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# A “Strong” Approach to Sustainability Literacy: Embodied Ecology and Media

Cary Campbell <sup>1</sup>, Nataša Lacković <sup>2</sup> and Alin Olteanu <sup>3,4,\*</sup> <sup>1</sup> Faculty of Education, Simon Fraser University, Vancouver, BC V5A 1S6, Canada; cary\_campbell@sfu.ca<sup>2</sup> Educational Research, Lancaster University, Lancaster LA1 4YW, UK; n.lackovic@lancaster.ac.uk<sup>3</sup> Linguistics and Cognitive Semiotics, RWTH Aachen University, 52062 Aachen, Germany<sup>4</sup> Faculty of Social Sciences, Arts and Humanities, Kaunas University of Technology, 44249 Kaunas, Lithuania

\* Correspondence: alin.olteanu@rwth-aachen.de or alin.olteanu@ktu.lt

**Abstract:** This article outlines a “strong” theoretical approach to sustainability literacy, building on an earlier definition of strong and weak environmental literacy (Stables and Bishop 2001). The argument builds upon a specific semiotic approach to educational philosophy (sometimes called edusemiotics), to which these authors have been contributing. Here, we highlight how a view of learning that centers on embodied and multimodal communication invites bridging biosemiotics with critical media literacy, in pursuit of a strong, integrated sustainability literacy. The need for such a construal of literacy can be observed in recent scholarship on embodied cognition, education, media and bio/eco-semiotics. By (1) construing the environment as semiotic (*Umwelt*), and (2) replacing the notion of *text* with *model*, we develop a theory of literacy that understands learning as embodied/environmental in/across any mediality. As such, digital and multimedia learning are deemed to rest on environmental and embodied affordances. The notions of semiotic resources and affordances are also defined from these perspectives. We propose that a biosemiotics-informed approach to literacy, connecting both eco- and critical-media literacy, accompanies a much broader scope of meaning-making than has been the case in literacy studies so far.



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**Keywords:** sustainability literacy; critical media literacy; biosemiotics; multimodality; embodiment

## 1. Introduction: The Embodiment Turn and Sustainability

In the past three or four decades, an embodiment turn has contributed to the collapse of mind/body dualism in the humanities and social sciences [1–4]. The notion of embodiment that we tackle in this article stems primarily from cognitive sciences (particularly, cognitive linguistics), residing in the claim that the mind is embodied [5]. However, this does not mean adopting a singular “mentalistic” view of embodiment or literacy. More precisely put, the possibilities of an organism to organize its experience into meaningful knowledge stem from its body. Varela et al. [3] explain that the embodiment notion supposes “first, that cognition depends upon the kinds of experience that come from having a body with various sensorimotor capacities, and second, that these individual sensorimotor capacities are themselves embedded in a more encompassing biological, psychological, and cultural context.” This paper presents an embodiment approach to literacy, the need of which has been revealed, in part, by a recent semiotic approach to philosophy of education (starting with Stables [6,7]) and to which these authors have been contributing (e.g., [8–10]). By explicating this approach, we also demarcate the position that we take in the current academic debates on educational philosophy, literacy and sustainability. Although we focus on articulating a particular (multimodal, biosemiotics and cognitive) approach to embodied literacy here, we acknowledge and embrace (individually to various extents) different approaches to embodiment, such as expressed in work by Merleau-Ponty and Deleuze, as well as in new sociomateriality studies.

## 2. The Main Argument

The theoretical implications of the embodiment turn are here developed in the scope of learning theory and sustainability literacy to answer the contemporary educational challenges and opportunities produced by both digitalization and the global ecological crisis. The ontological separation of mind and body results in a theory of knowledge that does not acknowledge the environmental relationality of knowing subjects within complex ecological systems [11]. Additionally, such dualism overlooks the multimodal constitution of meaning structures, which is more salient in new digital media than in historically preceding technological media.

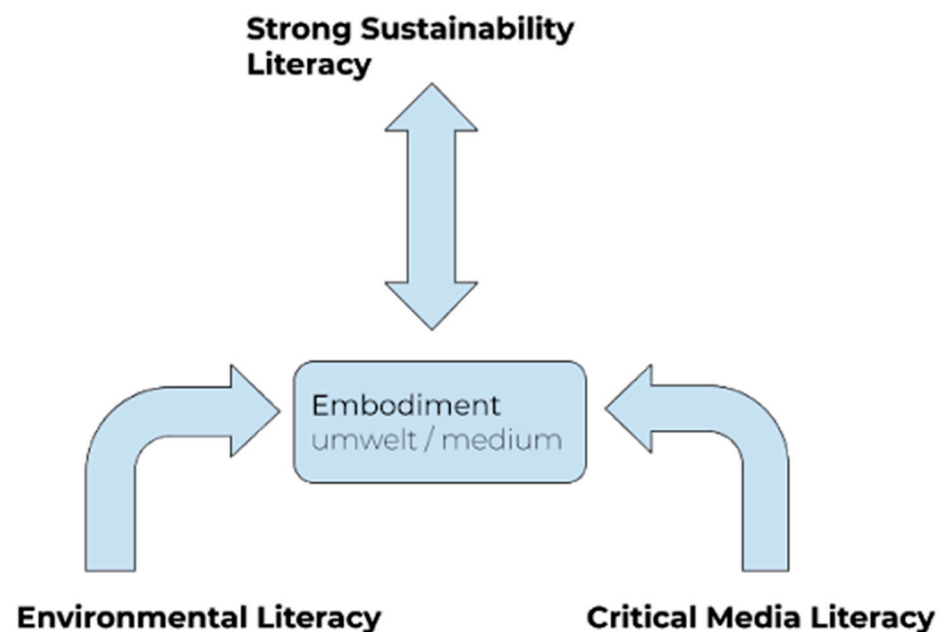
The key to developing a strong sustainability literacy [12], one that could conceivably prepare students to meet general sustainability aims (for instance, as defined by the UN under the UNSDG framework, see [13]), resides in an educational approach that goes beyond top-down and pre-specified benchmarks and aims. It means to prepare students, not only factually and informationally (pp. 1–37 in [14]), but also existentially and personally, in the context of their growing and changing lifeworld [15]. During a period of accelerated climate-change and mass extinction, literacy must come to recognize a wide spectrum of meaning-making that leads to both understanding and action in relation to sustainability issues. This task, we argue, requires the crucial understanding that mediality is embodied. We aim to arrive at a satisfying and meaning-based sustainability literacy theory, by critically reengaging with some of the key concepts and ideas from multimodal and social semiotic approaches to literacy through a (bio/eco-)semiotic theory of learning, again, to which we have been contributing [9,10,16].

We advance an approach to sustainability literacy that links environmental literacy and critical media literacy as two manifestations of embodiment at work. We claim that this integrated approach may be of service in developing a strong sense of literacy, generally, which rests upon a broad view of “literacy as semiotic-engagement” [6,12] with ecologically nested systems of matter and meanings, nature and culture, body and mind (similar to the complexity approach to sustainability literacy in [11]). This expands the narrow, or weak, view of literacy as the attainment of predetermined competencies or skills, mainly consisting of abstract symbolic processing traditionally associated with reading, writing and numeracy.

