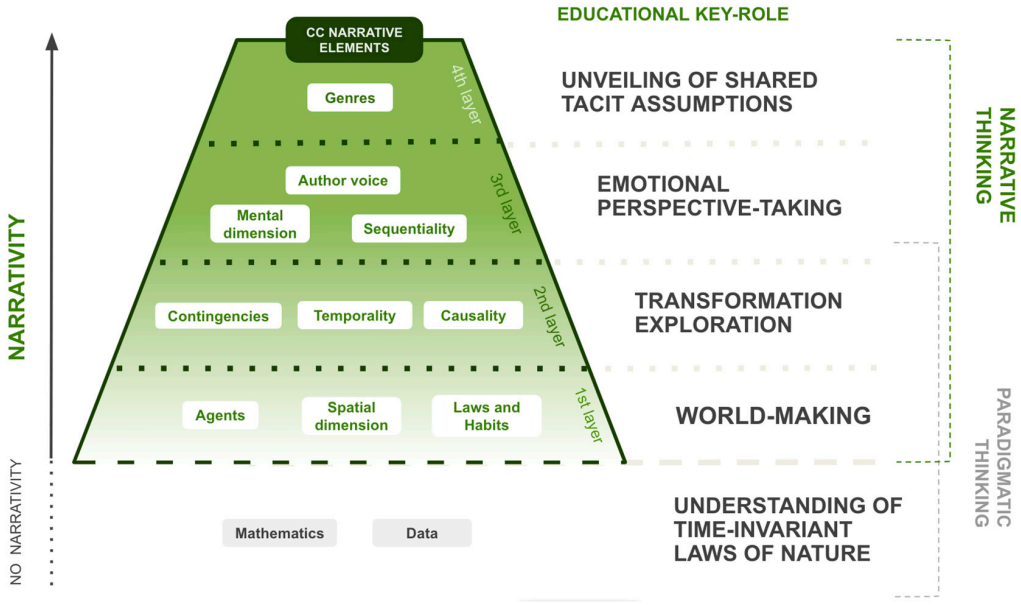

Figure 2. CC narrativity pyramid tool for CCE. This figure illustrates the multi-layered tool developed in this study to analyse the relevance of CC narratives for CCE through the concept of narrativity. It is structured into three hierarchical layers, each defined by typical elements. The dashed lines indicate the fluid boundaries between levels, allowing for hybrid narratives that may straddle multiple layers. The bottom layer includes non-narrative artefacts driven by paradigmatic thinking.

The three narrativity layers identified in Ryan's framework (Figure 1) have been adapted to fit CC, and a fourth layer has been added on top to highlight the aspect of genre and the distinct cultural influence that it has on narrative thinking. Looking at an artefact through the narrativity tool means that each narrative artefact can be defined by how many layers of narrativity it possesses, which is an indication of the complexity of

narrative thinking that can be activated by "working" with that artefact. Each layer is defined by specific narrative elements (the white boxes in Figure 2), which have been informed by those defined by Ryans, Norris, and Bruner and adapted for CCE. They can be considered as indicators: thus, typical but not essential elements of that layer. The four-level configuration does not imply that every narrative artefact fits exactly into one of the four levels of narrativity. In Figure 2, the dashed lines between the levels indicate that an artefact may straddle two levels, for example, by encompassing all the features of the levels below but only one or a few of the ones above. However, the concept of narrativity implies that it is impossible to have an artefact that has features of the upper layers but none of the ones below.

The area at **the bottom** of the tool, outside of the pyramid, represents hard sciences' CC artefacts linked to "pure" paradigmatic thinking and heavily characterised by mathematics and data. Artefacts of this kind focus on presenting knowledge about the *time-invariant laws of nature* and do not typically employ narrative elements. The line separating this area from the pyramid is dashed to indicate that, as the T-L framework theorises, artefacts (as texts) have an inherent hybrid nature. In other words, the narrative features and related thinking tools of low narrativity layers can be found in both paradigmatic and narrative artefacts. On the first and second layers, we will label as paradigmatic those that retain a strong link with mathematics and data, and so to the verifiability constraints of paradigmatic thinking.

