Botanical Gardens for Productive Interplay between Emotions and Cognition

Maciej Blaszak 1, Eliza Rybska 2*, Olia Tsivitanidou 3 and Costas P. Constantinou 3

1 Department of Philosophy, Adam Mickiewicz University, 61-712 Poznan, Poland; maciej.blaszak@wp.pl
2 Department of Nature Education and Conservation, Adam Mickiewicz University, 61-712 Poznan, Poland
3 Learning in Science Group, Department of Educational Sciences, University of Cyprus, 1678 Nicosia, Cyprus; o.tsivitanidou@ucy.ac.cy (O.T.); c.p.constantinou@ucy.ac.cy (C.P.C.)

* Correspondence: elizaryb@gmail.com

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Abstract: Botanical gardens are often designed with biological deliberations in mind, such as the need to preserve biodiversity. As in other community acts, functionality is also an important concern. In contrast, the need to connect with human values, such as tolerance, care or justice, and the facility to provoke interaction, reflection and discussion are often sidelined. More broadly, the social and educational aims of these institutions are often placed second in the design priorities, even though they are emphasized strongly in formulations of the underlying purpose and intentions. From an educational perspective, the interplay between emotions and cognition has an important influence on the visitor learning experience. In this paper, we elaborate on this interplay and we explore possible implications (a) for the design of botanical garden spaces, but also (b) for the formative process that emerges from the convolution of garden spaces, visitor expectations and interactive activities for teaching and learning. We introduce the term useful botanical garden and, through analysis, we develop a theoretical framework that provides a cognitive approach for the educational design of botanical gardens drawing on three dimensions: Sensibility (refering to those features of the design of botanical garden spaces that serve to create a sense of welcoming comfort, safety and homeostasis). Functionality (features of the garden spaces that scaffold interactions and cognitive processes). Rationality (refering to the facility of visitors to reflect on six values—care, fairness, loyalty, authority, sanctity, and liberty—and how they relate to the elements present in the botanical garden). We illustrate this model with reference to a range of botanical gardens. We elaborate on how these factors work together to highlight the educational features of botanical gardens and also discuss the implications of this model for the design of activities and educational experiences as well as for teacher preparation and professional development in the service of promoting environmental insight.

Keywords: botanical garden; model for educational designs; useful botanical garden

1. Introduction

Among different green areas located within urban spaces, botanic gardens are unique in the way that they serve multidimensional purposes. Botanical gardens refer to plant collections designed for display, recreation, research, and education [1] and they serve as worldwide educational and research centers [2,3]. The Botanical Garden of Blaj (Romania) has been identified as the first established botanical garden belonging to schools [4]. The New York Botanical has 125 years of history in research, education and public engagement activities. Botanic gardens have been venues for university education for more than five centuries [1]. The establishment of botanical gardens as educational centers creates benefits similar to those arising from the involvement of students with school gardens: increased student interest in learning [5]; improvement of students’ academic performance [6]; development
of collaborative and organizational skills, responsibility, patience, and team spirit [7]; and a sense of ownership [8] and positive attitudes towards nature [5]. Botanical gardens can become valuable venues for education and research, inspiring creativity and pleasant emotions, with the incorporation of well-equipped teaching laboratories, magnification devices, and a modest teaching space, as also suggested by Bennett (2014) [1]. Botanical gardens have been conceptualized also as recreational spaces, as sites for conversation of endangered plant species, but also as models for collaborative relations between human beings and the natural world [9]. Due to the expanding urbanization and the associated shrinkage of natural spaces, botanical gardens have emerged as recreational spaces, as displays of biodiversity and as theme parks for re-connecting with nature. Moreover, botanical gardens may be viewed as sites of experiments in two senses: as places of trials, of discovery and inquiry of what works and what does not, but also as places of experience and exploration. These elements differentiate botanical gardens from other types of gardens in the sense that the latter tend to serve more utilitarian purposes such as adding aesthetic or decorative value [9].

Even though botanic gardens can be perceived as creative educational environments aiming to promote the active involvement of children and visitors in general in their own learning, it has been reported that the embedded educational activities in botanical gardens, are often limited to observation activities, followed by visual art [3]. In contrast, the emotional and learning experience of a visitor in a botanical garden and the interplay between emotions and cognition have not been studied as much [10]. In an effort to define the special features that a botanical garden should entail for stimulating such interplays, it is vital to understand the underlying mechanisms underpinning the expression of emotions and the development of cognition, from a neuro-cognitive perspective. This could allow us to propose specific features so that botanical garden may constitute a pleasant environment where visitors can experience feelings of fulfillment and happiness, as well as rejoice in learning. Drawing on literature from cognitive science, environmental education and pedagogical research, we propose a model for educational designs of botanical gardens, drawing on three dimensions: sensibility, functionality, and rationality. Each of these dimensions is described and discussed from a neuro-cognitive and educational perspective.

2. Emotions and Cognition

People who seek to experience life to its full extent are striving for happiness. The notion of happiness has been an object of religious and philosophical reflection [11], and, over the last 25 years, it has also become an object of empirical research in many different fields, including cognition [12], psychology and behavioral economics [13]. One important outcome of prior research on cognitive processes is the conception of a modular structure for happiness, according to which it is not a unidimensional human state. According to Dennett, “Our tales are spun, but for the most part we don’t spin them; they spin us. Our human consciousness, and our narrative selfhood, is their product, not their source” [14], (p. 418). According to this conception, happiness emerges from the activity of many components of the human mind, on different levels of its organization [15]. It has been argued that happiness consists of three distinct dimensions, with aspects linked to the mind which are generated by three various neuronal networks, supported by the activity of the body and the effects of the external environment: pleasure, the sense of satisfaction, and potential realization [16]. The idea is built by linking the three aspects of happiness, with the three neuronal networks and the three dimensions of actions of the mind (sensibility, functionality, and rationality) [17].