Stables and Bishop’s [12] distinction of strong/weak literacy is here resituated within the current conversation around notions of education for sustainability (EfS) and the related, though problematic, policy and educational agenda of education for sustainable development, or ESD [17–19]. As explained by Blewitt (p. 71 in [17]), in the context of discussing a large-scale UK, ESD initiative called Learning to Last, the recent push by many governments and international organizations towards ESD exposes “a tension between a managerialist approach to project development, common within the Learning and Skills sector, and an ecological, networked and synoptic methodology more in keeping with and sympathetic to the values of sustainability [...]”. The basic strong/weak literacy distinction is useful in this discussion, as it allows us to explain why the underpinning assumptions of top-down (“target and output driven”) initiatives associated with ESD often contribute to an insufficient and weak approach to sustainability literacy and EfS, which in the end offer “restricted opportunities” for meaningful place-based and environmental education [17,20].

We argue that a multimodal view on meaning-making implies an environmental (ecological) view on meaning-making. Environments are modally and semiotically heterogeneous because they are constructed by embodied organisms that navigate and are situated within multitudes of relations. As Kress (p. 77 in [21]) explains from a social semiotic perspective, “the materiality of modes [ . . . ] interacts with the physiology of bodies”, which undermines the “separation of categories such as mind and body, of cognition and affect”. Moreover, from a cognitive perspective, the ability to understand other beings as mental and social agents rests on the multimodal modelling of the environment. Sweetser [22] explains that “we are not just capable of multiple viewpoints; we are in fact incapable of keeping to one single viewpoint of space, or of cognitive structure,

when other humans are present. A situation involving multiple humans is necessarily structured, for participants and for human observers, via complex multiple viewpoints” (p. 2). For society and education, fully considering multiple viewpoints and perspectives (including, potentially, more-than human viewpoints and perspectives) requires multimodal conceptual blending and the ability to engage and use a diversity of modes and sense-modalities (see p. 91 in [23]). The more perceptual channels and semiotic modalities an interpreting being musters, the more *semiotic freedom* they have to navigate, respond and adapt to their environments. Interactions and learning with both technological/virtual and environmental-media, we argue, must be understood as embodied and multimodal (theoretically and practically. See Figure 1 below).



**Figure 1.** “Strong Sustainability” literacy.

The basic mediality within which the human natural environment is constructed stems from the human body. More complex technological media that humans have created are, following McLuhan’s [24] celebrated and avant-garde definition, “extensions of the [hu]man”. Moreover, McLuhan (p. 42 in [24]) described media changes in terms of embodiment, explaining that humans are “impelled to extend various parts of [their] body by a kind of autoamputation.” This is to say that by extending our interpretative possibilities through the development of new technologies, we alter previously existing interpretative possibilities. From a more recent semiotic and embodied perspective, Elleström (see p. 281 in [25]) proposes changing McLuhan’s definition to regarding media as “extensions of the mind”. By doing so, far from advocating Cartesianism, Elleström is building upon a concept of the mind as embodied and extended. From this perspective, he construes a concept of medium (see p. 271 in [25]) as primarily evoked by corporeality:

A medium should be understood in a broad way as the intermediate stage of communication: thus, the term medium here refers not only to mass media, but also media used in more intimate communication; not only media based on external technological devices, but also media based on corporeality; not only premeditated media, but also casual media; not only media used for practical purposes, but also artistic media—and so forth.

Following this notion of medium as evoked by corporeality, we believe that theories of literacy, if they are to retain relevance and connection to the dynamic and changing nature of life in the Anthropocene [26,27], must be able to connect ecological situatedness with the realities of postdigital living [28]. Literacy, we note, has always been understood as a medium-related practice.

Specifically, we explore how developments in contemporary semiotics research (bio-, eco-, edu-) provide pathways and opportunities for a renewed, strong sustainability literacy. The implications of this bio/ecological approach to literacy are explored through redefining certain core concepts, common to constructivist educational research and multimodality and social semiotics, through the perspective/lens of biosemiotics, which provides an encompassing notion of meaning as embodied and environment as a construction of embodied minds. Figure 1 below shows a diagrammatic model of “strong Sustainability” literacy that encompasses environmental literacy and critical media literacy as two distinct (but connected) types of embodiment.

### 2.1. Strong/Weak (Sustainability) Literacy

The distinction of strong/weak literacy is from Stables and Bishop’s (2001) article “Weak and Strong Conceptions of Environmental Literacy” [12] and was part of a debate within environmental education about the practical usefulness of terms like environmental and eco-literacy [29]. Environmental education (EE) research has long been criticized for having unclear notions of what constitutes environmental literacy, and as such, failing to produce “pedagogy guiding” practices or frameworks. As noted in McBride et al. [30] in their excellent review of the concept: “numerous scholars have argued that the terms environmental literacy, ecological literacy, and ecoliteracy have been used in so many different ways and/or are so all-encompassing that they have very little useful meaning” (p. 2). How do we define literacy and environmental (/eco) literacy, then?

To begin with, a weak view of literacy results from seeing literacy as a determined compendium of skills/competencies, while a strong account recognizes that literacy itself must be broad enough to encompass all a student’s meaningful engagements with the world; how they are affected by the more-than-human, and their capacity to act agentively in shaping their ecological participation. As such, literacy is capacity for semiotic-engagement, displayed by what Stables (p. 97 in [7]) refers to as response-ability, namely involvement in a dialogical process of self-becoming not just by individuals, but relational to a group, community and the environment.

This (strong) notion of literacy/competency cannot be entirely determined in advance as it is undergoing uninterrupted change through the learning/life process itself. It is shaped not only by the individual’s development, but also by the unfolding of social changes. This follows a particular orientation in curriculum theory: if life and learning are understood as semiotic-engagement [6], then environmental literacy must come to embrace all of a student’s engagements and competencies for meaning-making, across a broad range of modes (different communication resources that exist in various forms, not only linguistic), media, texts, and in relation to a broad range of phenomena and events. It is impossible to account for the totality of a person’s meaningful engagements with the world—for her continuous repositioning within semiotic networks. Thus, education programs must acknowledge the infinite semiotic freedom of (human) learners in relation to the constraints and affordances that their enviroing imposes. In brief, as a guiding beacon of education, the concept of literacy must not result in cutting the student off from any of her (potential) resources for meaning-making—many of which are unique(/personal /experiential) as well as collective (/historical)—and rely on non-verbal, environmental, embodied modes of knowing and learning.

We consider that the modern program of education, as construed in the Enlightenment and tied to corresponding notions of citizenship, tends to impose upon individuals, as well as upon groups (e.g., consider settler-colonization) socio-politically accepted (narrow) sets of standards. Educationally and in terms of literacy, this results in inhibiting the use of many diverse resources for meaning-making in favor of a pre-selected few. Consequently, curiosity and imagination are deemed inappropriate means for scientific inquiry; and arts education is seen as supplementary and peripheral to, so-called, core curricular domains [31] and the so-called STEM disciplines. This also, of course, plays out in research and academia: disciplines and fields have claimed their tribes and territories to determine

disciplinary belongings [32,33], and being an interdisciplinary researcher or teacher may well also mean not belonging anywhere in particular which stifles career progress, as it may be preferable to “box” someone within a discipline in spite of claims by universities or research councils to highly value “interdisciplinarity”.

With these challenges in mind, the strong literacy that we endorse must foster response-ability across curricular domains and disciplinary boundedness through inter- and trans-disciplinary teaching and curriculum design, degrees or school programs, research projects, teams, centers or research institutes. Organizational support is here necessary. A strong environmental literacy would actually have to communicate the significance of ecological issues across educational levels and curricular domains, and indeed existentially. It cannot be an additional and optional course within environmental studies or specialist sustainability courses only. For it to be a practical and operational concept, sustainability needs to be integrated into an educational system as a whole, and not just on certain and often atomized levels.

