

Digital modeling of the ecophilic tendencies of university students' consciousness

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Abstract

The article presents a digital modeling of ecophilic tendencies of university students' consciousness based on the integrative application of digital, mathematical, anthropological, psychological methods and approaches. In order to determine the optimal number of clusters, we used the Hubert index and its graphical representation, hierarchical clustering with Ward's minimum variance method (Ward D and Ward D2) and its visual representation, distance matrix and visualization based on it. We clustered the objects using two clustering methods – K-Means and Canopy. Based on the study of ecophilic tendencies of consciousness using cluster modeling with the help of K-Means and Canopy methods, the 3rd and 4th clusters were formed. The 4 cluster models are more representative clustering models. In these models, the “ecophilic” clusters (25-28%) with medium and high levels of ecophilic tendencies of consciousness are defined as system-organizing, the “dominant” clusters (42-46%) with a slight development of ecophilic tendencies of consciousness; the “transitional” clusters (5-7%), which indicates the presence of “ecological potential” in the clusters with the lowest level of ecophilic tendencies of consciousness. This structure of clusters also reflects the presence of humanistic and democratic traditions in the system of which ecologization is realized in an intellectualized, aestheticized way, which corresponds to the ideology of sustainable development goals aimed at unlocking human potential. Accordingly, the results of the study of ecophilic tendencies in the consciousness of university students underlie the conceptualization of two directions of ecologization that can be simultaneously represented as existentially harmonizing and aesthetically harmonizing. The above directions are used to develop ecophilic tendencies of university students' consciousness, in particular, future mathematics teachers, students of information technology and to improve the health-saving competence of physical education teachers, in the system of which the ecological aspect is a significant factor for health preservation.

Keywords

ecophilic consciousness, digital modeling, cluster analysis, K-Means, Canopy, hierarchical clustering, Ward's method, sustainable development, ecological potential, university students, psychological modeling, mathematical modeling, anthropological approach, health-saving competence, environmental education, ecologization, humanistic traditions, aesthetic harmonization, existential harmonization, information technology education, physical education teachers

1. Introduction

Updating the anthropo-ecological visions of A. Peccei [1] and ecologically-valuably and ecologically-ethically understanding the significance of “Literacy for the Future” [2], we consider the development of the “New Man” – Homo Ecologicus, in which harmonious relations with the Earth are a master direction in the implementation of the strategic concept of Sustainable Development. Accordingly, we comprehend the leading importance for the future of the ecologization of education and pedagogical

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science and practice, which are crucial in the formation of Homo Ecologicus. Ecologization is primarily aimed at developing ecophilic tendencies of students' consciousness, which are considered as ethical, value-semantic and emotional-value foundations of Homo Ecologicus. Thus, higher education with the existing cross-cutting ecologization is a crucial condition for the implementation of Sustainable Development.

In relation to the above educational and anthropo-ecological intentions, the professional activity of a teacher should be directed to the ecologization of the professional, cultural, intellectual, and health-preserving dimensions of human existence, which, accordingly, in our pedagogical system is considered in relation to the preservation of the Earth and harmonious interaction with it. The primary and main anthropological factor in the implementation of such a cross-cutting policy of ecologization is the teacher. For example, a teacher or lecturer, due to the peculiarities of his or her professional activity, has the opportunity to promote the disclosure of not only intellectual potential in students, but also the existential dimension of consciousness. This determines the possibilities and pedagogical ways to existential comprehension of the problems of interaction in the "Man-Earth" system. This is realized by actualizing the existentials of temporality, care, spatiality, heart, health, and corporeality in the educational process. In accordance with the ideology of sustainable development, in the process of ecologization, teachers need to reveal existential care in students, including care for the Earth, as well as develop kindness, tolerance, responsibility, anticipation (foresight, forecasting) aimed at preserving the planet. These qualities should not only be "purely anthropological", they should be initially formed as containing an ecological "dimension" and orientation. Thus, ecologization is relevant, as it promotes the development of "eco-anthropological intentionality" (orientation) of a person in the educational process. An important aspect of the development of "eco-anthropological intentionality" is the integrative realization of ecologization, aestheticization, ethicization, existentialization and psychologization of the educational process, which are aimed at forming a holistic, valuable and positive image of the Earth. A relevant aspect of these ecophilic transformations of consciousness is the development of focus not only on oneself and the Earth but also on the "Earth in the future" (futures literacy) [1].

Let's consider current research, including ecophilic-oriented research, which reveals the anthropological, ecological, and digital aspects of environmental awareness and modeling of relevant phenomena, processes, and systems.

Puk [3] reveals the risks of using digital technologies through their active implementation in primary and secondary schools. The researcher points out that digital technologies to a certain extent form a "two-dimensional world" and a non-plastic "new" reality that can distance children from healthy ecophilic interaction with nature.

Saboya de Aragão and Alfinito [4] study the influence of human values on the conscious environmental behavior of consumers in a developing country. The researchers point out that there is a lack of understanding of the relationship between human values and consumer ecological behavior, which should be taken into account when developing policies.

Pu et al. [5] analyzing the impact of COVID-19 on global social psychology, environmental sustainability and development, the researchers identify the presence of actualization of creativity, innovation, altruism, and compassion. The qualities identified by researchers are significant components of not only effective and humane social interaction, but are also considered by us as important aspects of ecophilic personality orientation.

Zhen, Yue and Yulong [6] studied the formation of ecological physical education of college on the basis of actualization of multidisciplinary approach, including the application of innovations, pedagogy, ecology, psychology and principles of ecology, integrity, dynamism, systematicity. According to the author, this ecologization of physical education contributes to the development of personality, health, and the disclosure of creative abilities.