Personal experience is a basis for psychological well-being. Hence, an analysis of the way in which people experience the world from a neuro-cognitive perspective is necessary for outlining the features of spaces that can create feelings of happiness and conditions for learning progress. This is also true in the case of botanical gardens, where experiencing starts always from the perspective of the human body, which can make sentient the physicality of the garden space, is acting within the garden’s functional places, and can reflect and evaluate its own states of mind, generated in response to the form and organization of the garden spaces. Progress in cognitive science enables us to assign
the appropriate experiences of happiness to the appropriate dimensions of the experienced garden, recognized by dedicated neural networks of the brain. From this perspective, we define a botanical garden as *useful*, when it is designed in a way that generates all three aspects of happiness: physical pleasure, functional satisfaction, and rational assessment (Figure 1; Figure 2).

### 3. Neuro-Cognitive Perspective

The term “*useful botanical garden*” can be analyzed at three levels: theory-laden perception, mental representation, and neuronal implementation. These are similar to the three levels of analysis of cognitive processes proposed by Marr [18]: (i) computational level, which can be used for defining a purpose for the cognition, (ii) algorithmic level that can determine the algorithm which might be used to achieve the purpose, and (iii) implementation level, which clarifies the physical method of enactment of the algorithm.

On the theory level, botanical gardens possess qualities of sensibility, functionality and rationality. On the mental representation level, sensibility is received by unconscious feelings (sensepts) that generate a sense of pleasure. In this respect, a useful botanical garden would entail features that could potentially create to visitors a sense of welcoming comfort, safety, and a tendency toward a relatively stable equilibrium between interdependent elements, especially as maintained by physiological processes. The establishment of these feelings is deemed for triggering visitors’ cognitive processes required for higher order thinking. The functionality of garden spaces refers to features that scaffold interactions and cognitive processes, such as prompts, sources of driving questions, and reflective opportunities. They facilitate visitor motivation and self-regulation and enable the passage of visitors into a state of “flow”. In this sense, functionality is received through experiences that generate the satisfaction of a completed task. Finally rationality refers to the facility of visitors to reflect on the six values—care, fairness, loyalty, authority, sanctity, and liberty [19]—and how they relate to the elements that are present in the botanical garden through processes of emotional engagement. Rationality, through conscious reflection on experiences, generates goal achievement feelings and a sense of personal orientation with respect to realizing one’s own potential realization (see Figure 1).

Each of these mental representation levels is experienced due to the activation of different neuronal networks of the human brain. At a neuronal implementation level, the salience network is activated for sensations and feelings; the central executive network for perceptions and the default mode network for concepts, respectively.

![Figure 1. Useful botanical garden: levels of analysis.](image-url)
We begin our analysis from the neuronal implementation level, which reflects a brain response to the sensibility, functionality, and rationality of a botanical garden. Complex cognitive processes, which are linked to a sense of safety, as well as critical or creative thinking, are not enacted by separate parts of the brain. Instead those processes are realized by disperse neuronal networks that can integrate different parts of the brain located in various lobes [20]. These networks undergo dynamic processes of activation and deactivation depending on: (i) the state in which the body is in, (ii) the tasks that need to be handled, and, (iii) the amount of available energy. Mental states, which are generated by particular networks, take the form of feelings, informing humans of the homeostatic state of their body (feelings of salience network), level of fluency of task that is being performed (feelings of central executive network), or the values around which humans build their own identity (feelings of default mode network). All these feelings are embodied in nature, and are dependent on various forms of action to be taken: “we feel because we do” [21]. The implementation of this model is presented in Figure 2.

![Figure 2. Analyzed levels of a usefully-designed botanical garden. The theory (or problem) level is shown on the first (internal) circle; a comparison to the three states needed for happiness and mental representations are provided in the middle. The external circle shows mental representations in the sense of what is happening with the human body.](image)

**3.1. Sensibility Dimension for Sensation and Experiencing Feelings due to the Activation of the Salience Network**

The most fundamental relationship among three aspects - the bodily actions taken by a person and the feelings experienced - relies on the salience network [22], which is processing and integrating information about the degree of safety in the environment. The salience network functions collectively, as a key brain system for integrating cognition, action, and feelings; thus it is situated at the interface of the cognitive, homeostatic, motivational, and affective systems of the human mind [22]. Together with its interconnected brain networks, the salience network contributes to a variety of complex brain functions, including communication, social behavior, and self-awareness through the integration of sensory, emotional, and cognitive information [22–25].

Humans perceive “feelings” from the body that provide a sense of their physical condition and underlie mood and emotional state. However, the sensations of temperature, itch, and pain are associated with an “exteroceptive” somatosensory system; whereas the less distinct visceral feelings of vasomotor activity, hunger, thirst, and internal sensations are associated with a separate “interoceptive”
system [26]. The salience network collects sensory stimulations through interoception. This internal sense corresponds to any sense that is normally stimulated from within the body [27].

The salience network organizations can be mapped in relation to the major afferents and efferents [25]. In particular, afferent input to the autonomic nervous system activates or inhibits stress response and thus controls the efficient use of energy in the body. On the other hand, interoceptive sensations are transformed into embodied/corporal feelings - (e.g., “I’m hungry”; “I’m thirsty”) allowing a person to feel states of their body. Corporal feelings are the raw material for derivative social feelings generated by the frontal part of the insula (e.g., “it is nice”; “it is not safe”) by which it is possible to assess the situation or to undertake motivated action in the frontal cingulate cortex, so that the body can react on the basis of this assessment.

Two key parts of the salience network are significant in performing the functions of integration. The frontal part of insula cortex uses interoceptive sensations to construct emotional body awareness. The frontal part of cingulate cortex determines the level of control of cognitive processes over the task being performed. According to the theory of expected value of control [28], the level of control of cognitive processes depends on two signals collected and compared by cingulate cortex: The first, indicates the optimal level for the control of the task facing us, and, the second informs us of our ability to enforce the optimal level of control.

The significance of the adaptive role of the salience network indicates that the physical space of the botanical garden can have substantial influence on the physiological balance of the body, stress levels, and control of energy expenditure [29]. In the long-term, those parameters lead to both physical and psychological well-being [30]. Also, the sensibility of physical space, via the interoceptive sense of the salience network, clarifies why botanical gardens could have a ripple effect on the health, well-being, and quality of aging people [31].

3.2. Interpretation of the Sensibility Dimension for the Design of a Useful Botanical Garden

Sensibility refers to those features of the design of botanical garden spaces that serve to create a sense of welcoming comfort, the safety and homeostasis that are necessary to engage with learning and trigger the cognitive processes required for higher order thinking. Mental representation of sensibility refers to physical space and physical pleasure, so in terms of human action, sensepts are located here - the question that might be asked is “what do I (the subject) sense?” Without an aspect of sensibility, the subject may not feel safe, so may not develop any cognitive action. Even when a sensibility is not conscious, it serves as a base for any action and as a basic level for happiness.