As noted by many [6,30], part of the inadequacy of notions like environmental or eco-literacy stands in the fact that they have mainly been developed and discussed within the specific and narrow context of environmental education, and proceed without much awareness of broader issues in literacy and literacy studies:

(I)t is unclear exactly how the definitions employed by Marcinkowski for UNESCO (1991: environmental literacy defined in terms of knowledge, understanding, attitudes and active involvement) and Disinger and Roth (1992: environmental literacy defined as nominal, functional and operational) are related when neither is developed from any extensive prior debate about literacy. Indeed, Roth (1992) admits to the term lacking precise definition although he claims to have coined it in 1968. Roth’s rationale for his operational definition is built on a general awareness of expanding concepts of literacy, but this is not located within any broader philosophical or theoretical framework. (p. 90 in [12])

We agree with Stables and Bishop [12] that this confusion and lack of clarity around notions of environmental literacy seem to result from inadequate (or simply absent) philosophical and conceptual frameworks. The tendency is for researchers to turn to dominant anthropocentric and language-centric perspectives on literacy that highlight (rather than transcend) nature/culture divisions, and generally undermine the role of embodiment in learning (and teaching). This is highlighted in how curriculum in EE often tends to oscillate between observer-independent scientific information and data (disembodied and often decontextualized), or relativistic notions of nature and environment as human cultural constructions (see [11] arguing for a complexity approach to sustainability literacy). Yet another pathway is focusing on fostering some learners’ skills (attributes or capacities) through focused projects in the natural environment, without acknowledging fundamental connections to learning across disciplines.<sup>1</sup>

These approaches correspond to the two versions of modern dualism which Lakoff and Johnson [1,2] criticize as objectivism and subjectivism, respectively. The notion of cognition as embodied and environmental/situational emerged from Lakoff and Johnson’s criticism of these two late modern incarnations of dualism. This split underpins the proliferation of a stark humanities/hard sciences division (perhaps explaining the relatively late rise to prominence of the environmental humanities in educational research and higher education). Like Lakoff and Johnson, Stables and Bishop [12] argue that the (post-)Cartesian

<sup>1</sup> For instance, such curricular orientations are often expressed by Outdoor Education literature and initiatives. Such curricular practices and educational experiences, though frequently important and transformational for students, often function to further emphasize the discontinuity of place-based educational opportunities with what “normally happens” in formal schooling. For illustration, in a City of Vancouver report on the feasibility of Place Based Environmental Education (PBEE) in city parks, Roy [34] observes that: “Public schools have, for quite some time, established outdoor education programs in “natural” areas in far away places, but this is often kept separate from the local urban context in which children grow up [...] In this model, children would experience wilderness over an intense period of time of a week to several weeks engaging in such activities as canoeing, hiking and bird watching separated from their regular indoor classroom activities. They would then return to their regular classroom setting to learn subjects such as geography, history and biology removed from any environmental context” (p. 8).

notion of reason implies localizing human competencies for meaning-making in a narrowly localized notion of mind, as distinct from the body (intelligent, or educable, mind; trainable, or mechanistic, body). Modern dualism, then, ignores a vast domain of potential meaning-making resources, which are not accessible to a mind deemed to operate only on purely mental ideas. Further, Stables and Bishop [12] argue that this limited concept of mind results in a reductivist construal of the Earth (or nature):

An environmental education which runs independently of an exploration of cultural, aesthetic, personal and even irrational views of the environment will prove insufficient to our needs, as it will harness not ‘hearts and minds’ but merely part of the mind, in a limited range of contexts, and with a limited view of the Earth as essentially mechanical and liable to breakdown (the catastrophic view of nature) but not to improvement. The development of a strong conception of environmental literacy thus has the potential to result in an increased care for the world in a way that conventional models of environmental education alone cannot. (p. 96 in [12])

A strong (semiotic) sense of literacy therefore demands and necessitates fluid transdisciplinary education, that must transcend narrow disciplinary boundedness and “incoherent cross-curricular approaches that reduce environmental education to one subject among many [...]” (p. 96 in [6]). For example, Stables [35] early on argued that the arts and humanities have not been traditionally incorporated into conceptions of environmental literacy, stemming from and contributing to a weak sense of literacy, whereby environmental issues, and human (sign-mediated) relationships to the environment are viewed as not fundamentally open to interpretation, or involving the direct experiences and meaning-making of learners. Strong sustainability literacy also energizes relational complexity thinking, where different levels of environmental and human existence are considered, such as emotional, social, political or economic layers.

In more recent years, there has been a significant shift of focus in policy and research away from earlier notions like environmental literacy and eco-literacy—with their explicit connections to environmental education and that field’s strong groundings in science education—towards an understanding of sustainability education that is all encompassing and transdisciplinary [36–38]. As Sterling (p. 223 in [39]) notes in a well cited passage, sustainability is “not just another issue to be added to an already overcrowded curriculum, but as a gateway to a different view of curriculum, of pedagogy, of organizational change, of policy, and particularly, of ethos”. It is important to observe the gradual change in dominant terminology:

‘Sustainability literacy’ follows in the footsteps first of ‘environmental literacy’ and then ‘ecological literacy’. The thrust has been away from a narrow focus on [issues such as] environmental pollution, towards wider concerns with how the environment can provide basic necessities for current and future generations. As a consequence, the trajectory has been for definitions of the new form of ‘literacy’ to become less specific and more general in scope. (p. 12 in [18])

This general movement towards sustainability literacy can be seen, at least partially, as concurrent and in line with Stables and Bishop’s [12] weak/strong proposal. The move from environmental literacy to sustainability literacy is certainly an increase in generality and a door to transdisciplinarity. However, it also encourages educators and researchers to explore a broader assemblage of phenomena and relationships: “While over-generalised definitions can be all-encompassing, the benefit of such generalisation is that learners from many disciplines can be included in the common quest for a sustainable future” (p. 427 in [38]). This development, we observe, also parallels a recent turn in media literacy scholarship. Meyers, Erickson and Small [40] argue that, regarding digital literacy, embodiment theory calls for “a holistic perspective that combines skills, mental models and practices into a whole that can be identified by an understanding of certain concepts and an engagement in certain activities.” (p. 361). Scolari (see p. 12 in [41]) sees this as a

display of a greater move in scholarship from media to transmedia literacy. These initiatives are all underpinned by the expansion of notions of knowledge and mind to encompass the entirety of human competencies for meaning-making. They are pragmatically useful because they endorse transdisciplinary inquiry, with the important understanding that a strong sustainability literacy must go beyond the narrow view of ESD as discussed earlier.

See Table 1 below for a summary of the distinction between weak and strong conceptions of environmental literacy and the importance of a notion of literacy-as-semiotic engagement.

**Table 1.** Strong-weak environmental literacy distinction (adapted from [6], see p. 94).

<b>Strong Environmental Literacy</b>	<b>Weak Environmental Literacy</b>
Broad view of literacy (literacy as semiotic-engagement)	Narrow view of literacy (literacy as reading and writing)
Broad view of text (everything can be seen as text [however, we need to learn how to “read” and connect these different “texts”, or, use and enact “semiotic resources”])	Limited view of text (e.g., landscape cannot be seen as text)
Environmental literacy is broader than environmental education	Environmental literacy is a subset of environmental education

## 2.2. Our Proposal for Sustainability Literacy Education

Bio/eco-semiotic conceptualizations may be of service in developing a strong sense of sustainability literacy, whereby students: (1) recognize their place and impact in the semiosphere, which is evoked by the entire biosphere and, as such, includes human as well as more-than-human relations and production, and (2) cultivate both the requisite conceptual awareness and perceptual dispositions to adequately and critically interpret and act upon these relations across other subject-domains, and indeed, throughout their lives.