Volkova, Proskurova and Yevsieieva [7] studied the attitudes of Ukrainian citizens towards environmental issues in the context of the theory of generations X, Y, Z. It was determined that citizens of three generations (X, Y, Z) share common ecological values, although Generation Z does not care about the environment.

Zhang and Liu [8] study the smart home (ESHS). The authors use the theory of the technology

acceptance model to update the knowledge of ecological awareness.

Mulrow, Gali and Grubert [9], studying digital technologies as cyber-physical systems (CPS), point to their favorable impact on ecological results. The authors argue for the need to take CPS into account in ecological assessment. Thus, it is possible to articulate the idea of a certain integration of the digital and natural environment, which determines the opening of new opportunities for both the ecologization of consciousness and the development of digital technologies.

Galati et al. conducted a study to investigate the environmental motives for students of the University of Palermo to choose to buy water in bio-bottles [10]. The researchers applied fuzzy clustering methods, since they believe that the data obtained are not mutually exclusive, and the objects of clustering can belong to several clusters.

Lian, Qian and Bao [11] investigates ecological behavior based on structural equation modeling (SEM). Based on their model, the researchers point to a positive relationship between environmental awareness, risk perception, cognitive capacity, law-abidingness, and environmental behavior.

Arya and Kumar [12] use Value Behavior Norm Theory to study the ecological behavior of university students. They show that the presence of altruistic and egoistic values and responsibility significantly predict pro-ecological behavior. At the same time, the presence of biosphere values, awareness of consequences and personal norms are not significant for pro-ecological behavior.

Park, Kwon and Kim [13] studied the impact of green information transmitted through online platforms and the moderating role of ecological awareness on customers' ecological perceptions. The researchers note that green information contributes to customer satisfaction.

At present, four relevant interrelated and interdependent strategies can be identified in education – actualization of human potential, innovation, humanization and ecologization [14], which are implemented on the basis of student-centeredness, partnership pedagogy, values-based education, competence-based and activity-based approaches. One of the system-organizing and transformative strategies of education is the formation of “environmental competence” [15], which is carried out on the basis of the development of ecophilic tendencies of consciousness and the actualization of ecophilic cultural values and meanings and value-sense contexts.

Human consciousness, which is actively influenced by education, is the primary, determining and system-organizing factor in the realization of sustainable development goals and the development of future ecocentric transformations of relations between humans and the planet Earth. Education is primary and decisive in the formation of both ecologically oriented cultural values, ethical intentions and understandings, value and meaning contexts, and a new human being – Homo Ekologicus. In addition, in the processes of ecologization, which are legitimized by program documents and legislative acts, the educational sphere is also a defining and system-organizing one.

An important aspect of the educational implementation of greening and its disclosure as a cultural and educational trend is the use of digital technologies [16]. Despite the wide representation of ecologization in the scientific pedagogical literature, the problem of digital modeling of ecophilic tendencies of consciousness is not sufficiently addressed. Given the importance of the development of ecophilic tendencies of consciousness for the realization of sustainable development goals, we define this problem as relevant.

The purpose of the study is to digitally model ecophilic tendencies in the consciousness of university students.

2. Selection of methods and diagnostics

The methodology of modeling ecophilic tendencies of university students' consciousness was developed through the integrative application of mathematical and informatics approaches, as well as using methods of ecology, anthropology and humanities. Accordingly, this methodological system is represented by: ecological, competence, health, systemic, ecological and anthropological, ecological and psychological [17], ecological and pedagogical [14, 18], reflective, axiological, problematic, ecological and ethical, psychological, existential, transdisciplinary approaches and methods.

In the system of this study, the methodological potential of the following concepts is actualized: sustainable development [19, 20], sustainable development goals [21], New Enlightenment, Earth Charter and the Visual Turn paradigm [22] and the ecological paradigm.

The study used mathematical and informatics methods and approaches [23, 24]: system analysis, cluster analysis [25, 26, 27, 28, 29], methods of mathematical statistics, digital modeling, digital data visualization, etc. Let us consider some of them.

To determine the optimal number of clusters in the dataset, we used the Hubert index and its graphical representation, hierarchical clustering with Ward's minimum variance method (Ward D and Ward D2) and its visual representation, distance matrix and visualization based on it.

According to the Hubert graphical method, the optimal number of clusters is determined. For a square proximity matrix P ($n \times n$) of the data set and a square matrix R ($n \times n$) of distances between representative points (rc_i, rc_j) of the corresponding clusters, which include elements x_i and x_j , the Hubert index (H) (1) is calculated using the following formula [27]:

$$H(P, R) = \frac{1}{N} \sum_{i=1}^{n-1} \sum_{j=i+1}^n P_{ij} R_{ij}, \quad (1)$$

where:

n is the dimension of the matrix;

$$N = \frac{n(n-1)}{2};$$

P is an $n \times n$ the proximity matrix;

R is an $n \times n$ the distance matrix between the representative points;

i, j are indices of rows and columns of the matrix, $i = 1, \dots, n$ and $j = 1, \dots, n$.

It should be noted that if the number of clusters is equal to 1 or n , the Hubert index is not defined.

In the Dindex Value plot of the Hubert index we need to determine a significant deviation, which corresponds to a significant increase in the value of the index. In the Second differences Dindex Value plot of Hubert index, you need to determine the significant peak. Significant deviation and significant peak determine the optimal number of clusters.