According to the Attention Restoration Theory, green areas around schools, recreational spaces, and homes are crucial for social well-being in modern society [32]. In fact, images of nature have been found to improve attention and previous research findings from various domains have justified this claim. From educational research, the findings of Li and Sullivan [32] suggest that high school students perform better on tests if they are in a classroom with a view of a green landscape, rather than a windowless room or a room with a view of built space, and the differences are statistically significant. Interestingly, in the study of Li and Sullivan [32], students also did better on attention tests when their classroom offered a green view. In particular the capacity of those students to pay attention while performing the tests increased by 13%, compared to when students were placed in a windowless room. They also showed greater physiological recovery from the stress that might arise from the test activity. This implies that views onto green landscapes from the classroom may help students to recover from mental fatigue and stress. Also the findings of Li and Sullivan [32] revealed that students in windowless classrooms or in classrooms with a view onto a built space had identical performance on attention tests.

Dadvand with colleagues [33] demonstrated that greater surrounding greenness at home and school correlated with improved cognitive development (in particular, with better progress in working memory and reduced inattentiveness) in schoolchildren. This association was partly explained by reduced exposure to air pollution, and better supply of oxygen.
There is a growing literature with studies showing the positive impact of green space exposure on ADHD and related symptoms [34–36]. Studies from health sciences have replicated similar effects. Ulrich [37], with his pioneering research on the restorative impact of nature on the human body, has documented a faster process of health recovery of patients who have undergone surgery, when they had instances of looking out on a greenbelt, as compared to a concrete wall, while resting in a hospital room. It has been claimed that people surrounded by nature not only feel healthier and safer, but are also more likely to behave in accordance with accepted social norms. This claim is associated with the findings of Kuo and Sullivan’s research [38], which showed that contact with nature may reduce the levels of criminal behavior through activation of local communities and the elimination of psychological precursors of violence [38]. Also, a pilot intervention study has shown that using community gardening and providing education about nutrition and a healthy diet helped obese and overweight children to improve their Body Mass Index status by the end of a seven-week-long intervention programme [39].

Therefore, sensibility of physical space clarifies why green spaces, such as botanical gardens, could have a ripple effect on the health, well-being, and life-quality of aging people [31]. In this respect, sensibility, the first dimension of our proposed model, constitutes a set of features of well-designed botanical gardens that may lead to potential triggering of cognitive processes.

All these positive effects influence human sensibility and happiness and are connected with physical pleasure. E. O. Wilson [40] introduced and popularized the biophilia hypothesis, suggesting that humans possess an innate tendency to seek connections with nature and other forms of life. Wilson defines biophilia as “the urge to affiliate with other forms of life” [40]. A similar description of biophilia was given by Fromm [41]. Nevertheless, the conviction that nature has a positive and therapeutic effect on humans arose in ancient times; nowadays one might observe a growing interest in biophilic design. As Kellert and co-workers [42] claim, our physical and mental well-being are strongly influenced by contact with the natural environment.

Contact with the natural environment is a necessity, not a luxury, and only such contact can help to achieve satisfaction and physical fitness even in the modern urban environment. As Szkolut and Modrzewski [43] state, the evolutionary context of development of human interaction with nature is dominated by its key features (and qualia) such as light, sound, smell, wind, weather, water, vegetation, animals, and landscapes. But, at the same time, this context is also defined by some relationships that exist in the environment such as the proportions, divisions, rhythms, fractal patterns, and sequences; all are visible features of spatial order, which stem from the universal, timeless principles of “Natural” geometry. The same authors claim that a creatively designed environment can be a positive stimulus or harmful obstacle for the biophilic need to stay in contact with natural processes and systems.

As a biological species humans present strong responses to various forms of nature and also to occurring processes and patterns [44]. The implementation of the idea of the biophilic botanical gardens that refers to the sensibility aspect of human happiness would need to be based also on the theory of design patterns described by Christopher Alexander. Alexander [45] claims that some places indeed are functioning well, they do not just look like they are. In this context, design should be perceived as methodologic intent, deliberate and repeated, based not so much on vague flashes of “inspiration” from nature, or on purely mechanistic (scientific) premises of twentieth-century rationalism, but rather based on phenomenological premises. From this perspective, botanical gardens seem to be perfect places for educational environments, not only from the sensibility dimension.

3.3. Functionality Dimension for Generating Satisfaction due to the Activation of the Central Executive Network

The central-executive network (CEN) is a brain network responsible for high-level cognitive functions, notably the control of attention and working memory [20]. It is active during tasks that require concentration, such as a critical problem solving activity, reasoning, and controlling of habitual reactions. The areas of the brain forming an anatomical substrate of a central executive network [20] are:

(i) the dorsolateral prefrontal cortex involved in the formulation of objectives and working memory,
and (ii) the posterior parietal cortex, responsible for the control of focus attention system. Vigilance is essential to long-term projects, but the energy cost of maintaining its activity at a high level is significant and can lead to disorders of the executive brain [46], also known as acquired attention deficit disorder (ADT—Attention Deficit Trait) [47].

Taking into account the costs of operating the mechanism of attention control, the human body uses opportunistically-processed and valuable environmental information, prompting the cognitive system to perform the needed adaptive actions. Such opportunities to act are called affordances [48]. In particular, “the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill” [48], (p. 127). The affordances of things for an observer are specified in stimulus information; they seem to be perceived directly because they are perceived directly. For example, humans have the habit of sitting as distinguished from kneeling or squatting. If a surface of support with the four properties is also knee-high above the ground, it affords sitting.

In order to have our cognitive autopilot operating, it is a prerequisite that suitable shapes are offered (affordance), allowing the immediate association of the form, function, and purpose of the object. For example, glass doors prompt push or pull actions, without the need for further reflection (or a button in an elevator prompts a push action, that does not require further thought). The collection of such examples tailored to the body and mind of a human creates a functional cognitive niche. The social significance for human beings relies on what other persons afford.