In particular, we explore how this (strong) semiotic approach to sustainability literacy involves a rethinking of the environment as both Umwelt (subject-dependent phenomenal world, [42,43] and medium. In Section 2, we will unpack the theoretical and philosophical relevance of adopting the biosemiotics concept of Umwelt into literacy studies. We consider how this perspective on environment includes the transformed relations to both the environment and to literacy brought about by the increased digitization of the life-world in recent decades. In Section 3, we highlight how technology needs to be critically considered as it also affects the environment negatively, having been, particularly in the second half of the 20th century, intimately linked to colonization and environmental exploitation [44,45]. We will explain how digital media are embodied and linked to external (material, non-virtual) environments and artefacts.

We are developing an approach to literacy studies that can accommodate the entire spectrum of signification and meaningful experience, starting from basic, embodied and environmental experiences that a human individual undergoes to all technological medialities that construct contemporary human societies. This (strong, semiotic) approach to literacy is, at least in part, a move towards understanding embodied interactions and events in education across representational and physical/environmental materiality. This also includes an understanding of local and global webs of influences that constitute it and need to be critically inquired.

Overall, we propose that the challenges and complexities of living through an era of climate change and global ecological and biodiversity collapse (the era of the Anthropocene) demand fluid, transdisciplinary inquiry and educational proposals, that respond to real-life problems and affordances emerging in the lifeworld.

Further Points of Clarification and Differentiation

Our approach to literacy studies seeks to transcend the language-centered notion of text in educational research, by regarding learning and literacy as environmental modelling.

This consists of two main conceptual moves: by (1) construing the environment as semiotic (Umwelt), and (2) replacing the notion of text with model. By doing so, we develop a theory of literacy that understands learning as embodied/environmental in any mediality. As such, online, digital and multimedia learning are deemed to rest on environmental affordances and resources. A biosemiotics-informed approach to literacy accompanies a much broader span of eco-awareness than conventionally afforded through the conceptual/philosophical framework of social semiotics, hence it expands specific representationalist and culturalist assumptions about meaning-making.

In Table 2, below, we present the suggested conceptual realignments in the domain of literacy and proceed by discussing the conceptual importance of aligning literacy with models and modelling rather than texts and text encoding/decoding, further unpacking biosemiotics and Umwelt in Section 2.

**Table 2.** Sustainability literacy: conceptual realignments and expansion in the domain of literacy.

Bio/Eco-Semiotic, ‘Strong’ Sustainability Literacy Approach	Dominant/Classical Approaches to Literacy
-Model and Modelling, -Umwelt/medium	-Text (text-encoding/decoding) -Environment (or learning environment)
-Sign as dynamic (multimodal) event	-Sign as static (textual, abstract) representation
-Sustainability as sustained ecosemiotic relationality	-Sustainability as attaining outcomes/targets/competencies
-Nature/culture continuity	-Nature/culture discontinuities
-(Bio/eco)-semiotically shaped modes/resources, affordances and competences	-Culturally (socio-linguistically) shaped modes/resources, affordances and competences
-Equality of iconic signification to symbolic communication/processing	-Primacy of abstract symbolic processing (language, numbers, notation)

The adoption of model in place of text requires that we understand human “cultural” learning as continuous, not discontinuous, with broader forms of ecological and animal learning. All living systems model their environments, while not all animals necessarily cognize or use and produce symbols. This follows from a notion of learning-as-modeling, in line with research alignments between edu- and biosemiotics [9,16,45–47]. As some of us (see p. 90 in [10]) have observed recently: “To learn about something is to develop models of it, a process which evokes new affordances.” By considering learning as species-specific meaning-making (or modelling), we can account for learning without reducing it to either anthropocentric, psychologist/mentalistic or computational accounts. Olteanu and Stables (p. 421 in [16]) clarify further:

From its beginning, biosemiotics was defined by [Thomas] Sebeok [48] [ . . . ] as a modelling theory and, while useful for cognitive theories as well, it does not impose any particular assumption about cognition. Thus, from this perspective, a theory of learning does not necessarily imply a discussion on cognition. An educational theory and system can conceive learning in terms of signification only.

A notion of models and modelling implies mediality and, in fact, the basic recognition that all modelling (animal semiosis) is inherently multimodal and embodied. Mediality is evoked by the body or, more exactly, by how the body relates to a landscape/interface. Media made possible by technological devices extend the (immediate, natural) mediality of the human body, augmenting some semiotic possibilities and inhibiting others. Hence, if media builds on media, so do their corresponding literacies. Print literacy and digital literacy, for example, should not be construed as a disembodied manipulation of abstract



symbols (as mathematical equations or coding might tempt some to think). They are products of human environmental situatedness, even if indirectly.

Literacy has the same connotation to human symbols as text. The term suggests that competencies for thriving in society (goals of education) come down to the manipulation of abstract symbols. Both of these terms, literacy and text, particularly in social semiotics, recently expanded their meaning critically [49]. Indeed, our contribution in this study very much depends upon which terms we keep with amendments and which we entirely replace. The arbitrariness of signification built into dominant conceptions of literacy and the consequent notion of text (as a culturally produced system of signs) does not accommodate an eco-awareness or eco-literacy in the strong sense. Taking arbitrariness as the criterion that makes a semiotic system social and, therefore, operational, leads to a construction of environments (natural and social) and of the body as cultural constructions. We need a model of semiosis that recognizes that meaning-making is not grounded in arbitrariness and the combinatorial differentiation characteristic of natural language, but rather, ecological participation and flourishing: “the wider and more complete participation of all components in a whole” (Bookchin, as cited in (p. 91 in [44])). To summarize, our argument here is to replace the concept of text with (a dialectic of) model and mediality, and to ground literacy in this broader notion of modelling.

More than just relying on the concept of text in his early work, Stables’ ([6,12], and with Gough [50]) initial approach to environmental literacy was inspired by (what can be called) *text semiotics*, which follows the tradition of de Saussure’s notion of the sign as the arbitrary and psychological articulation of signifier (form) and signified (content). This was motivated by the criticism of Cartesian dualism and subsequent mechanistic views of learning found in text semiotics. Such criticism, Stables explained, is critical for education, both in general and particularly in regard to sustainability. His initial proposal of living and learning as semiotic engagement [6] gradually led him to discover affinities with biosemiotics (with Gough, [51]) and to investigate learning in light of a construal of interpretation and adaptation as mutual and co-extensive, in a broad sense [16]. As such, he took a critical stance towards the notion of literacy, given its substantialist and anthropocentric implications, and proposed the more broadly encompassing term *semiosy* [7] instead. The term *semiosy* links learning not with the capacity for using textual codes but with semiosis in general, which, on this account is considered coextensive with biological life. The notion of *semiosy*, then, undermines the effectiveness of schools as guided by the constant aim of delivering fixed skills and competencies to students in favor of cultivating the students’ more general capacity to discover and use resources (p. 84 in [7], see also [16]) across all aspects of their life and experience.