The **first layer** of narrative thinking concerns "world-making". There are different interpretations of what that means [30]; in our case, it involves establishing and describing "what", "where", and "how" things work. This provides a coherent description of a world in a specific state when events unfold in a "predictable" manner. As Bruner suggests, both science and literature can be seen as forms of "world-making" [8,9]. While the bottom layer of paradigmatic artefacts is concerned with investigating and describing time-invariant laws of nature, at this layer they are concerned with describing the place-specific implications of those laws and/or time-specific natural/societal states of the organisation (habits) of that specific place. The same applies to narrative worlds, with the difference that, in such contexts, data and mathematical logic can be twisted (creating fictional or fantasy worlds), as long as the world maintains what Bruner calls "canonicality in human interaction". In line with this, three typical narrative elements characterise this level:

Laws and Habits: These describe "how" natural and social groups interact in that specific world. "Laws" are the time-invariant rules, while "habits" are the organisational ones that describe the state of a world at a specific moment. They can be scientific/fact-based or imaginary.

Agents: These are human, non-human, or even non-living entities that influence each other through the laws and habits defined for the world.

Spatial dimension: This is the specific spatial frame that agents inhabit. It can also be intended as focusing on a specific scale of human/ecological organisation (individual, collective, or global).

A "world" is, of course, the basis of any narrative but we can also find artefacts with just this layer (or particularly focused on this layer of representation). They could be geographic maps (representing spatial relationships), conceptual maps (representing relationships among agents and/or objects) or descriptions of the routines or natural/artificial processes (illustrating laws/habits) of a specific place/group of agents.

The potentiality of a world-making layer is multifaced. It is linked, for example, to the capacity to situate abstract knowledge, to see and describe "interconnection", to reflect upon "spatial/organisational scales", or to frame "sustainability" as a "state of equilibrium" between natural "laws" (sustainability boundaries) and human "habits". It also lies in the acknowledgement that the two forms of world-making have been influencing each other

over time. and some of the greatest limitations of contemporary narratives stem from a deterministic worldview that hinders the representation of complex worlds [22,23].

World representations possess narrativity because they can evoke numerous "full" (higher narrativity) narratives but, strictly speaking, those will only emerge when something "unpredictable" occurs, breaking the "equilibrium" and marking the transition to the second layer of narrativity.

The **second layer** of narrativity is concerned with the *investigation of temporal evolution and contingencies*, rather than invariances. It embodies what many scholars consider the core of narrative thinking: that evolutionary trait of the human mind that pushes us to detect environmental irregularities and hypothesise from cause to effect before acting [19,30–32].

We use our minds as simulators of "what-ifs" to make sense of the past and guide our decisions for the future, constantly striving to mediate between certainty (laws/habits of the world) and uncertainty (contingencies) [18,30,33,34]. The focus of this layer moves from describing a world "state" to understanding the causal chain of physical "events" that can transform it over time. Examples of narrative artefacts at this layer include all those aimed at telling how things happened or can happen without looking into the emotional sphere and motivation for acting. Narrative explanations of this kind are widely used in natural sciences that do not study the invariant (temporally stable) laws of nature but investigate how ecosystems change, reorganise, and evolve while still adhering to those laws. While natural historical sciences are focused on exploring the past, futures studies employ this same layer of narrative thinking to explore the future. Climate science explores both the past and future through storylines and scenario-making techniques. In line with that, artefacts at this layer have three typical narrative elements:

Physical events are defined as *non-totally predictable occurrences*, in the sense of actions driven by a coherent set of living or non-living agents in specific physical places and leading to a change in their physical state.

Temporality means that events are chronologically related. At this level, any kind of temporal logic is accepted, like multiple timelines, cycles, or time branches.

Causality refers to the way events are connected through cause-and-effect relationships, creating a logical sequence that drives the narrative forward. Rather than simply presenting events in a chronological sequence, causality ensures that each event influences what comes next, indicating why events happen, not just when they happen. It is dependent on the "laws and habits" of the world where the events take place.

We argue that the significance of this layer for CCE lies in the interplay between constancy/transformation and predictability/unpredictability as central to understanding the complex evolution dynamics of the natural world and humanity's role within it. The causal and temporal "what-if" exploration is a way of thinking that can be fostered in students to look at the future as a spectrum of possibilities.