The Hubert graphical method was implemented using the R [30] language in the Posit Cloud environment [31]. The NbClust package was used. The Euclidean distance measure (d) (2) was used as an argument to calculate the difference matrix [27]:

$$d(x, y) = \left(\sum_{j=1}^n (x_j - y_j)^2 \right)^{\frac{1}{2}}, \quad (2)$$

where:

n is the dimension of the vector;

j is an index, $j = 1, \dots, n$;

x and y are standardized n -dimensional vectors, $j = 1, \dots, n$.

Hierarchical clustering with Ward's minimum variance method (Ward D and Ward D2) was also used to diagnose the optimal number of clusters. For this purpose, a distance matrix was constructed using the Euclidean distance measure (d) [26, 28]. Hierarchical data agglomeration based on the distance matrix was implemented using the Ward D and Ward D2 methods [32]. Ward's minimum variance method is a hierarchical clustering algorithm aimed at minimizing the increase. In our case, it is appropriate to use it because it is assumed that the clusters will have different sizes and densities. The result of applying Ward's method is a dendrogram that visualizes the hierarchical structure of clusters [32]. Ward's linkage is calculated as the within-cluster sum of squares (within-cluster inertia), the distance dc ((3) and (4)) between clusters X and Y after their merging, and characterizes the increase in the error sum of squares (ESS) when two clusters are merged at each step [32, 33, 34]:

$$dc(X, Y) = ESS(X, Y) - [ESS(X) + ESS(Y)], \quad (3)$$

where ESS is calculated by the formula

$$ESS(A) = \sum_{i=1}^{N_A} \left| a_i - \frac{1}{A_X} \sum_{j=1}^{N_A} a_j \right|^2, \quad (4)$$

where:

N_A is the numbers of elements in the cluster A ;

i, j are indices of the elements of the A clusters, $i = 1, \dots, N_A$ and $j = 1, \dots, N_A$;

a_i and a_j are the elements of the A clusters, $i = 1, \dots, N_A$ and $j = 1, \dots, N_A$.

The Ward D and Ward D2 methods used by us differ in that the Ward D method in the minimize the increase process determines the sum of squares of deviations from the mean of the merged cluster, and the Ward D2 method determines the sum of squares of deviations from the centroid of the merged cluster (differences between clusters are more clearly distinguished, which makes them easier to identify) [32].

The graphical method based on the distance matrix was implemented using the R [30] language in the Posit Cloud [31]. The $dist()$ function was used, with $method = "euclidean"$ (2) as its argument.

In order to determine the clusters of objects, we used two clustering methods, K-Means and Canopy, described in more detail in the study of Klochko et al. [28].

The *K-Means* algorithm can be generally described as follows [28]:

1. The number of clusters (k) is determined. Select the required number of points to create the initial cluster centers. As the initial centers (centroids) of the clusters, k points are randomly selected from a given set of points.
2. Calculate the Euclidean distance of each point to the cluster centroid.
3. Point is assigned a cluster number that corresponds to the number of the nearest centroid k , the Euclidean distance to which is minimal.
4. The coordinates of the centroids of all clusters are listed.
5. Stages 2, 3, 4 are repeated until the change of centroids stops or the specified number of iterations is reached.

The Canopy algorithm is one of the simplest, most accurate, fastest methods. The Canopy algorithm is often used for pre-clustering data. The algorithm uses two distance thresholds: the loose distance ($D1$) and tight distance ($D2$), $D1 > D2$.

A general description of the *Canopy* algorithm is as follows [26, 35]:

1. Clustering objects are represented as points in a multidimensional feature space.
2. One point is randomly deleted to create a canopy (cluster) containing this point.
3. Each point remaining in the set is assigned to a new canopy (cluster) if its distance to the first point of the canopy is less than the loose distance $D1$. If, in addition, the distance of the point is less than the tight distance $D2$, it is removed from the initial set of points.
4. Repeat steps 2 and 3 until the initial set of points is empty.

Before using the above methods for determining the optimal number of clusters and data clustering methods, the data is normalized. In our case, the answers to the questions were assigned values of 0, 1, 2, 3, and there were no peak values, so we did not perform data normalization. Also, before applying these methods, we did not clean the data, since the electronic questionnaire options required answering the question in the equivalent range of 0, 1, 2, 3.

The authors used their own methodological developments, namely, the "Fedorets' Questionnaire for Determining Ecophilic Tendencies of Consciousness".

"Fedorets' Questionnaire for Determining Ecophilic Tendencies of Consciousness":

1. I find beauty in various landscapes of natural origin.
2. I see beauty and perfection in natural things – stones, water, mud, animals, insects, flowers, roots, weeds.

3. Swamps, deserts, and impenetrable forest thickets do not disgust or dislike me; they are beautiful in their own way.
4. I feel very sorry for wild animals in zoos and laboratory animals.
5. It is painful for me to see how the Earth's natural landscapes are being destroyed.
6. I am concerned about the future of the Earth, from which its authentic natural landscapes may disappear.
7. I feel very sorry for animals and plants that may disappear from the Earth forever.
8. I feel sorry when old trees are cut down that may still be growing.
9. It is painful for me to watch the earth being covered in concrete and asphalt without any urgent need.
10. I feel sorry for the planet Earth as a living being that is being destroyed and "suffering" from the total impact of man.

The variants of answers to the questionnaire: 1 – No; 2 – Yes; 3 – Yes+; 4 – Yes++.

Let us consider the ideas and meanings on the basis of which the Fedorets' Questionnaire for Determining Ecophilic Tendencies of Consciousness was developed.