Such a view vis-a-vis media and sustainability education is particularly needed in an age of increased digitization and accelerated media production and consumption: new media, which restructures societies and education, gives way to new, creative industries [52] and practices, for which skills cannot be exhaustively prescribed. To prepare individuals for a society of limited and pre-determined skills is to reduce and overlook human intelligence: to deny the capacity of individuals to discover unique semiotic resources and master unique semiotic competencies that can be both socially and environmentally useful. One of the realizations that digita(li)zation offers is that it is impossible to predict the totality of skills that secure an individual’s (or group’s) fulfilling life in society. For similar reasons, Lankshear and Knobel [53] advocate for switching from literacy, in the singular, to the plural literacies, particularly in the case of digital literacies. While we advocate for the theory entailed by the term *semiosy*, as the term was not specifically adopted in literature broadly, for pragmatic reasons, we retain the old literacy term. It should be noted though, that, with Stables, we observe the inappropriate correlation between educational learning and operations with textual symbols (letters) that this term implies.

Finally, we need to let go of the iconic-symbolic sign dichotomy in literacy approaches. This dichotomy is evident in the persistent dominance of and value placed on linguistic communication and numeric computation, and the marginalization of non-verbal forms of

communication. Seeing words that represent concepts as separate from their instantiation or manifestation in tangible, material or visual reality is a fallacy [8,54]. The point is not to dispute the importance of language and symbols, but to bring other media of communication and everyday embodied living into relationship with the symbolic.

### 3. (Bio)Semiotic Contributions

In this section, we discuss some of the conceptual and theoretical implications of adopting the biosemiotic concept of *Umwelt* into literacy studies. We redefine (essentially) constructivist concepts from multimodality, such as *semiotic resources* and *semiotic competencies* under a biosemiotic frame.

#### 3.1. Culture/Nature Conceptions: Towards *Umwelt*

The classic notion of environmental literacy tends to imply that the environment is a cultural production. This construal of environment, typical of modern philosophy, has been inherited from German romanticism, where, notably, the discipline of ecology also originates from [55,56]. The concept of *nature* that guided the development of the natural sciences comes from this strand of humanism [57], its epistemological and ideological implications still enduring in covert, unchallenged forms. Mind/body dualism and the educational rationale of Enlightenment are intrinsic to it. Amusingly and quite evidently, while this scholarly tradition deems *nature* an entirely cultural concept, it defines it in contrast to the concept of culture. From this perspective, nature is what cultured humans (can) think of nature. In a more elaborated sense, nature is the raw material for the human construction of nature through culture (see [58] for a sustained critique). Herein, the vicious circle of dualistic solipsism is at work, implying culturalism through the implication that cultured humans can only grasp the raw materials that their culture allows them to.

Following [59], Ljungberg [60] explains that “understood as the result of human practice and of representation” (p. 170), romantic concepts of nature and wilderness have ideological consequences for construing science and, consequently, education: “the arts have, in turn, reflected the mechanistic worldview of Cartesian dualism; the Romantic view of nature as mysterious, resourceful and communicative; or, following Darwin’s evolutionary theories, the naturalist view of nature as a battlefield on which only the fittest survive.” (p. 171). We concur that all these views are somewhat problematic. Furthermore, Ljungberg argues that the epistemological relativism of modernity, particularly the exaggerated cultural relativism that characterized German Romanticism, implies that solutions to ecological problems must always be sought and understood through culture. With examples from fiction literature, Ljungberg further emphasizes that it is possible “to break free of the constraints of mapped and civilized space and to negotiate new identities beyond the traditional boundaries between nature and culture.” (p. 183 in [60]) We wonder about the pedagogical and curricular possibilities of “ecology without nature” [61].

The global ecological crisis is a stark reminder that the biosphere is of one piece and that all ecosystems are interrelated. This is not to deny the importance of place-based environmental knowledge or stewardship, nor the fact that climate change is, most of the time, experienced and acted upon locally, with unique local effects and consequences. Different localities and bioregions have unique affordances and constraints for sustainable practices. Still, the environment is very real, and much more than just a cultural construction. Environmental damage caused in one place affects the entire globe. The lifestyle and consumer preferences of North Americans exist in relation to the fate of Polynesian islanders, as one example among many. Environmental degradation and climate change extend beyond the political/cultural boundaries that humans set for (or against) themselves and literacy must be able to recognize this minimal realism.

Furthermore, this belief in the strong relativity of human ideas around nature makes it difficult to speak about the relationship of global climate change to global industrialism and colonialism, resulting often in ahistorical perspectives and practices, as noted in research in decolonization and indigenization in education [62–64]—the basic political recognition

that not *all* peoples and all ways of life are equally responsible for ecological degradation and exploitation characteristic of the Anthropocene.

As noted in Hern and Johal [44], any understanding of an “ecological politics, the politics required to answer global-warming, must acknowledge that the domination of other-than-humans and the land is made permissible by the domination of humans by humans” (p. 94). Sustainability education and literacy must be subtle and nuanced enough to recognize the interrelatedness of ecology, capitalist exploitation, colonization and decolonization. This links to our decision to place embodiment at the center of sustainability literacy. The persistent human compulsion to power and domination, of nature and of fellow humans, is always related to satisfying embodied senses that are directly linked to material and natural resources—land, territory, water, soil, minerals, crude oil and built environments.

### 3.2. *Umwelt, Affordances, Resources*

From a dualist perspective, culture, like *nature*, is a production of the human mind, and thus, a *textuality*. We argue that, while humans (like many other species) cannot ‘escape’ their cultural world, culture and environments are not constructed arbitrarily, through the unconstrained modelling possibilities of symbolic conventions. The morphology of the body and its relation to the physicality of the landscape evoke both possibilities and constraints to organisms’ creation of environments. To draw from Gibson’s [65] celebrated concept, culture, like environment, is developed according to the *affordances* that the landscape presents to an organism, including the competency in extending and enhancing these affordances through technology. The landscape thus admits semiotic resources, as potential affordances [9,66], within the unfolding sphere of activity and action that an organism enacts within an environment, or what has been called the *taskscape*.<sup>2</sup>

Stables (with Bishop, [12]) initially embraced the Saussurean notion of sign to account for the subjectivity of learning, arguing that studies on environmental literacy “have not explored the ramifications of a view of the environment itself as text (see also [35])” (p. 90). This was, at the time, a reaction to the language-centered and objectivist notion of learning coming from analytic philosophy, which had been the unchallenged mainstream of philosophy of education [71–73]. Stables brought to the attention of teachers and education policy-makers that, being an intimately embodied, intellectual and collective-historical endeavor, learning is unique and personal for each individual. Further, by considering life and learning coextensive with semiosis, Stables was then led to overcome the construal of environment as text because of the hard relativism that this concept implies, subduing landscape, nature and, ultimately, reality to a sociocultural version of solipsism.

Biosemiotic theory relies on the conceptualization of environments (*Umwelt*, following [42,43]) as modelling processes (semiosis) of embodied organisms. According to Jakob von Uexküll, an animal’s *Umwelt* is a functional circle (or cycle) of perception and action signs. Through iterations of perceiving, acting upon the perceived and thus modifying the perceived, the animal creates its subjective phenomenal world—an environment. Sebeok [ . . . ] merged this biological theory with the semiotics of Charles S. Peirce into a theory that accounts for the continuity of meaning throughout the biosphere, which he termed “*biosemiotics*”. From this perspective, human-articulate language cannot be deemed the ground level of human environment-building. *Text*, in the strict sense, must rely on more basic semiotic (or modelling) competencies, which are nonverbal. These are environmental,

<sup>2</sup> The taskscape concept was developed by anthropologist Tim Ingold (see the article “the Temporality of the landscape,” [67], and the book *The Perception of the Environment* [58]). Musicologist Gary Tomlinson [68] describes how the taskscape is more properly sonically conceived, over and against the more static designation landscape and its implicit visual connotations; an observation that helps to explain the development of soundscape ecology from out of landscape ecology [69], and the recognition within biosemiotics [70] of the semiotic importance of acoustic codes and soundscapes for interspecies and intraspecies communication and the health and flourishing of biodiversity: “the taskscape emerges from the varied actions of a social group, the mobile performance of these actions, their structuring of the lived environment, and indeed the sounds they make [ . . . ] the taskscape is not external and static but changeable and manufactured, it is not so much seen, in the manner of an unmoving tableau, as made and heard. The taskscape creates from the rhythms of action sequences that form its own *temporality*, one based on moments of *mutual attention* commanded among its participants by movement and gesture” (*our italics*).

stemming from the relation between the outer (landscape) and the inner (body) world of an organism. With Danesi, Sebeok [74] famously posited that “the ability to make models is [...] a derivative of *semiosis*” (p. 5). They [74] defined modelling as “the capacity of a species to produce and comprehend the specific types of models it requires for processing and codifying perceptual input in its own way” (p. 5, see also pp. 182–183 in [75]).