We pay close attention to the optical and acoustic information that specifies what people are and what they do. For example, when we try to count the number of ball passes between players, we use an attention-driven objective, which is energetically very costly. When, in our neighborhood, we hear a loud explosion, our attention is engaged automatically, often completely beyond our control. Outside the system of attention control there is the second type of control, triggered by sudden stimuli occurring in the environment. Interestingly, when analyzing the perceptual system used in the processing of views of greenbelts, it has been shown that the level of energy costs associated with the control of attention is much smaller than when perceiving an urban scene. Moreover, when looking at the green area, saccade eyes movements are faster, and the points of fixation shorter, than when a metropolitan environment is observed [49]. Thus the amount of energy that the body has to spend on perceptual processes decreases. Such situation takes place because in the natural environment the number of distractors is decreased, and distractors attract our attention against our will.

It has been also shown that memory performance and attention spans may demonstrate significant improvement when individuals spend time interacting with nature. Interestingly this effect can be achieved not only by walking in botanical gardens (versus walking along urban main streets), but also by looking at photographs of nature (versus looking at photographs of urban settings). These findings are consistent with a theory that natural environments are better at restoring attention abilities, because they provide a more coherent pattern of stimulation that requires less effort, as opposed to urban environments that provide complex and often confusing stimulation that captures attention dramatically and requires directed attention [50]. According to Berman et al. [50], simple and brief interactions with nature can produce marked increases in cognitive control. In this sense, nature cannot serve merely as an amenity, but it also has an impact on effective cognitive functioning.

One of the problems of today’s urbanized world, which is overloaded with too much information of low relevance, is dwindling resources of attention focused on goals. Control has become the economic asset that defines today’s era not as the economics of information, but the economics of attention. “Wealthy” people pay for narrowing their area of attention, which is acquired from other persons who are paid for completing the tasks that usually distract attention focused on a goal. This allows them to concentrate on the things that are important, relevant, here and now [51].

The psychological effect similar to the delegation of tasks by “wealthy” people to their assistants can also be achieved in two other situations: When we commune with neither the natural world, which reduces the dispersal and control of attention, and when we smoothly respond to the problems with the use of tools. In all three situations our mind is able to be in a state of flow, in which there
is a match between implemented and existing cognitive capabilities and a clear sense of progress in operation [52]. The flow state generates positive emotions that are associated with control of the task, full engagement into its process, and intense attention focused on the goal, which is not accompanied by significant energy expenditure. That paradoxical state - a pleasant effortless concentration - is due to the different physiological state of the body [53], accompanying ambitious measures, a high sense of human cognitive competence, and advancement of the goal.

3.4. Interpretation of The Functionality Dimension for the Design of a Useful Botanical Garden

Functionality refers to those features of the garden spaces where an interaction of visitors with the environment take place, thus such spaces scaffold interactions and cognitive processes. They include prompts, sources of driving questions, and reflective opportunities. They facilitate visitor motivation and self-regulation and enable the passage of visitors into a state of “flow”. The mental representation of functionality (as illustrated by the levels of analysis in Figure 1; Figure 2) refers to the functional place and the functional satisfaction. Therefore, functionality is related to the feeling described as a “sense of satisfaction”.

Offering opportunities for recreational spaces and green areas, either as visual stimuli or as more interactive spaces, are crucial for social well-being in modern society; and botanical gardens can address both purposes. Such opportunities comprise efforts of a wider umbrella of objectives, which target establishing a responsible environmental citizenship. Shaping responsible environmental citizenship may be influenced by a variety of factors and condition circumstances. Borden and Francis [54], relying on Maslow’s hierarchy of human needs, suggests that people who have satisfied their basic personal needs are more likely to act ecologically because they have more resources (time, money, energy) to care about superior, less personal, and thus social and pro-environmental issues.

Functionality in the term of educational design needs to take into account aspects of educational research that cope with affordances and purposefully design space. One example of such research was presented by Nyberg, Hipkiss and Sanders [55] who concluded that in order for plants to be noticed in animal-rich environments, they need to be prominent in the design of spaces with information about them displayed clearly. Supported by rich educational research dedicated to multimodality, these authors claim that multimodal and sensory experiences might be significant tools for a shift from an observed phenomenon called plant blindness [56] toward appreciation of plants. Wandersee and Schussler [56] have described this phenomenon as “the inability to see or notice the plants in one’s own environment”.

Despite debate about whether this phenomenon is caused by the “slowness” of plants [57] or just people being more attentive to animals [58], we would like to focus the attention on the design principles among which one refers to sensory-rich indoor environments can provide affordances for fruitful learning [55,59–61]. Multimodality in the botanical garden can be provided naturally by experiencing the natural objects, not necessarily through digital support (as many research on that field are focused on). What researchers agree on is that interactive cognition is also usually multimodal, taking place in sensory-rich environment. Such environments offer well-designed objects, artifacts that encourage visitors for interaction on intuitive manner. As a result of the action a person generates own personal knowledge (e.g., procedural knowledge) (e.g., [62]). In the case of botanical gardens such plant characteristics as color, shape/size, and smell, not only drew students’ attention [63], but could naturally work as affordances for educational actions. Designing botanical gardens in a way that will allow visitors to interact with sensory plants, to smell flowers, touch them, even eat some eatable fruits or encouraging students for actions that are taken naturally or in an intuitive manner would fulfill these aspects of functionality. As was shown in Mangione’s research [64], aesthetic practices vary depending on how artifacts are made accessible, and exemplify how botanical gardens rely on multisensory affordances. This is also true for the idea of Buehler Enabling Garden, that is designed in a way that is accessible for everyone regardless of age, gender, culture, or disability, since functional criteria are equally as important as, for example, visual ones. Within this approach, botanic gardens
can also provide a context for critical inquiry into ‘interactive landscapes’ [65] and can offer affordances for action that makes learning possible.