The **third layer** is about *portraying and investigating subjective (usually human-like) perspectives and verisimilar experiences*. Typical elements of this layer are informed by the definitions of "full" narratives proposed by Ryan, Bruner, and Adams [4,8,25]. What they encapsulate, we argue, is a different trait of the human mind: our specific perspective, due to a conscious and linear experience of time. At this layer, a new type of events is introduced: those occurring within the mental dimension of humans or other sentient (often humanised) beings. This does not mean that individual perspectives are the only ones that can be depicted: agents can be collective (such as peoples, nations, and species) but they are usually reduced to a unified whole. Moreover, in the artefacts of this layer, the two types of events (physical and mental) are strictly ordered in a linear sequence, and a unique, authorial voice becomes prominent. Specifically:

Mental events are defined as those moments where there is a change in the mental state of an agent (a decision is taken, a fact is learned, an emotion arises, a goal is settled, etc.). They are chronologically and causally related, both among their kind and to physical events.

Sequentiality refers both to the chronological order in which events take place in the real or imagined world (known as 'fabula'), and the order in which the reader (or watcher, listener or player) became aware of the events ('sjuzet', or plot). The same fabula can be told following different sjuzets. Contrarily to the second narrativity layer, the only order permitted at this layer is a linear sequence.

Author's voice is the unique perspective of the author (or authors). It is a combination of linguistic and communicative choices that permeate the narrative, often revealing the author's values or stance toward the subject matter.

The significance of this layer for CCE lies in the opportunity to construct personal meaning and empathy through emotional engagement. As South African senior science communication researcher Marina Joubert writes "it is about making people care" [33]. This translates not only into making people understand CC but in helping people develop a personal and emotional connection with it. Mental states and author's voice are what allow narrative artefacts to be linked to personal experiences, emotions, and values, and at the same time, empathise with the perspective of others. To gain the right depth, we need to craft a verisimilar experience in the form of a sequential order of (mental and physical) events, since it is in this way that we, as humans, experience time. So, to acquire this level of narrativity, narrative artefacts must sacrifice the exploration of a wide temporal spectrum of possibilities that are instead typical of the second layer. In exchange, we obtain a nuanced emotional understanding of the reasons that move agents into action and recognise the conflict between them.

Finally, at **the fourth layer,** we find *genre-specific artefacts*. This layer relates to what the TL framework defined for any kind of text but has been adapted for narrative artefacts. Genres can be described as a set of literary conventions, influenced by socio-cultural norms, which can strengthen the narrative artefact sense of identity and relatability by aligning with recognisable forms [24,34–36]. Each of them has specific rules that pose both limits and opportunities regarding what a narrative can address and how (it thus poses limits on the narrative features of the layers below). Some examples of CC-related narrative genres are novel, cli/sci-fi, memoir, reportage, mockumentary, etc. The same sequence of events (fabula of sjuget) can be crafted in different genres. There can be a specific mix of genres and there are also narratives that do not fit within a specific one or that blend and transcend genre boundaries altogether.

The only narrative element of this laver can be described as follows:

Genres: Conventional rules, recognised culturally, which drive both the content of a narrative (such as defining specific themes, characters, or time setting) and the form in which the content is depicted, such as structure, tone, and style.

The significance of this layer for CCE lies in the fact that genres are strong carriers of tacit cultural knowledge [34,35]. Genres are the carriers of power relations, social roles, and ideologies, and may thus (both by their very existence and through the conscious use by individual actors) hold back knowledge and skewer action [35].

To conclude, by developing this narrativity-based tool, we have constructed a flexible operative framework for categorising CC narrative artefacts across a spectrum between paradigmatic and narrative thinking: from world representation grounded in scientific data to full narratives fully immersed in genre-specific conventions. In the next paragraph, we will explore a selection of examples for each layer.

4. Example of Use of the Narrativity Tool

Specific types of artefacts that exemplify the distinctive narrative elements and functions characteristic of each narrativity layer are illustrated in Figure 3.