The questionnaire is based on the idea of a holistic, panoramic, multidimensional and aesthetically oriented perception of the Earth in a visual format as a landscape, as a painting [22]. This aspect reflects the aesthetically oriented stereometric nature of human perception and actualizes the understanding of spatial perspective characteristic of European consciousness, which to some extent correlates with cosmism, anthropocosmism, and multidimensionality. The idea of the diversity of manifestations of earthly landscapes, presented aesthetically as landscapes, is important. This aspect is reflected in Question 1: "I find beauty in various landscapes of natural origin".

Question 2: "I see beauty and perfection in natural things – stones, water, mud, animals, insects, flowers, roots, weeds" contains the idea of perceiving reality as special unique phenomena, which, according to E. Husserl [36], are correlated with certain structures of consciousness. Phenomenology (German: *Phänomenologie* – "the doctrine of phenomena") "returns" us to the primary cognition of things (E. Husserl's famous idea "Back to the things themselves!"), to their primary, often unique and unified meanings. The earth, which "gives rise" to various phenomena, gives us the opportunity to comprehend them as beauty, as well as a panorama of earthly and vital meanings, which, in turn, helps us to reveal a sense of unity with the earthly, understood as alive, and forms respect for it and admiration for it. An important aspect is the phenomenon of biodiversity as a manifestation of life and the Earth.

Question 3, "Swamps, deserts, and impenetrable forest thickets do not disgust or dislike me; they are beautiful in their own way", contains the idea of an aesthetic and ethically oriented perception of the Earth and its landscapes as diverse and unique, as such, through which special elements, Forces, and spiritual entities manifest themselves. The power and meaning of the Earth's elements is not always revealed in a "pastoral" perfectly created landscape. Earthly elements can generate "elements" of chaos and tension. In addition, this question reveals ways to an ecophilic, value-based, and ethical understanding of the phenomenon of "wilderness" [37], through which the non-anthropogenic nature of the earthly is manifested.

Question 4: "I feel very sorry for wild animals in zoos and laboratory animals" refers to the manifestation of human nature through the ability to sympathize with the living and, above all, with animals that have a sufficiently developed psyche, feel pain and often understand the fact of their "slow" death or prolonged suffering in a laboratory or zoo. The idea of developing this issue, in addition to our own understanding of it, was formed by E. Frome in his concept of biophilia [38], the essence of which is the focus on the love of the living and the creation of new things.

Question 5: "It is painful for me to see how the Earth's natural landscapes are being destroyed" reflects the deep multidimensional connection between humans and the Earth. In the system of this interaction, humans and the Earth are presented as one. Therefore, the destruction of the landscape is felt and experienced as its own problem and its own tragedy. This question also diagnoses the presence or "limitations" of the anthropocosmic dimension of consciousness, within which a person consciously

or unconsciously feels part of the vast earthly cosmos. The system-organizing aspect of this question is the consideration of the significance and value of landscapes for humans as a “manifestation” of certain landscapes and, accordingly, a holistic, aesthetic, stereometric perception of the earth.

This Question 5, as well as Questions 1, 6, 9, and 10, are formed in the spirit of the Visual Turn [22] as a humanitarian direction aimed at actualizing and studying visuality. We use the ideas of this direction to actualize visuality in the individual and develop visual culture, which is presented as ecologically oriented.

Question 6: “I am concerned about the future of the Earth, from which its authentic natural landscapes may disappear” is a clarification of the previous Question 5. In addition to actualizing the existentials of care and spatiality, this question is aimed at manifesting human temporality and anticipation (the ability to foresee, which includes the actualization of the metacognitive level of consciousness). This, accordingly, reveals and actualizes the ability to think about the future of the Earth and determines the presence of ecophilic metacognitive strategies in the form of goal setting, reflection, planning and foresight.

Question 7 – “I feel very sorry for animals and plants that may disappear from the Earth forever” is essentially a clarification and expansion of the previous Questions 5 and 6. Although it has its own special vital (in the sense of life) and biophilic-oriented meaning. This question relates directly to the problem of life, which is embodied in the “kingdoms” of flora (plants) and fauna (animals). The existentials of topicality, love, care, and responsibility are actualized in this issue. It is responsibility that is to a certain extent personalized and largely related to living beings, which stand out as special from the “panorama” of inanimate objects and from the landscape and are considered as “special living worlds” essentially close to humans.

Question 8 – “I feel sorry when old trees are cut down that may still be growing” – reflects the attitude towards flora and towards the landscape and life in general, which is largely shaped by vegetation. This question reveals the problematic of the existing or absent experience of being in the natural environment and the ability to interpret it in an ecophilic way. An important spiritual and archetypal aspect is the ability to comprehend by actualizing this issue the concepts of the world tree (Latin: *Arbor mundi*) and the tree of life (Latin: *Arbor Vite*; English: *Tree of Life*; Hebrew: **עֵץ הַחַיִּים**: *Etzheim*, *Tree of Paradise*) as one of the main symbols of many world cultures. The tree of life and the world (cosmic) tree are seen as distinct spiritual, mythological, or archetypal (according to C. Jung) phenomena. Traditionally, it is believed that the symbolism of the tree is vital and it reflects the essence of life itself.

Question 9 – “It is painful for me to watch the earth being covered in concrete and asphalt without any urgent need” reveals the understanding of the Earth and its landscapes and landscapes and their reflection in the existential “depth” of a person, in their intrinsic value and givenness, as a manifestation of a living entity that has the ability to feel and suffer, and not just as a “dead” resource. Such an understanding can emerge as a result of life practices and experiences of communication with nature, provided that at least “elementary” positive intentions towards the “living world” (biophilia according to E. Frome) are revealed in the human soul [38]. This value attitude towards nature is mainly possible as a manifestation of the ecophilic nature of humans.