3.5. Rationality Dimension for Potential Realization of Concepts due to the Activation of the Default Mode Network

When we are not engaged in tasks that require a high level of control of attention, the brain automatically switches to the mode of operation of the default mode network [66], in which the mind easily wanders in time—evoking memories of autobiographical experience and planning the future—or wanders in space, with empathetic thoughts and feelings for others, as well as morally assessing their and own actions. The default-mode network (DMN) is a large-scale network of brain areas that form an integrated system for self-related cognitive activity, including autobiographical, self-monitoring, and social functions [20]. While the activity of an executive network is focused on the functional niche, the states of the default mode network relate to the content of the mind, especially those related to the system of values encoded in a ventrolateral frontal cortex, in the side pole frontal brain (lateral frontal area) [67]. The values implemented in the brain form a modular human conscience [19], responsible—in the form of moral intuitions—for our immediate ability to assess actions in axiological terms. Henceforth, the default mode network is most commonly shown to be active when a person is not focused on the outside world and the brain is at wakeful rest (e.g., during daydreaming and mind-wandering), but it is also active when the individual is thinking about others, thinking about themselves, remembering events from the past, and planning for the future [68]. In this sense, the network is being activated “by default” when a person is not involved in a task. The exposure to and interaction with natural scenes overall and botanical gardens in particular, may refresh the brain by activating the default mode network in a particularly effective way, allowing the brain to subsequently return to action (“task-positive network”) with renewed vigor (i.e., well synchronized brainwaves). This activation is actually linked to the emotional engagement of individuals.

If moral values are still recognized as “the inner voice of conscience”, revealing the appropriate emotions and behavior in the social context (blushing with shame, feelings of guilt, etc.), the epistemic values can be recognized in subjects (extension of social intelligence by technical intelligence) and in organisms (extension of social intelligence by intelligence of Natural History) as their essences [69]. These essences, which are the subject of the concepts, refer to axiological source, or human mind; in a similar way to how perceptions refer to a functional source. In other words, the offers (affordances) of cognitive niches and simples impression relate to the physical source or material objects in the world [17].

The different types of representations of mental states of a modern human mind (experiences, perceptions, concepts) are presented in Table 1.

3.6. Interpretation of the Rationality Dimension for the Design of a Useful Botanical Garden

Rationality refers to the facility of visitors to reflect on six values—care, fairness, loyalty, authority, sanctity, and liberty—and how those values relate to the elements present in the botanical garden and the emotional engagement of visitors. Mental representation of rationality (as illustrated by the levels of analysis in Figure 1) corresponds to the judgment of the state of the mind as a reaction to the world’s form so it serves as a so-called “real judgment”. This aspect of happiness is strongly related to the state of mind and to the feeling of potential realization.

A person’s values, attitudes, self-efficacy, ownership, and personal interest comprise the several aspects of the affective dimension [70]. The affective domain of environmental sensitivity reflects one’s emotional engagement and is linked to our third dimension of happiness—rationality.

It seems that information that is encoded in six modules of values—module of care, fairness, loyalty, authority, sanctity, and liberty [19]—plays an important role in our efforts and the process of designing our environment, which began in human evolution probably around 50,000 years ago [71], when there was a cultural explosion. At that time, the material culture—was enriched with artistic creations, the form of which indicates the imagination and innovation of their creators. Creatively
minded Cro-Magnons probably resulted from the integration of knowledge in their brains, which in earlier forms was isolated in the modules of social intelligence, the technical module, natural history and linguistic modules [72].

What distinguishes the mind of modern humans, who for 50,000 years have accelerated their own evolution by means of cultural artifacts, is the ability to objectively diagnose problems with which people have to face. Problems encountered by a person can be diagnosed only on the basis of values implemented in the human brain. After endarterectomy of detailed intelligence modules from before 50,000 years, the range of applicability of the six values has widened diametrically, from the area of social intelligence, into areas previously axiologically neutral: The production of artefacts (technical intelligence), or the relationship with the natural world (knowledge of natural history). The moral values of social intelligence served as adaptations to life in the world of the Middle and Upper Pleistocene, while the same values - let us call them epistemic - as an evaluation criterion of reality in all its dimensions, became exaltations to life in the modern world.

Fietkau and Kessel [73] were two of the first authors to consider the connections between values and pro-environmental behavior. They suggest that values are responsible for shaping much of our intrinsic motivation [74]. Blake [75] points out that the most pro-environmental behavior models are limited because they fail to take into account individual, social, and institutional constraints and assume that humans are rational and make use of the provided information [75]. Also Smallbone [76] claims that many efforts for increasing environmentally friendly behavior often fail because they overlook the role of values and the opportunity to show the link between behavior (e.g., recycling) and value-fulfillment [76]. Nordlund and Garvill [77], in an effort to explain these situations of failure, suggest that the choices a person has to make between acting in a pro-environmental manner and not doing so, often involve a conflict between immediate individual and long-term collective interests [77].

These authors conducted a study testing a hierarchical model of the effects of psychological factors on different levels of abstraction, such as general values, environmental values, problem awareness, and personal norms, on general pro-environmental behavior. The study was conducted in Sweden, which is recognized as a very pro-environmental country. The findings stressed the importance of the personal norm for pro-environmental behavior, even though an unexplained variance was observed. Stern [78] has described personal moral norms as the main basis for individuals’ general predisposition to pro-environmental actions, and described four major types of causal factors that might influence behavior [78]. Those are attitudinal factors, such as values, beliefs, and norms; contextual factors, such as material costs, rewards, feedback, and the availability of technology; personal capabilities, such as financial resources, behavior specific knowledge and skills; and habits or routines that may need to be changed. Also Oreg and Katz-Gerro [79] performed a cross-national research on predictions of pro-environmental behavior relying on one’s values [79]. Their findings revealed that pro-environmental behavior requires environmental insight, which is only acquired through education. They suggest that cultural value orientations, independent of knowledge, need to be targeted as the basis of programs dedicated to environmental education [79].

Any particular value is highly dependent on the community, its cultural context and ethical perspective. Typically, environmental education aims to develop values, attitudes, knowledge, and problem-solving capabilities. Thus, it is not surprising to notice country-specific value orientations. Nor is it surprising to find values taking second place amongst other educational priorities. Several studies have focused on the role of values in environmental education. Several values are presented and analyzed in different studies, depending on the theoretical framework used. Nevertheless, the values examined in several studies are not aligned with the values discussed in this paper, which ought to be universal and situated in cognition i.e. they should be adhered to consciously. In many studies values are considered as external constructs and not internalized parts of cognition. For example Redclift and Benton [80] claimed that people’s values are “negotiated, transitory, and sometimes contradictory” [80]. From this point of view, the moral values that have to be taken into consideration as a basis for designing a useful botanical garden belong to people’s internal system of judgment.
However, what makes a difference from one individual to the next is the weight attached to the respective values. This specific configuration of the validity of values is formed during the lifetime, from childhood to adulthood, and is shaped by the community environment. Often what is changing, when an individual person transfers from one social context to another, is not the value itself but the internal validity attached to the specific value.