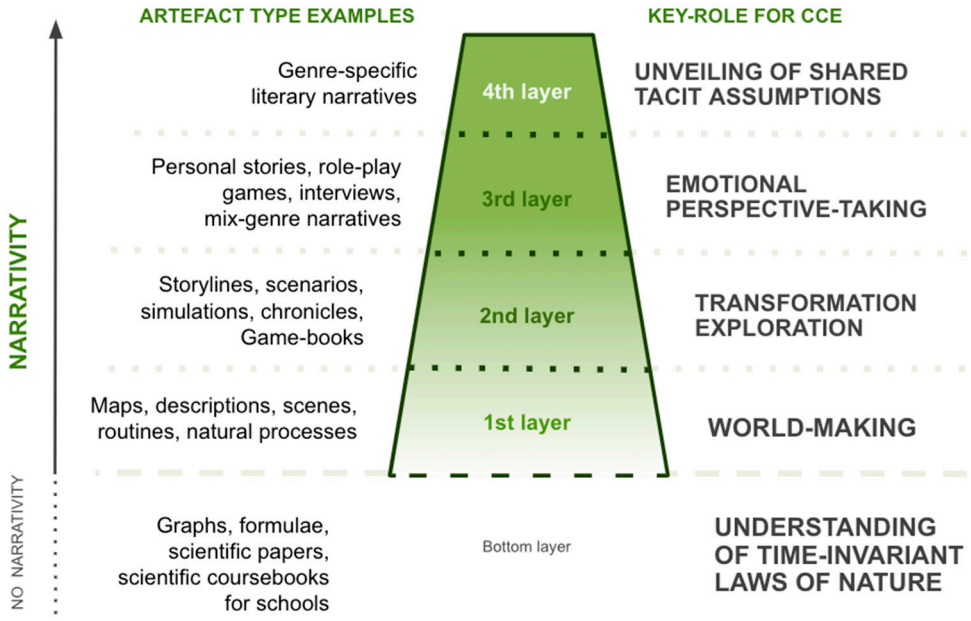

Figure 3. Artefact type examples. This figure illustrates artefact type examples for each of the layers and their correspondent key educational role.

In this paragraph, we present a selection of CC artefacts analysed through the lens of our tool. Specifically, we will discuss the following artefacts and some ideas for activities based on them:

- The text "Ottavia" from Calvino's book "*Le città invisibili*" [37];
- A map of the carbon cycle (adapted from [38];
- The Shared Socio-economic Pathway scenarios [39];
- The "*Change Game*" videogame [40];
- The short story "Carbon" by Primo Levi [41];The short story "To labor for the hive" by Jamie Liu [42];
- The movie "*Siccità*" by Paolo Virzì [43].

The following short text is Calvino's "Ottavia" [37]:

> "*There is a precipice between two steep mountains: the city is over the void, bound to the two crests with ropes and chains and catwalks. You walk on the little wooden ties, careful not to set your foot in the open spaces, or you cling to the hempen strands. Below there is nothing for hundreds and hundreds of feet: a few clouds glide past; farther down you can glimpse the chasm's bed.*
>
> *This is the foundation of the city: a net which serves as passage and as support. All the rest, instead of rising up, is hung below: rope ladders, hammocks, houses made like sacks, clothes hang on the hangers, on the lines, pots, and braziers. Suspended over the abyss, the life of Octavia's inhabitants is less uncertain than in other cities. They know the net will last only so long*".

The text is a nice example of an artefact of the first narrativity layer: the description of a place (spatial dimension) with the natural constraints of its landscape features (laws) and its citizens (actors) who, aware of these restrictions, developed a way of living (habits) that is in equilibrium with it. An artefact like this, on its own, could be used as an evocative

metaphor to ignite a reflection on the natural specificities of our planet regarding the concept of climate (not yet climate change). This reflection could be enhanced and balanced with paradigmatic thinking by taking a step back on the no-narrativity layer, and introducing some of the time-invariant natural laws that underpin the functioning of the Earth's climate, such as the Stefan–Boltzmann law and the Law of Conservation of Mass. Those artefacts could be employed to explore paradigmatic thinking skills like modelling, for example, by guiding the investigation around why the Earth is not as cold as the space around it, modelling the Earth–solar system with or without the atmosphere and obtaining a basic knowledge of the natural greenhouse effect.

An example of an artefact of the first layer, still strongly linked to a paradigmatic way of thinking (the bottom layer) through the use of data, is the map of the carbon cycle as illustrated in Figure 4. Regarding the narrative elements, in the "world" pictured by this map, the boxes can be seen as the agents, the Earth is the spatial scale involved, the laws are the conservation of mass and the carbon cycle timing, and the big blue arrow represents a human habit. This artefact is well suited to being narratively balanced through the city of Ottavia reflection, for example by exploring the question: Is this habit (human emissions) "aware" of the world "laws" as the Ottavia citizens were of the constraints of their world?" To gain insights into this, one idea could be to explore the element of "spatial dimension" through the concept of system scales (individual, collective, and global), by comparing those of the climate system with human-organisation ones.