Question 10 – “I feel sorry for the planet Earth as a living being that is being destroyed and “suffering” from the total impact of man” is inherently generalizing, philosophical, anthropocosmic, and transforming ecological problems into a being, sensual, and heartfelt format. For an authentic (in the sense of one’s own) comprehension of this issue, a certain life, sensual, intellectual, life-creating and spiritual experience and understanding is necessary. Undoubtedly, a positive solution to this issue is also possible as a result of the indoctrination of the ideology of ecologism into the public consciousness. In this issue, the idea of compassion is seen as a manifestation of the spiritual nature of man, his cordiality, mercy and kindness. This issue is aimed at harmonizing the relationship between man and the Earth.

Experimental base of the study: Berdyansk State Pedagogical University; Vinnytsia Academy of Continuing Education; Mykhailo Kotsiubynskyi Vinnytsia State Pedagogical University; Dragomanov Ukrainian State University; Vinnytsia Humanitarian and Pedagogical College; Vinnytsia National Technical University. The study, which was conducted in 2021-2022, involved 166 students, including teachers undergoing advanced training.

3. Results

The realization of the sustainable development goals [21] is possible, first of all, provided that a modern person acquires an ecophilic orientation of his or her consciousness. The ecologically oriented interpretation of human consciousness, which is considered as a determining anthropo-psychological factor in the preservation of the Earth and the realization of sustainable development goals, is revealed in this study on the basis of actualization of ecological-anthropological, ecological-psychological, ecological-pedagogical [14] and ecological-ethical approaches and visions. Accordingly, the idea of actualizing the ecological orientation of *Homo sapiens*' consciousness is defined as system-organizing and defining. This idea in this study is presented in the format of ecophilic tendencies of consciousness. Accordingly, ecophilic tendencies of consciousness are aimed at actualizing anthropological strategies for achieving the goals of sustainable development not only through technological progress, but primarily through changes in human behavior, which is based on the formation of environmentally oriented human qualities. This determines the need to model ecophilic tendencies of consciousness.

Having analyzed the ideas and developments of researchers who have studied various aspects (ecological, spiritual, philosophical, socio-political, educational, psychological, cultural and ethnic, anthropological) of ecological consciousness [14], ecophilia, biophilia [38], we can present the definition of the concept of "ecophilic tendencies of consciousness".

Ecophilic tendencies of consciousness are a system of intentions (orientations of consciousness), values, meanings, attitudes, which are a manifestation of the biophilic dimension of human nature, as well as and to a large extent, are conditioned by the socio-cultural sphere and represent a system of psychological patterns associated with the vital and existential spheres and the personal principle, existential and value-sense spheres and the personal principle, and accordingly determine a good, harmonious, tolerant, reasonable, constructive attitude towards the environment and the Earth, which is considered as a living being or entity endowed with special qualities and one of the highest values, and underlie ecophilic behavior.

In order to conduct the study based on the results of the questionnaire and given that the application of the methods specified in the section "Selective methods and diagnostics" involves processing data in a numerical format, the values of the test results were replaced accordingly: "No" to 0, "Yes" to 1, "Yes+" to 2, "Yes++" to 3 (table 1). Q1, Q2, ..., Q10 are denoted respectively as Question 1, Question 2, ..., Question 10.

Table 1

Correspondence table to present the test results in a numerical format.

Answer to the question	Numerical format of the answer to the question
No	0
Yes	1
Yes+	2
Yes++	3

As a result of testing students of higher education institutions using the Fedorets Questionnaire for Determining Ecophilic Tendencies of Consciousness, we obtained the data set shown in figure 1. The results of the testing are also presented below in the format of a bar chart (figure 2).

Let's analyze the results of the "Fedorets' Questionnaire for Determining Ecophilic Tendencies of Consciousness", presented in figure 2 according to each question of the test.

The answer "Yes" (marked as 1 in the diagram) is represented by the highest percentage of responses to all the questions in the questionnaire. It reflects the lowest intensity of a positive response – in almost all the questions studied, the percentage of "Yes" answers is approximately 50%, with a range of fluctuations of about $\pm 10\%$. This indicates a positive understanding of the problem, which is inherent in half of the respondents. At the same time, the low intensity of the positive response combined with a significant number of people who have it (about half) indirectly indicates the instability of the existing


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'data.frame': 166 obs. of 10 variables:
 $ Q1 : int 2 3 1 3 0 2 3 1 2 1 ...
 $ Q2 : int 1 3 1 2 0 2 3 1 1 1 ...
 $ Q3 : int 1 1 0 1 1 3 3 1 1 1 ...
 $ Q4 : int 2 2 2 1 3 2 1 1 3 0 ...
 $ Q5 : int 3 2 3 1 3 2 2 1 3 1 ...
 $ Q6 : int 1 1 1 1 0 2 1 1 3 1 ...
 $ Q7 : int 3 3 2 1 1 3 1 1 3 0 ...
 $ Q8 : int 3 1 2 1 0 3 0 1 2 0 ...
 $ Q9 : int 3 3 2 1 0 3 1 1 2 0 ...
 $ Q10: int 3 3 2 1 0 3 2 1 3 0 ...
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Figure 1: Dataset of test results.

ecophilic tendencies of consciousness. This is especially significant given the fact that the respondents are familiar with ecological issues in the course of their educational and professional activities.