This notion of the environment has proved highly fertile, as biosemiotics quickly became a prominent semiotic theory (see the lively discussions within Springer’s journal *Biosemiotics*, for instance, started in 2008), informed by state-of-the-art natural sciences. While literacy has been a topic of interest for semiotics in general (particularly within social semiotics and multimodality), it has not been approached from a biosemiotic perspective. We consider that replacing *text* with *model*, in the biosemiotic conception, as the underpinning and guiding principle of literacy offers a new and applicable theoretical framework to advance a comprehensive theory of sustainability literacy. It answers to the need, particularly as imposed by digital media, to acknowledge the embodied multimodality of meaning articulation. Fundamentally, this means acknowledging that meaning is environmental: in articulating meaning, all available sense perception channels and semiotic modalities are involved. By taking into consideration all a learner’s semiotic competencies, this encompassing notion of meaning articulation raises awareness that *the learner is ultimately free in her inquiries*. There being a multitude of competencies to discover meaningful relations in (and with) the environment implies that the body–environment relation provides an infinity of potential semiotic resources.

Learning as the selection of semiotic resources and their combination into structures of meaning (signs), throughout organisms’ experience, is therefore unique, personal, but also historical and environmental. However, limited and instrumentalized views of literacy have resulted in education that selectively supports the use of certain resources, while silencing or dismissing others, quite regardless of the specific learners. As Lakoff (p. xii in [76]) explains, this is typical of modern objectivism, which assumes “that rational thought consists of the manipulation of abstract symbols and that these symbols get their meaning via a correspondence with the world, *objectively construed*, that is, independent of the understanding of any organism.” By delivering specifically preselected resources in the form of systems of abstract symbols, following the educational rationale of Enlightenment, the practices of literacy and formal schooling have, in many ways, inhibited creativity and imagination. Moreover, such practices enforce an extractivist and productionist logic, arguably the kind of usage of resources that led to the current environmental crisis. These individualistic languages of learning (learner extracts learning capital from productive learning environments, for individual advancement) are implicitly linked with extractivist ways of being. Below we explain in more detail that such a technocratic perspective of learning, as solely exhibited by productive/good outcomes, aligns with the modernist account of the non-human world as standing-reserve—something to be used freely and without concern, for the sake of individual human advancement (whatever this may entail, culturally or environmentally).

Social semiotics has tackled literacy in various scopes [49,77]. It is in this line of research on literacy that the notion of semiotic resource [78] emerged and, in light of it, a concept of meaning as multimodally articulated was developed. Despite multimodality being founded on a criticism of the Saussurean notion of meaning as a fixed articulation of content and form [21,79], the concept of meaning as textual still supports epistemological relativism. For instance, acknowledging the *status quo* in social and cultural semiotics and without challenging the notion, Marrone [80] clearly illustrates the hard relativism it entails: “The text is not a given entity, nor phenomenal evidence; it is the result of a double construction: a socio-cultural configuration before and an analytic re-configuration afterwards” (p. 108).

Nevertheless, a tendency in multimodality studies, including approaches to literacy [81,82], seeks to nest an embodied notion of meaning. In this respect, we consider that the biosemiotic concept of model can be adopted and generate an expansion towards a

more comprehensive concept of literacy, as required to address both contemporary challenges of new media and ongoing ecological challenges. Literacy has been traditionally construed in close connection to the print medium. The competencies for thriving and practicing responsibility (or, response-ability) in society, however, depend on all the media that partake in the respective society.

Mediality, first of all, is evoked by the body. It is not only technological. It is where the meaningful environment is constructed, enacted, discovered. If the environment is a (semiotic) model and learning is semiotic engagement, then learning is modeling. The mediality within which the environment is constructed provides affordances for discovering semiotic resources. Discovering and using semiotic resources through ongoing activity in specific environments results in new semiotic competencies. Some of us, together with Kalevi Kull, propose a definition for semiotic competence as “the organism’s ability to activate semiotic resources in the form of affordances” (see p. 459 in [83], pp. 423, 429 in [16] and p. 371 in [9]). A semiotic approach to learning, like a notion of mind as embodied, can only account for competence, resource and affordance as mutually interdependent.

We define a *semiotic resource*, minimally, as “something that can be used to represent” (p. 358 in [9]). This notion originates in social semiotics, particularly in van Leeuwen’s (2005) argument for replacing *sign* with *semiotic resource*. van Leeuwen fundamentally argues against the arbitrariness of the Saussurean sign as socially imposed form–content articulation. We consider that, understood as a triadic phenomenon, the Peircean conception of sign is not targeted by van Leeuwen’s criticism. Rather, it is compatible with the multimodality approach, which indicates how biosemiotics and social semiotics can be bridged. Note that van Leeuwen (see p. 5 in [78]), too, relates resource with affordance. Extrapolating from Gibson [65] in a biosemiotic scope, we define affordances “as potential semiotic resources that an organism enacts (detects, reads, uses, engages) to channel learning-as-choice in its environment” (p. 367 in [9]). Minimally, this suggests that education (curriculum and pedagogy) must be receptive to the fact that distinct individuals will find and enact different affordances and resources in the same apparent material surroundings and in the same mediality, and that habitually and recurrently enacting these affordances/resources, directs future learning and discovery (even if not by the same individual, community, or for that matter, species, as the example of shared animal trails/paths as a kind of ecological scaffolding demonstrates, see [84]).

Recently, the notion of affordance has started to be applied in media studies. The motivation for this theoretical extrapolation lies in the observation that, like natural environments, (technological) media are multimodally experienced and present diverse possibilities to different individuals and communities of practice [85–88]. So far, this has been clearly argued by Hopkins, who observes that “digital media is a uniquely human technology—perhaps the most human of all technologies—that can be considered alongside other abstract human creations such as language or art.” (p. 49 in [89]) The reason for which digital media are so naturally *human* is that, by simultaneously involving a plurality of senses and semiotic modes (multimodal) and by being participative and interactive, digital media and so-called natural environments present very similar affordances for modelling/learning to the human subject. Following [25], media are extensions of the mind. As humans have extended their minds impressively through outstanding technological scaffoldings, each new medium altered the affordances provided by previous ones, revealing new possibilities and implicitly obscuring others [90,91]. Interestingly, the new digital media seem to bring us closest to where we started, to our full sensory-embodied immersion in natural environments, which they increasingly and convincingly simulate, as well as enhance in various ways. However, digital models can be easily manipulated and modified, unlike the natural environment. Digital media allow virtual simulations of non-virtual events that can be reproduced and recontextualized almost boundlessly, transforming meaning and signification in each new context of enactment and reproduction. For this reason in particular, the scrutiny of literacy as depending on media affordances is now particularly salient in an era of widespread disinformation.