**Table 1. Levels of representation of mental states.**

<table>
<thead>
<tr>
<th>Types of Representations of Mental States</th>
<th>Relation between Types of Representations of Mental States and Their Source</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensations</td>
<td>They relate to the physical source (to the world)</td>
<td>Running water, lowers stress levels, indicating safety.</td>
</tr>
<tr>
<td>Experiences</td>
<td>They relate to the functional source (to the niche)</td>
<td>Drinking water offers quenching of thirst, signaling functionality</td>
</tr>
<tr>
<td>Consciousness of experiences</td>
<td>They relate to axiological source (to the mind)</td>
<td>Clean water: purity indicates the value of holiness (untouched by germs), which is the essence of flowing drinking water. When someone drinks clean, flowing water, they may have a feeling of moral cleanliness (effect of Lady Macbeth) [81].</td>
</tr>
</tbody>
</table>

4. Educational Implications: Designing Botanical Gardens as Learning Spaces

Considering the potential benefits that may arise from connecting with nature and the environment, with respect to cognitive and affective development, we recommend that botanical gardens should become a place of frequent and scheduled educational activities. From a design perspective, the role of exhibition plants in a botanical garden, could productively shift from an object-focused design, towards a visitor-focused approach, in which the very nature of the visitors’ experience becomes the driving force. In this respect, the design of the botanical garden should aim to provide a framework for intentionally organizing visitors’ experiences, so as to engage them at an emotional level and in so doing attach personal memories to the experience of the visit and the physical setting [82].

Broadly two main exhibition types can be defined: emotive and didactic [83]. Emotive exhibitions are those produced for primarily aesthetic or evocative purposes. Didactic exhibitions on the other hand, are those with a more explicit educational intent and thus greater emphasis on interpretation, creating what could be called a “three-dimensional essay” [83], (p. 63).

Recent innovations in the available media have also made exhibition design more sophisticated, as described by Dernie [82], who categorizes exhibitions primarily as:

- Narrative space: the juxtaposition of objects and displays in a way that sightlines and visitor movement reveal an unfolding narrative and layered storylines;
- Performative space: where the emphasis is on action rather than observation on the part of the visitor, usually afforded with interactive exhibits; and
- Simulated experience: immersive multimedia experiences and scenic reconstructions that could be considered an evolution and extension of the traditional museum diorama.

Hein [84] discusses two additional implications of experience-oriented exhibitions: (i) change in the communication style of the exhibition, through which the story is elicited rather than told, and, (ii) a change in the definition of an exhibition, where the collecting, organizing and displaying techniques are replaced by experience-making technologies.

Kaplan [85] defines exhibitions as “products of research, [which are] organized and designed to convey ideas” (p. 37). Exhibitions, as forms of interpretation, communicate through the senses with their primary focus on visual perception [86]. To better classify exhibitions, it is imperative to take into account what they aim to accomplish [87]. This classification is based on intent and the use of
existing collections. This perspective encourages us to look at the useful botanical garden as a narrated interpretive environment.

Relying on our proposed model, the design of activities and educational experiences, as well as teacher preparation and professional development, should meet the criteria of sensibility, functionality and rationality. In particular, a well-designed functional botanical garden, a useful botanical garden, should be designed in a way that creates a welcoming comfort to students and visitors, which is necessary for triggering cognitive processes and emotional engagement. Of the qualities that define an excellent exhibition, perhaps the most important is an engaging story. The concept of narrative or storyline on which an exhibition is scaffolded, requires certain design elements like content knowledge, interpretation, and social impact that serve to enhance the exhibitions and the intended messages. In this vein, “the narrative” space for a botanical garden, as in a science museum, should go beyond its role of displaying collected items, in this case, plants. It should be based on the premise that the displayed items have to be presented in a context that allows their full significance to be understood and appreciated. The narrative continuum is as important as the objects themselves. Drawn into the flow of the narrative, visitors view the display with their senses tuned to sequence, coherence, and transformation.

We propose crucial features that need to be considered while designing a botanical garden to this end. First, ecological psychologists, cognitive scientists and architects should assure that green and natural space should be the dominant element of a botanical garden, Any industrial buildings within the botanical garden, like shops or cafeterias, could be covered with plants. Pathways should be safe and, if possible, made from natural materials (stone or wood). Second, architects in collaboration with biologists, botanists, and environmental education researchers should discuss a common prototype, with proper affordances, such as a wooden logs, shaped in ways that can serve as benches or spaces for children where equipment can be used in an intuitive manner. The prototype would have to take into consideration the design of situations that trigger the desired values, e.g., benches arranged in a semicircle or circle, a situation liberating mutual respect. Third, environmental education researchers and botanists in collaboration with sociologists and/or ecological psychologists would be responsible for testing and evaluation of the prototype (see Figure 3).

![Figure 3. Evolutionary process of designing.](image)

In such an environment, learning can be experienced through social interactions or the so-called “participationism” by Sfard [88]. Etienne Wenger describes learning as changing levels of participation in authentic communities of practice [89,90]. Learning, as social situated activity, is placed in a context of life experiences, where pupils are engaged in collaborative activities [91] and naturally embroil themselves in situations of discourse, reflection and collaborative learning. By providing intuitive activities - through well-designed affordances – botanical gardens evolve into places for meaningful science and environmental education. Such learning opportunities may be offered through
educational displays, art exhibitions, open-air theatrical and musical performances, inquiry oriented activities with the provision of essential scaffolding and also the use of technology. While offering such experiences, it is also essential to afford a sense of control to students. That could be achieved with the inclusion of prompts, sources of driving questions and reflective opportunities. Such facilities require appropriate teacher preparation and professional development, which could be offered by the individual botanical gardens in advance, in accordance with the targeted learning objectives and principles of the proposed model.