In addition to the answers to questions Q8 “I feel sorry when old trees are cut down that may still be growing” and Q9 “It is painful for me to watch the earth being covered in concrete and asphalt without any urgent need”, negative answers amount to 31.3% and 33.7%, respectively. These values make up about 1/3 of the answers to the question, are significant in size and characterize the presence of rather stable ecophobic tendencies, especially if we take into account that the respondents are quite familiar with ecological issues. Such a large number of negative answers can be explained as follows: these questions reflect specific phenomena that are significant simultaneously in aesthetic, economic and worldview aspects; there is a persistence of cultural and professional ecophobic stereotypes of a pragmatic and “simplified” aesthetic orientation that determine the specifics of the answers; there are absent or unstable ecophilic stereotypes that could be competitive with ecophobic ones. These questions are those in which environmental issues are revealed in specific phenomena presented as a practical problem to be solved.

The true attitude towards the Earth and nature is largely determined by these specific issues. It is one thing to “love” nature, the Earth “at a distance” or “in general” and another to solve specific problems and issues. Based on the significant importance of these two issues for the practice of nature conservation, we believe it is necessary to conduct research in this area, as well as to include these specific questions as relevant when considering environmental issues in universities, colleges and schools. Question Q8 “I feel sorry when old trees are cut down that may still be growing” can be interpreted in its expanded form as “Will the forest remain in a certain area as a result of economic activity?” Question Q9 “It is painful for me to watch the earth being covered in concrete and asphalt without any urgent need” can be interpreted more broadly as “Is every piece of land with unique natural landscapes being built up?”

In order to determine the groups of students according to the degree of manifestation of ecophilic intentions and values, we will apply cluster analysis.

Let’s determine the optimal number of clusters in the data set that represents the results of testing using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of Consciousness” using the Hubert index, Ward’s minimum variance method (Ward D and Ward D2), and distance matrix.

In the process of applying the Hubert index, the results are presented in table 2 and figure 3.

Table 2

Proposition of the best number of clusters among all indices by the Hubert method.

Number of clusters	Proposal of the best number of clusters
2	4
3	14
4	4
5	1

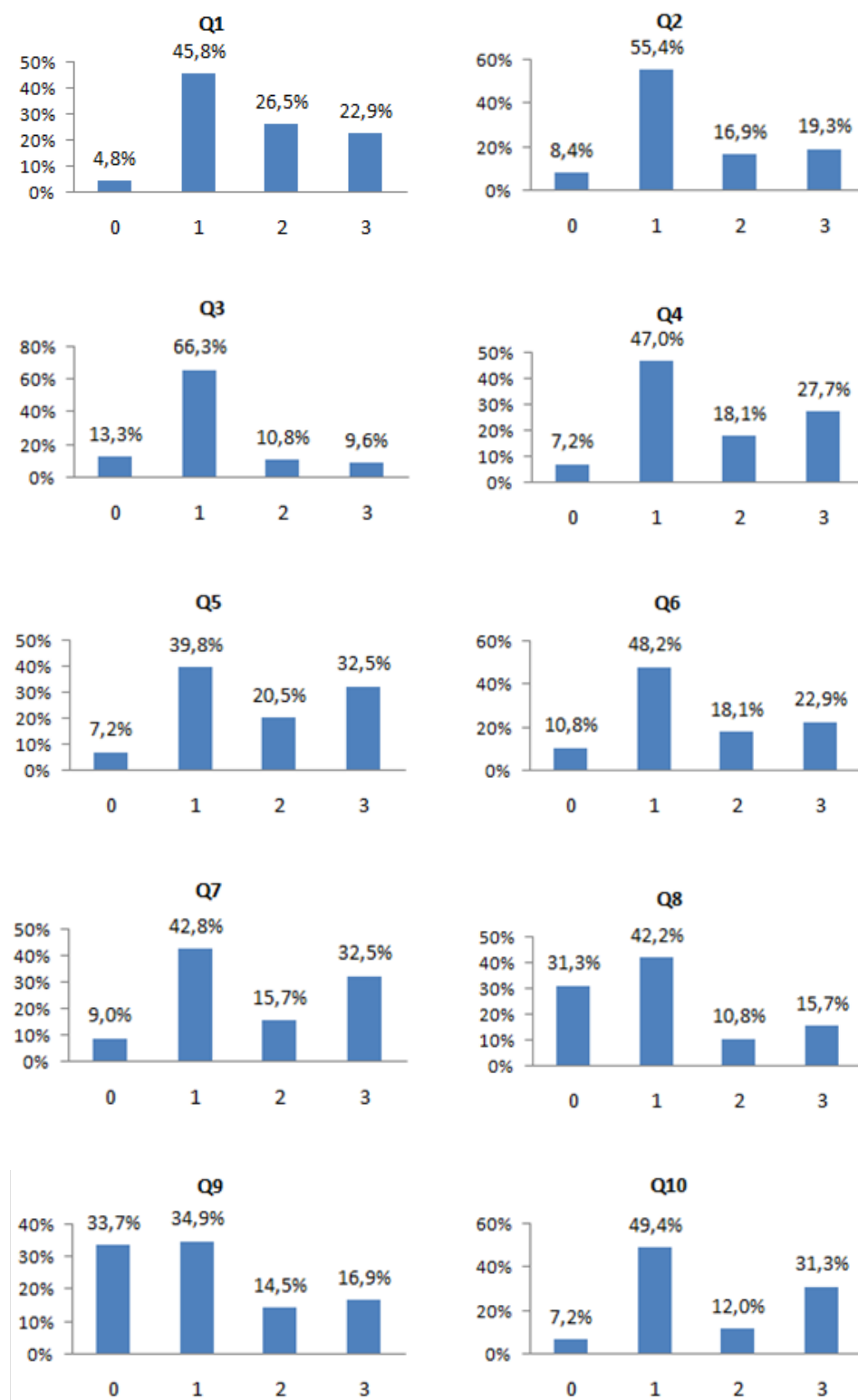


Figure 2: Dataset of test results.