## 4. Digital Media Embodiment

### 4.1. Critical Media Literacy and a Link to Sustainability Literacy

This article has so far tackled the development of sustainability literacy through the concept of a strong literacy that encompasses embodied communication, mediality and environment as a (bio-cultural semiotic) model (*Umwelt*). We moved away from classical notions of literacy, aligning our work with more recent trends in literacy and semiotic studies. These considerations will now be further developed by accounting for the digitalization of communication through a critical media literacy that includes digital materiality. We introduced, in the beginning, two aspects of embodiment as linked to: semiosis (material-natural-semiotic connection through the notion of *Umwelt*) and media (material-representational in semiotic terms). In this section, we focus on the latter: how critically exploring the multimodal affordances of *digital media and technology* can support and contribute to strong sustainability literacy. Such affordances are here defined as material and representational embodiments of technology or, equivalently, *potential semiotic resources that an organism enacts* (see above and [9]).

First, we explain the “material”, or, in other words, embodied sides of digital media, expanding on Leonardi’s [87] definition of digital materiality as: (1) consisting of matter, (2) instantiating theory/abstraction/concept, and (3) showing salient aspects of digital interactions. Digital materiality is not material in the traditional sense of materials, although it includes such meaning. We also provide a concept of “representational materiality” as related to (2) digital instantiation. This embodied material approach to digital media, we argue, calls for us to integrate critical media literacy within a broader sustainability literacy.

We are positioned in the world with our bodies and we understand and interact with this world through our bodies. At one level of digital materiality, digital media can be seen as different technologies with different technical and tactile affordances—the hardware, the design that requires clicking and tapping, and so on. This aligns with a notion of materiality as something physical, some “tangible stuff” [91] and physical substance [87] that our bodies come into contact with. One consideration of such classical materiality is therefore linked to what body movements, adaptations and engagements technology “demands” from us and the environment. In relation to that, we only need to remember how the affordances of digital technology are changing body movements (e.g., when young children get used to interacting with mobile phones and react by default to anything that looks like a digital screen by tapping, swiping or scrolling it with their fingers).

Another obvious aspect of classical materiality is to consider matter in its traditional sense of *physical materiality/substances*. What are the materials that technology is made of and what are its impacts on ecological and human life? As an example, we will refer to the work of Kate Crawford and Vladan Joler, who developed a graphical representation of the “anatomy” of an AI system [92]. Their work demonstrates the importance of taking a systemic, bird’s eye view of embodied meanings and networks of the digital through its globalized material supply chains, production and distribution, all which have both a global and a local impact on human and more-than-human world. A mobile phone, for example, is a complex system of material (physical) and virtual networks organized and connected globally, from cobalt mines in certain countries that use child labor for the production of lithium-ion batteries to global logistic infrastructures and trade networks.

An ongoing process of shrinking the boundaries between digital technology matter and living matter (e.g., human bodies, ecosystems), such as the advancements in nanotechnology, is another example of where technology is both material (albeit at a micro-scale) and virtual. Whereas these developments can provide remarkable breakthroughs in medicine—for instance, through the work in biotechnology—history teaches us that technology can be a dubious tool in human hands that could create a dystopian image of invisible control over our own bodies and lives. We understand that many would rather not think about all these complexities and interdependencies of sustainability futures, but unless we apply complex, relational thinking to problems that are complex and relational, we may not be doing any

notable work to change the status quo. Sustainability literacy needs to ask questions in relation to how everyday materiality, digital or not, comes into being and what impact it has on living sustainably and ecologically.

The second side of digital materiality, as suggested by Leonardi [87], is linked to *practical instantiations* of theories or abstract concepts via technology, arguing that “when principles, beliefs, or values are made manifest in some way, they become material”. Instantiation here means how theoretical insights, plans, models and diagrams are realized in materials and in practice, which may mean a practical action, e.g., by making something a written requirement, guideline, law or rule, or habitualized process/action. Leonardi provides an example of digitally materializing/instantiating an engineering car crash simulation diagram into an animated car crash simulation example that explains the diagram through a visual model. The animation is an example of practical instantiation that bridges a strongly symbolic model into an actionable example or practice model that is strongly pictorial and in motion. The main question here is how technology helps to translate an idea into action and/or visual representation. Such translation is digital instantiation that can also be understood as representational materiality.

The third aspect mentioned by Leonardi [87] is linked to using digital software affordances in different and diverse ways. From this perspective, some features have different salience in different contexts used by different users and user communities. This is an example of how users instantiate the features or technological affordances that are salient for their own use. Leonardi calls this *digital significance*. All these aspects of digital technology need to be embedded in critical media literacy to support sustainability literacy.

Critical media literacy is a semiotic field which, while defined in various ways by many, essentially examines the practices, tools, competencies, and processes that people use and enact to understand and engage with media critically, exploring connections between whatever media and everyday life, and enhancing a mindset to inquire media critically, and act accordingly. This field can connect an exploration of digital materiality and sustainability, by focusing on medial meaning-making as environmental and embodied, with socio-cultural, political, emotional, and cognitive impacts. We expand on this, by recognizing the importance of materiality in literacy and of understanding practical instantiations of digital media. It is important to note, at this stage, that materiality alone imposes constraints on learning: to have a high degree of semiotic freedom does not mean to have absolute freedom to operate on symbols disconnected from material surroundings. Semiotic freedom, rather, is “the complexity of choice an organism has for channeling learning in a way that sustains meaningful relationships within its *umwelt* (see also [4]).” (p. 372 in [9]). To remind the reader, the environment as *Umwelt* is both material and semiotic (symbolic, iconic, indexical). What we interact with on the digital screen are instantiated signs. These signs are some representational materiality shown on the screen—things, shapes, fields, pixels—that stand for something such as a real object, person, events or environments, a code or programming language. Thinking about these relations and digital translations is important to better understand what actions they support and their impact on sustainability.

Digital materialities are particularly salient for exploring sustainability challenges. Learners can explore how digital media and the information in different modalities, such as verbal or visual, relate to key sustainability challenges and terms (that mean many things to many people). For example, digital images represent but also influence models of reality (see [8,52,92] for an example of how digital images make meaning as representational materiality and why and how *iconicity* is important in critical-thinking and education). In our framework, the sign is triadic, following Peirce’s classic concept and thus explicitly embodied and mediated: sign is something standing for something other than itself to some *body-mind* that interprets it.

News or social media operate with signs that are seemingly non-material or “virtual”. However, they mediate the practical instantiation of abstract ideas into real life environments, human behaviors and actions. The presumed virtuality obscures the fact that digital

data is intrinsically linked with embodied and material reality, as it aims to represent and/or influence it. Herein occurs the importance of mediating representations of the environment that are, as much as possible, like the environment—a unique characteristic of digital media (see above). This influence can be materialized as negative human activation or deactivation. On the one hand, real-life compliance, the erosion of genuine care and compassion, and the rise of neglect or violence can be (and often are) mediated by digital media, hence impacting humans negatively. For example, the wide online presence and repetition of information that shows human hardship can banalize human suffering and the need for action towards change at systemic level. Shared media information can also call for and instigate the desire to act violently. On the other hand, digital technology also parades as or replaces physical engagement or activity through representational instantiations that offer entertaining and enticing content full of action and images that feed desire [28], creating a constant need for digital content. This passivizes human bodies, reinforcing intensely commercialized digital consumption as a lifestyle with minimal body movement or contact beyond the virtual (e.g., interactions with friends via social media can replace interactions in person). Access to various digital content can also change body engagement (e.g., digital pornography might erode human contact based on love and intimacy replacing it with one based on commodified lust). The key need of bodies is to move in some way, on their own or assisted (e.g., in wheelchairs), to be in some movement and action. These various negative digital influences (alongside many positive ones!) represent a change and shift at the psychological, cognitive and emotional states of the body. What this means for sustainability literacy is to understand and explore bodily movements, sensations and needs in relation to both our physical environments and digital media and networks of information-material production and consumption, while asking critical w-questions of who, what, why, when, where<sup>3</sup>. It means to understand planetary and localized biological and environmental existence as having an interdependent relationship with semiotic and digital existence, where the dynamic nature of meaning-making takes the central stage.