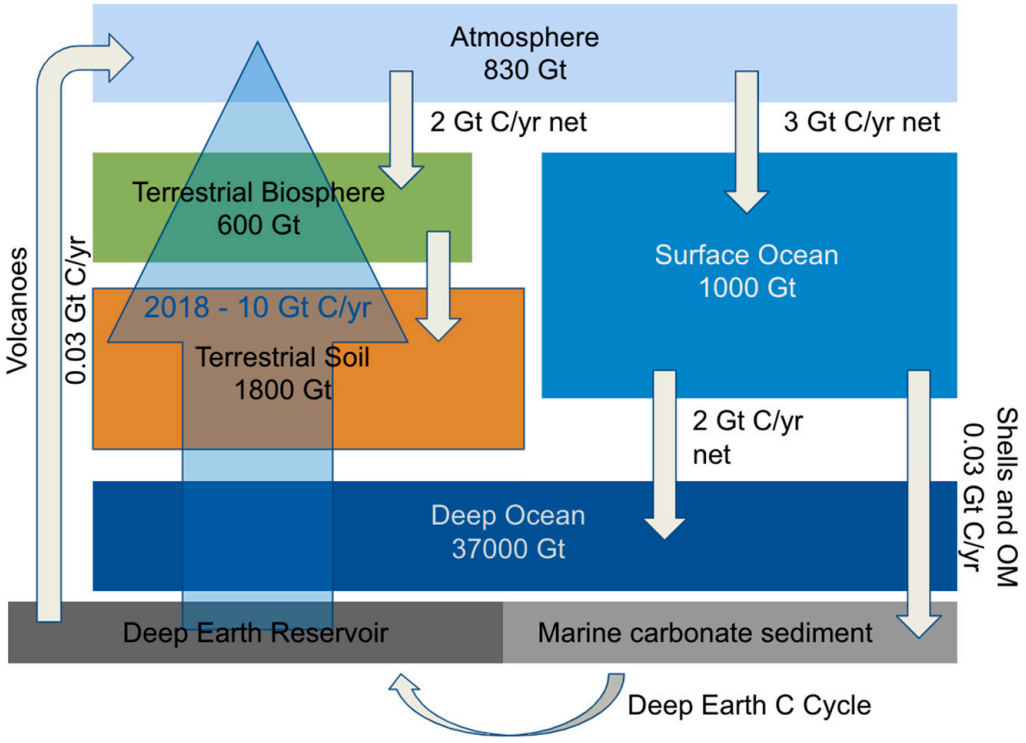

Figure 4. Example of a carbon cycle map. This figure is an example of a CC paradigmatic artefact belonging to the 1st layer of narrativity and strongly linked to the bottom layer through the use of data. Image adapted from [38].

A nice example of a narrative that links the first to the second layer of narrativity by introducing the concept of contingency while reinforcing the idea of the systemic interconnection of agents is the videogame called "*Change Game*" [40]. Developed by the Euro-Mediterranean Center for Climate Change (CMCC) in collaboration with MelaZeta and CLIMATE-KIC, the game is built like a science-based interactive simulation that im-

merses players in different environments (coastal, island, mountain, etc.) where they must devise strategies to address climate challenges. Its objectives are to enhance understanding of the complexities of the climate system and its interactions with humanity and ecosystems (focusing on key elements like feedback loops, nonlinearity, and self-organisation), while stimulating reflection and sensemaking on the systemic approach needed to achieve a zero-emission, climate-resilient society.

An example of artefacts on the second layer are the Shared Socio-economic Pathways (SSPs): a set of scenarios developed within CC research to explore how choices upon different social and economic factors could impact future climate outcomes in the year 2100. Developed to complement the Representative Concentration Pathways (RCPs), SSPs outline five potential global pathways describing the future evolution of key aspects of society that would together imply a range of challenges for mitigating and adapting to CC. Contrarily to RCP scenarios, which are pure quantitative tools, SSPs pair the quantitative information with so-called narratives [39], described as qualitative descriptions of plausible future conditions at the level of large world regions. Specifically, by pairing quantitative information (Mathematics and data) and narrative texts, the SSPs illustrate how specific global (spatial dimension) human (agents) attitudes (habits) adopted in the present (the year 2014, when the paper was published) would imply certain outcomes in 2100 (Causality and temporality). As shown by Nikoleris et al. [44] this artefact is a very good example of the limits of a CC narrative that is completely coherent with data and scientific knowledge; this means a scientific narrative explanation [11] in the form of a CC artefact employing both ways of thought (paradigmatic and narrative) is a strategic compromise between the two modes.