According to table 2, according to the majority rule, the number of clusters 3 received the most proposals (14). There were also 4 proposals for the number of clusters 2 and 4.

According to figure 3 Dindex plot, a significant knee is observed at the number of clusters 3. According

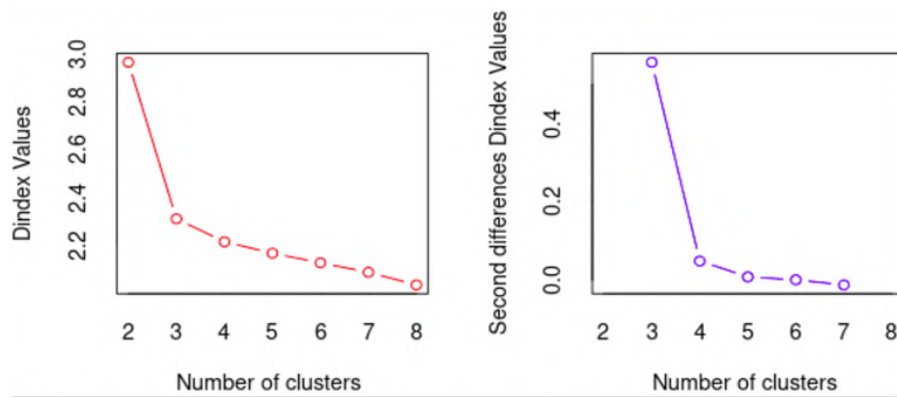


Figure 3: Graphical representation of the Hubert index application results (Dindex plot and Dindex second differences).

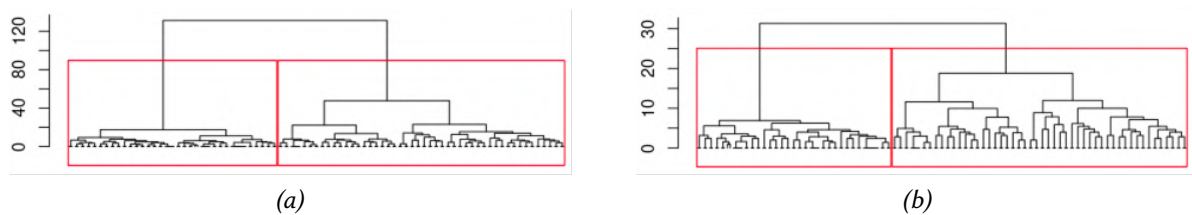


Figure 4: Dendrogram of the hierarchical structure of clusters based on Ward's minimum variance method (Ward D (a) and Ward D2 (b)), 2 clusters are identified.

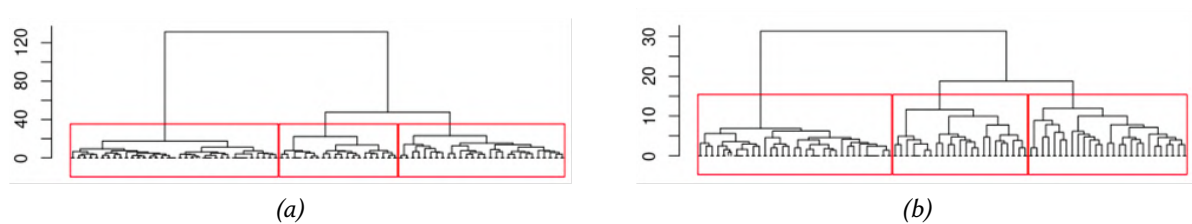


Figure 5: Dendrogram of the hierarchical structure of clusters based on Ward's minimum variance method (Ward D (a) and Ward D2 (b)), 3 clusters are identified.

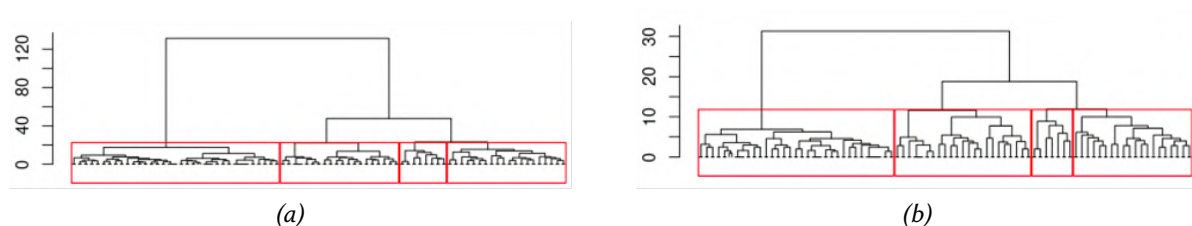


Figure 6: Dendrogram of the hierarchical structure of clusters based on Ward's minimum variance method (Ward D (a) and Ward D2 (b)), 4 clusters are identified.

to figure 3 Dindex second differences plot the significant peak is also observed at the number of clusters 3.

As a result of using hierarchical clustering based on Ward's minimum variance method (Ward D and Ward D2) to diagnose the optimal number of clusters, the results are shown in figure 4, figure 5 and figure 6. The selected clusters in these figures are highlighted by red frames.

Thus, according to the results of hierarchical agglomerative clustering based on Ward's minimum variance method (Ward D and Ward D2), based on visual analysis and considerations of possible interpretation of the clusters in figure 4, figure 5 and figure 5, it was found that clusters 2, 3 and 4 can be more clearly distinguished.