In brief, the semiosphere is evoked and sustained by the biosphere, as well as built environments, cultural artefacts and the technosphere; ecological and sustainability issues are deeply connected to economic, political and social issues.

#### 4.2. *A Strong Sustainability Literacy, Diagrammatic Model*

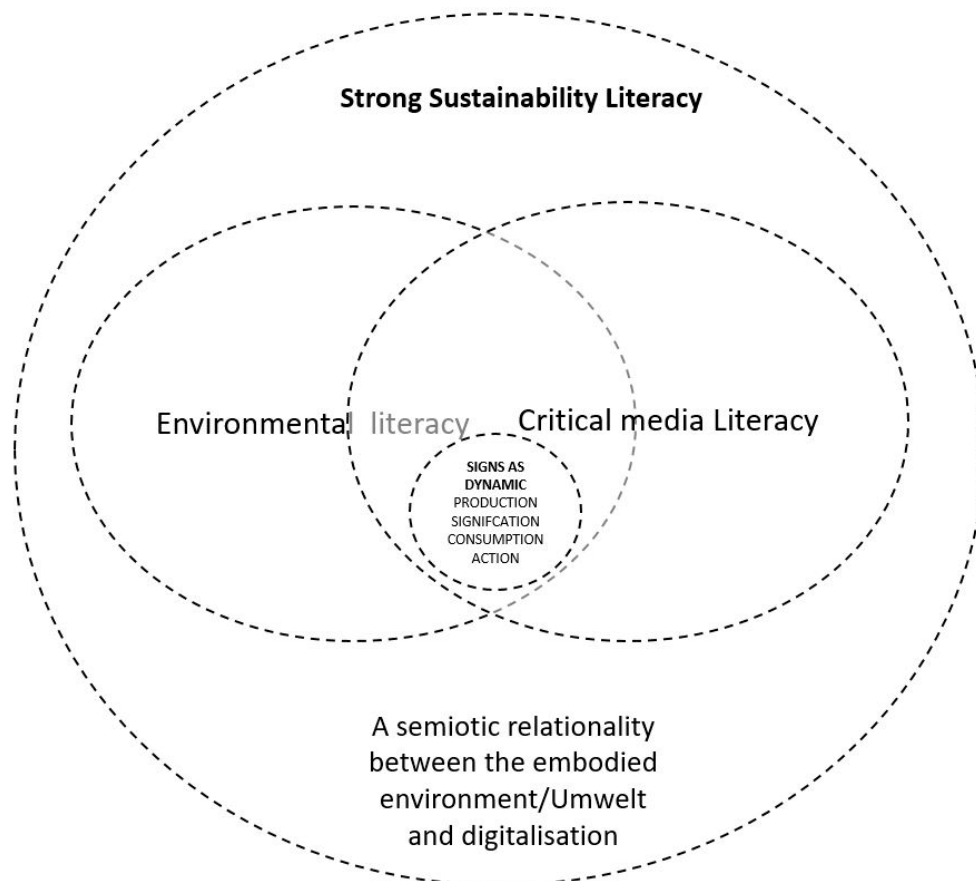
A strong sustainability literacy must embed pedagogical models that account for relational and holistic approaches to sustainability literacy, such as the ones we sketched in this chapter to bridge biosemiotics and critical media literacy, exploring the meanings and impact of digital materiality. We close this chapter by offering a relational figure of strong sustainability literacy. It supports an approach to sustainability literacy that can be adopted as an inter- or trans-disciplinary field, across environmental and sustainability education and digital media and technology studies.

The model materialized in Figure 2 aims to present strong sustainability literacy as a field with three key components. Hence, we have decided to present the diagram as a circle/bubble, in a different format to the previous Figure 1, as it serves a different communicative purpose. The circles are not closed or inflexible, hence the interrupted lines (dashes). The SSL field operates through critical explorations of semiotic relationality between the embodied environment (that requires strong environmental literacy/EL) and digitalization (that requires critical media literacy CML). Signs and sign-action (semiosis) are at the center in the smallest circle as SSL mediators. The sizes do not reflect importance or hierarchy, but co-containment, meaning that SSL is a field that contains both EL and CML as subfields and that both contain a myriad of possible sign-actions and meaning-making pathways that can be extrapolated and explored for their interconnected productions, signification and consumption in different contexts of enactment. The main point of this

<sup>3</sup> See [54] for a PSC—production, signification, consumption—critical media literacy pedagogical model; [93,94] for an inquiry media model with graphic types of information; [11] for an example of sustainability literacy practice in science education.



conceptualization is to approach sustainability literacy as an exploration of meanings, materialities and actions in relation to both sustainability terms and challenges, as well as the actual (real) life and environmental opportunities and constraints that learners are confronted with, on both local and global scales. The next step is to translate this model into practice by applying, adapting and developing pedagogies and curricular frameworks that would include relevant examples, questions and inquiries (we provided references to some possible pedagogical models in footnote 3 that align with these ideas above).



**Figure 2.** A model of the field of strong sustainability literacy.

## 5. Conclusions

This article offered an embodied conceptualization and theory of strong sustainability literacy and literacy in general, through adopting and fusing both multimodal and (bio/eco)semiotic understandings. By relying on the biosemiotic concept of Umwelt (in place of environment) and adapting several key terms from social semiotics and literacy within a biosemiotic framework (resources, affordances, model in place of text), we have also explored how digitalization, is not only a symbolic or cultural process, but also embodied, environmental and material, with real-life consequences.

It is important to be cautious and observant of the movement to subsume environmental education, eco pedagogy and sustainability literacy (along with transdisciplinary education) under narrow, outcomes/target-based SED initiatives. We acknowledge highly contested agendas associated with sustainable development. By focusing on how sustainability literacy can “produce” citizens who can achieve specific, pre-determined and often, explicitly economically and ideologically justified goals/deliverables, such research is often reduced to a problem that contains its own fix (or, pedagogically, questions that already assume their answers). This often advances an overtly consumerist and globalist agenda for education [6]. We are sensitive to such kinds of reduction and (technocratic) uses of

the concept of sustainability. With this in mind, we exploited the entanglements between embodiment, multimodality and environmental positioning. These entanglements support a strong approach to sustainability literacy, from a semiotic perspective. The resulting conceptual realignment, expansion and our model of the field (Figure 2) aim to grasp our human relationality to the more-than-human world in its full range of complexity. Obviously, not all aspects of structure and agency can be accounted for, but pedagogies can aim to develop complex inquiry frameworks for complex sustainability questions that can be explored across diverse programs and courses.

We hope that our conceptualization will be of relevance to colleagues working in the areas of environmental or ecological education, sustainability in education, eco pedagogies, multimodality, as well as anyone interested in reconceptualizing and advancing education for sustainable futures.

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