As discussed in the previous paragraph, to overcome narrative limits of the second layer, artefacts within the third layer abandon their aspiration to function as proper scientific tools, but in return gain the capacity to portray human-like verisimilar experiences and expand their emotional potential. An example of a CC artefact on this layer is the story "Carbon" from Primo Levi's "*The Periodic Table*". It explores the lifecycle (sequentiality) of a carbon atom (agent) from its own individual perspective, from its origins in ancient geological formations to its integration into complex organic structures (temporality and causality). The story is a spatial and temporal exploration that has clear discrete physical events, although not mental ones, and it is a poetic reflection on life, change, and continuity that captures Levi's fascination with the way scientific principles can tell deeply meaningful stories (author's voice).

To conclude, as examples of the fourth layer, we present a comparison of the "to labor for the hive" short solar punk story and "*Siccità*" cli-fi film.

- "To labor for the Hive" is a short story by Jamie Liu, winner of the 2024 edition of Imagine 2200, a climate fiction contest celebrating "stories that offer vivid, hope-filled, diverse visions of climate progress" [42]. The artefact, responding to the contest's goals, can be defined as a solar punk short novel, as it depicts a positive view of the future and is centred upon the psychological and social development of one individual, the beekeeper called Huaxin, who finds a new sense of purpose and community after helping to develop a warning system for floods.
- "*Siccità*" is a 2022 film by Italian director Paolo Virzì from a screenplay by Paolo Giordano [43]. The narrative can be defined as an apocalyptic cli-fi. It is set in Rome in a dystopian present (or near future), where it has not rained for three years, and a series of characters must cope with the drought that has reduced water reserves to a minimum, as well as an epidemic of sleeping sickness carried by cockroaches.

By adhering to their conventions, each genre engages with climate change in ways that are uniquely suited to its goals: solarpunk inspires action through hope and possibility,

while cli-fi warns of inaction through dystopian scenarios. "To labor for the hive" challenges deterministic and exploitative worldviews by picturing a future where individual agency overcome systemic barriers. It embeds an ideology of empowerment and sustainability, suggesting that humanity can create a harmonious future. Cli-Fi stories like "Siccità" reflect anxieties about climate change. They critique the naivety of an optimistic vision of the future by emphasising the power dynamics, social roles, and ideologies that shape societal inaction, existing power structures and social inequality.

The examples illustrated in this paragraph demonstrate how, by using the lens of the tool, it becomes possible to identify the wide variety of artefacts that incorporate characteristics of narrative thinking, even though they may not qualify as 'full narratives' (fourth narrativity layer). By employing the tool as a new definition of narrative, artefacts such as a graph of the carbon cycle or a simulation game can be included, as they respectively activate mechanisms of thought related to world-making or the exploration of contingencies. Furthermore, these narrative artefacts can be positioned along a discrete spectrum between paradigmatic and narrative thinking, providing a foundation for investigating the balance between these two modes of thought. Specifically, this theoretical work serves as the basis for designing a course on balancing paradigmatic and narrative thinking in the context of climate change, which will be presented in a subsequent publication [45].

5. Discussion and Conclusions

This study set out to develop an operational framework for understanding and categorising CC narratives for education. By employing the concept of narrativity, we proposed a multi-layered tool that not only avoids over-simple or over-complex definitions of narrative, but also moves the focus from narratives as simply tools of representation or communication to a role as artefacts fostering a specific way of thinking, providing a "measure" to bridge paradigmatic and narrative thinking by positioning them within a discrete spectrum. Each layer of the spectrum shows a distinct educational potential, such as exploring temporal and causal complexities or fostering perspective-taking.

This approach could be further developed to create a versatile tool for educators, aimed at integrating narratives into science courses, balancing the analytical strengths of paradigmatic thinking with the imaginative and emotional depth of narrative thinking.