Educational experiences in botanical gardens can lead to the development of practical skills including plant identification, and may offer many benefits with respect to the teaching of key competencies, due to the accessibility, diversity of collections, and the opportunity for frequent repeat visits [1]. Apart from the development of practical skills, such educational experiences entail emotional engagement of students, since learning in botanic gardens also offers a pleasant respite from the hectic school or college campus, and the aesthetic garden’s environment is conducive to learning and creativity [1]. This aesthetic perspective, of botanical gardens, which may be the prime example of the human-nature relationship, complies with the rationality dimension of our proposed model for emotional engagement of students, which emerges due to the activation of the default mode network.

Wang, Chen, and Zhang [92] suggest that recent developments in mobile and wireless communication technologies may play a vital role in designing a learning environment of botanical gardens, that could combine both real-world and digital learning resources. Wang et al. [92] stressed the importance of assisting students in maintaining the control of a task and managing the abundance of available materials, in an effort to avoid instances of cognitive overload, which could undermine effective learning outcomes. This is in line with the sensibility dimension for sensation and experiencing feelings, which emerge due to the activation of the salience network.

In the case study by Wang et al. [92] an Orchid Island botanical ecosystem course was conducted in classrooms and at the Botanical Garden of National Museum of Natural Science in Taiwan, during which the participants used a learning system integrating context awareness and ontological technology. Their findings demonstrate that this innovative approach can enhance learning intention [92]. The integration of technology and its potential learning benefits in educational activities of botanical gardens have been also reported by Salman, Zimmerman, and Land [93]. In their study, elementary school students, throughout their tour in a botanical garden, were facilitated by a Naturalist and used mobile technology (e.g., iPads) to focus on specific characteristics of trees on their touch screens while observing the trees and discussing about them. The findings of Salman, et al. [93] revealed a collective engagement of students afforded by a coordinated interaction between sensory modes (verbal, gaze, touch, spatial) and mobile technologies (iPads, AR content). This agrees with the functionality dimension of our proposed model for scaffolded interactions and reflection processes, which emerge due to the activation of the central executive network.

Botanic gardens that are designed in accordance with the proposed framework offer places and spaces for feelings of safety by designed placing of trees and other green objects (which refers to sensibility). Gardens can be designed in ways that promote, for example, cooperation, communication and creativity (all important from an educational perspective and referring to the level of functionality), giving the participants a feeling of being included in the group/community (which refers to the axiological level, identified here as rationality). Cooperation, in particular, can be enhanced by the way space is organized, for example, by setting benches in a semicircle, where people sitting face-to-face are prompted to interact with each other. Connecting objects and experiences with stories can be particularly productive both for engagement purposes and for long-lasting learning.

Moreover, botanical gardens may display a mix of themes resonating strongly with the general public, highlighting topical issues such as climate change or water and energy resource distribution. In these so called “themed botanical gardens”, information and activities relating to the environmental issues at the start of the 21st century, especially those relating to “plant conservation” and “sustainability”, may be incorporated.
5. Conclusions

It is true that botanical gardens may serve different purposes for individuals [94]. For example different motivations may trigger individuals to visit them as part of their outdoor recreation [95]. In this sense, botanical gardens may serve different purposes depending on the target group’s special interests, such as utilitarian, pleasure, educational, cultural, and spiritual purposes. Connell [96] reports that actually people tend to choose botanical gardens as places to visit because they perceive botanical gardens as pleasant environments to be in. Moreover, a majority of botanical gardens’ visitors in Great Britain demonstrate a general interest on plants. In any case, botanical gardens offer convenience, value, and security, social interactions, comfort, facility, and all those parameters have been reported as human needs by Beioley [97]. They have much to offer to individuals and society in general. Our proposed model for educational designs of botanical gardens could be nested within and linked to environmental education, which might in turn lead to local ecosystem services and human and community well-being. It looks like an uneasy struggle to design a useful botanical garden, but taking under consideration the global need for nature protection and human tendency to seek happiness, this effort is worth taking, and provides a path that could make more robust connections between environmental knowledge and behavior.

Usefully-designed botanical gardens that serve educational purposes would address all three dimensions of the presented model: sensitivity, functionality, and rationality. Sensibility in a botanical garden that is designed to serve as a learning space, is connected with a sense of safety and an environment that invokes pleasure. It is the easiest aspect to fulfill. For this purpose, a botanical garden could adopt a natural style, giving visitors an impression of being immersed in nature. Such a garden would have no or minimal concrete elements. Wood would be recommended, and if there are buildings, they could be covered with plants. This recommendation would also fit the design of educational spaces dedicated to bigger groups of people, also catering to the needs of pupils. Functionality could be implemented in two different ways. First by rendering the botanical garden a place where pupils would have opportunities to “act”, to manipulate natural objects, to collect different types of leaves, to take care of plants and animals as parts of nature. A botanical garden should also have some places with anthills, and beehives, where pupils could observe and discuss the biological relationships among animals and between animals and plants. Pupils would be able to work together collaboratively in order to prepare natural food for themselves, or to prepare some medicinal substances (e.g., aspirin from Salix). Second, a botanical garden should provide visitors “affordances” where they can naturally think about what has to be done in order to use something. Such affordances should work intuitively.

In other words, pupils should be able to use tools and procedures without a need to figure out how they work. Rationality could be enacted on the basis of the first two aspects. In educational spaces, pupils would be able to sit around the round table and collaboratively solve problems or respond to challenges. For example, pupils would be able to produce musical instruments from materials they would be able to find in the garden. Such activities would connect with personal values. For instance, if every individual in a group were contributing towards the accomplishment of the group task, the value of loyalty becomes relevant. Reflection processes would encourage pupils to think about themselves as a part of society, about connecting with other people, about accessing the services of authorities and also their own roles (e.g. guide, teacher or beekeeper).

There are problems that all people encounter, because their lives proceed in finite space and time. If choice means loss (we lose the opportunity to experience other options), how would our brains value the external world? If we know the value of available choices, how much does each choice cost? Survival is hard and out of the pressure of desperation comes cognitive efficiency. Cognitive neuroscientists recognize that all evolved brains—regardless of age, gender, ethnicity/race, religion, sexual orientation, or any other social or personal characteristics—take dramatic steps to minimize energy costs. They postulate saving principles, universal to all brains of evolutionary successful people: batteries must be drained slowly, space and bandwidth must be saved, and computations must have goals [98,99].
We also speak of a common logic shared by a variety of what, on the surface, may seem unrelated activities: visiting botanical gardens, learning, or behaving morally. We try to explain and understand them in neuroscientific and behavioral terms. Looking through the lens of brain science, ecological and environmental psychology can teach us about the nature of the human mind, the meaning of rationality, and simply how to live safely, productively, and creatively.

We understand that the notion that studying the inner workings of human brains might reveal how botanical gardens make us feel safe, help us think, and decide and guide our axiological feelings and judgment, might strike many people as reductive. However we think, as many authors before us [100], that applying the lens of fundamental research to everyday life has consequences at many educational levels. Most immediately, such an approach offers practical, concrete suggestions for how to feel safe (green areas stimulate positive feelings in the insula cortex that motivate people in the anterior cingulated cortex), how to solve specific problems (look for affordances in botanical gardens), and how to find balance between different values in the moral brain. Examining cognition (understood as the combined activity of three principal brain networks) as a means of solving educational problems posed by botanical gardens can change the way people think about human ecological rationality [101].

6. Possible Practical Implications

Although the public space of a botanical garden can be thought of in terms of its physicality—natural scenes and educational paths—it is also a place of visitor communities behaving in remarkably similar ways worldwide. The interplay of physical space and social networks gives rise to cognitive phenomena of extended minds, whose boundaries encompass individual brains, bodies, and designed artifacts. Extending boundaries of the mind beyond boundaries of the brain increases individual creativity and intelligence, social innovation, and economic output. Table 2 presents an overview of the cognitive dimensions of public spaces, as they apply to botanical gardens.

The size of the public space of botanical gardens is changeable, depending on social network density (families vs. students), connectivity (intimate vs. conventional), and transitivity (formal vs. informal) [102]. From the onset of our lives, when attachment rules our emotional world, we live in intimate networks that range in size from three to seven people [103]. What counts then is an intense exchange of emotional resources during face-to-face interactions. They create the first cognitive dimension of public space, which can be called “experiential dimension”, following Steen Rasmussen’s book on architecture [104]. Experiencing is analyzed at the level of mental sensations, implemented by the salience network, whose key part—anterior cingulate cortex—registers both physical and social pain. Social stigmatization hurts more than a broken leg, and ostracism can be among the most intense forms of punishment [105].

Then goes the effective network maintained to deal with the logistics of everyday life, when people pursue instrumental goals associated with work, leisure, career, and accumulation of material and symbolic resources. Emotional exchanges give way to epistemic strategic exchanges, mainly in the form of mindreading, carried out both by the default mode network and the central executive network. Mindreading ability develops between 2 and 4 years of life, and engages mental percepts, which refer not to physical world attributes (like sensations), but cognitive niche composed of packets of valuable information. They are called “affordances” and defined as what the environment “offers the animal, what it provides or furnishes, either for good or ill” [48]. The effective networks range from 6 to 34 people [103] and constitute the functional dimension of the public space. “Functional” because strategic games played by social actors let them treat others as smart tools, forming a cognitive scaffolding for their own brains.

The last network is called “extended” and consists of distant kin, professional acquaintances, and “friends of friends” [102], numbering between 100 and 400 persons. Relations between them are “weak ties” [106], crucial—as Mark Granovetter has shown—not only for our professional success, but—thanks to Matthew Lieberman’s neurocognitive work—indispensable for building conceptual
selves among teenagers (13-18 years of age). Their brains, in the area of the default mode network, create the sense of self mostly on the basis of other people’s opinions.

The mental states created by the default mode network are conscious concepts referring to axiological content of the moral neural sense (our conscience) located probably in the lateral frontal lobe [67]. It means the objects of consciousness are not the states of the physical world, nor affordances of the cognitive niche, but mostly values of our moral minds. Jonathan Haidt claims there are six of them [107], responsible for our decisions, questioning the economic analysis of costs and benefits [108], and crucial in the process of self-formation. The third cognitive dimension of the public space can be called “rational”, supplementing our perception of other people as biological organisms (sensations), cognitive tools (perceptions) with concepts letting us see them as axiological subjects.

Table 2. Three cognitive dimensions of public space.

<table>
<thead>
<tr>
<th>Size</th>
<th>Intimate networks</th>
<th>Effective networks</th>
<th>Extended networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behavior</td>
<td>Experiential</td>
<td>Functional</td>
<td>Rational</td>
</tr>
<tr>
<td>Sensations:</td>
<td>The sentient self</td>
<td>The epistemic self</td>
<td>The reflective self</td>
</tr>
<tr>
<td>Mind</td>
<td>(“I feel therefore I am”)</td>
<td>(“I think therefore I am”)</td>
<td>(“I imagine therefore I am”)</td>
</tr>
<tr>
<td>Brain</td>
<td>The salience network</td>
<td>The central executive network</td>
<td>The default mode network</td>
</tr>
</tbody>
</table>

The study of public spaces of botanical gardens cautions scientists against naively breaking the system into independently acting individual agents [109]. The postulate of “cognitive dimensions of public space” points to the idea that the content of mental states isn’t fully defined by activity of the human brain. The valuable information implemented in cultural artifacts and in minds of other people is equally important. It seems that the brain is not the only level of causation in psychology, and the science of human development shouldn’t be neuro-centered the way Francis Crick saw it in “The Astonishing Hypothesis”: “You’, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules” [110].

To sum up, the proposed framework offers a variety of possible implications. We will start with the recommendation that policy makers and architects would find it productive to interact with cognitive scientists in the process of designing botanical gardens as such socially useful places. The design process requires an interdisciplinary approach. From an educational perspective, introducing such a framework opens up new space for research, including observations and measurements of:

- the effectiveness of types of actions that such spaces encourage;
- types of affordances that are most effective;
- the educational effects of interacting in the garden spaces, including on cross-cutting competences, such as problem-solving and creativity;
- types of group interactions.

Botanical gardens designed to reflect an analysis of cognition at work can play various roles including:

- therapeutic - by e.g., engaging visitors to interact with objects, plants, animals and people;
- educational - through appropriately designed affordances they can accelerate a child’s development, and reduce cognitive load during teaching-learning activities; and
- affective – by promoting values and inter-connectedness.

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