In particular, the adaptability of the framework across various media formats and its focus on narrativity could allow educators to navigate a wide spectrum of narrative artefacts, from data-driven climate models to immersive fictional novels. This flexibility will ensure that educators can tailor their narrative choices to specific educational purposes, such as enhancing knowledge retention, stimulating ethical reflection, or fostering skills for future-oriented thinking. Importantly, this approach bridges the gap between scientific inquiry and personal engagement, enabling learners to connect abstract climate data with tangible human experiences and envision actionable solutions.

However, while the narrativity tool provides a structured framework, the complexity of narratives and narrativity and their varied interpretations may lead to differences in how artefacts are positioned through the tool and utilised across educational contexts. Moreover, this study primarily focuses on theoretical development, with limited empirical validation of the framework's effectiveness in real-world educational settings. Future research will aim to assess its practical applicability, and an upcoming study will present the design of a climate change education course based on the narrativity tool. It will be the initial step of a larger study intended at gaining a deeper understanding of its significance and what it implies to foster a balance between Bruner's dual modes of thought for a holistic sensemaking of climate issues, opening new understandings and spaces of possibilities

to integrate narratives across various media into science courses, allowing for a balanced emphasis on both scientific facts and imaginative, empathetic perspectives.

6. Discussion

This study provides a novel approach to integrating narratives into CCE by introducing a multi-layered narrativity tool. By moving beyond the traditional view of narratives as mere communication tools, the research reframes narratives as artefacts fostering distinct modes of thinking. This approach not only highlights the unique strengths of narrative thinking but also bridges the cognitive gap between paradigmatic and narrative reasoning.

The strengths of this approach lie in its adaptability and theoretical grounding. Drawing from Bruner's dual modes of thought and Ryan's narrativity framework, the tool enables educators to systematically analyse and design narrative artefacts based on their educational potential. The inclusion of a transmedial perspective extends the framework's applicability across diverse media formats, allowing it to address the varied needs of educational contexts. For example, the analysis of artefacts such as Calvino's "Ottavia" and the Shared Socio-economic Pathway scenarios illustrates how the tool can link abstract scientific principles to tangible, human-centred experiences.

However, the study also reveals some challenging aspects. The complexity of defining and applying narrativity may lead to inconsistent interpretations among educators and researchers. While the theoretical foundation is robust, empirical validation is lacking, leaving questions about the framework's practical effectiveness in diverse educational settings.

Moreover, this study primarily focuses on theoretical development, with limited empirical validation of the framework's effectiveness in real-world educational settings. Future research will aim to assess its practical applicability, and an upcoming study will present the design of a climate change education course based on the narrativity tool. It will be the initial step of a larger study aimed at gaining a deeper understanding of what it means and what it implies to foster a balance between Bruner's dual modes of thought for a holistic sensemaking of climate issues, opening new understandings and spaces of possibilities to integrate narratives across various media into science courses, allowing for a balanced emphasis on both scientific facts and imaginative, empathetic perspectives. Indeed, future research envisaged in the larger research project will address these gaps by conducting empirical studies to test the tool's impact on more comprehensive learning outcomes related to the role of narratives and narrative thinking in CCE.

7. Conclusions

This research offers a transformative perspective on the role of narratives in CCE by shifting the focus from representation (narratives used merely to engage readers/listeners) to cognition (narratives as a complex proper way of thinking). The proposed narrativity tool provides a structured, operational framework for categorising and leveraging narrative artefacts, balancing paradigmatic and narrative modes of thought to enhance multidimensional learning experiences. By integrating theoretical insights from narratology, cognitive science, and science education, the study establishes a foundation for bridging abstract scientific knowledge with human-centred perspectives [46]. This approach fosters not only understanding but also imagination and action—essential components for addressing the complexities and uncertainties of climate change.

The study's contributions are part of broader research—framed within the EU-funded CLIMADEMY (https://climademy.eu/ (accessed on 11 November 2024))—which investigates how a narrative approach can cultivate consciousness, imagination, and attitudes necessary to navigate CC's uncertainties. Future research is already in progress, with the focus of exploring the narrativity tool application across diverse educational contexts,

through empirical validation, and expanding its theoretical underpinnings to include interdisciplinary perspectives.

In conclusion, this work posits narratives as central to CCE, offering educators a versatile tool to engage students in meaningful, transformative learning experiences. By leveraging narratives to connect abstract data with lived experiences, the study paves the way for a holistic and actionable approach to CCE.

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