Table 3

The optimal number of clusters determined by the Hubert index, Hierarchical Clustering with Ward’s minimum variance method (Ward D and Ward D2) and the Distance Matrix.

Methods	Optimal number of clusters
Hubert index	3
Hierarchical Clustering with Ward’s method	2, 3, 4
Distance Matrix	3

Let’s analyze the visualization of the results of dividing objects into groups based on Distance Matrix Computation (figure 7 and figure 8). As a result of analyzing the visual representation of the division of objects into groups, we can conclude that in figure 7, 3 groups of objects can be clearly distinguished, although some objects are located on the border of clusters 3 and 2. As a result of the analysis of the visual representation of the division of objects into 4 groups (figure 8), it can be concluded that cluster 2 can be more clearly distinguished, although there are objects that are located on the border of clusters 2 and 3, but the areas of clusters 1, 3 and 4 overlap.

Based on the results of the analysis of the division of objects into groups based on Distance Matrix Computation, it can be recommended to divide the objects into 3 groups in the study.

Thus, it has been established that the optimal number of clusters into which it is recommended to divide the objects of the test results using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of Consciousness” in our study is 3 clusters (table 3).

In order not to lose the unique clusters of data that are grouped into respondent groups based on the results of testing using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of

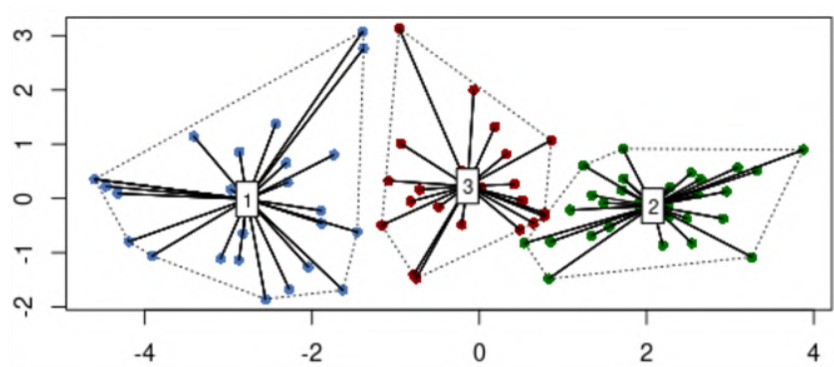


Figure 7: Visual representation of the results of dividing objects into 3 groups based on Distance Matrix Computation.

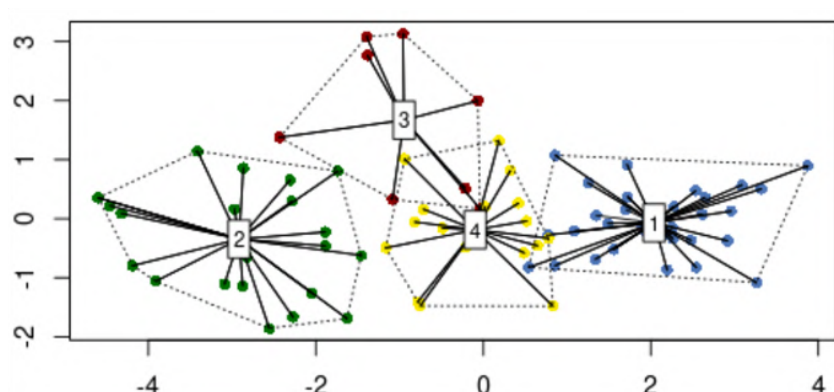


Figure 8: Visual representation of the results of dividing objects into 4 groups based on Distance Matrix Computation.

Consciousness” in accordance with the specific features of the degree of manifestation of ecophilic intentions and values, the number of clusters 3 and 4 was chosen for the study.

We will use the K-Means and Canopy methods to cluster objects. Let’s analyze the results of dividing the data of the test results using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of Consciousness” into 3 clusters using the K-Means method. The results of dividing the objects into 3 clusters using the K-Means method are presented in table 4 and table 5.

Cluster 1 has the following centroids – 2, 2, 2, 2, 3, 3, 2, 3, 2, 2, 3. This cluster contains 30% of the data, which is 50 instances. The cluster indicates the presence of a rather stable ecophilic orientation of consciousness. Ecophilicity as a significant characteristic of consciousness has a high degree of intensity.

Cluster 2 has the following centroids: 1, 1, 1, 1, 1, 1, 1, 0, 0, 1. The cluster was formed on the basis of the answers of 70 people (42%). The cluster represents a group of people who have an ecophilic orientation of consciousness with a low degree of intensity of manifestation, as well as those who have no or no ecophilic orientation of consciousness.

Cluster 3 has the following centroids: 2, 2, 1, 2, 2, 2, 2, 2, 1, 1. The cluster contains 28% of the data, which amounts to 46 instances. The cluster reveals the presence of a rather stable ecophilic orientation of consciousness with a high degree of intensity of manifestation.

Let’s analyze the results of dividing the data of the test results using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of Consciousness” into 4 clusters using the K-Means method. Table 6 and table 7 show the results of the distribution of objects into 4 clusters using the K-Means method presented in table 7.

The presence of a fairly significant set of objects – 28% of people forming Cluster 2, and, accordingly, having stable tendencies of ecophilic consciousness and the transitional group represented by Cluster 3 (5% of all respondents), which indirectly reflects the trend of development of ecophilic tendencies of consciousness, indicates the need to apply such strategies and technologies for ecologization, which include distinct aesthetic and worldview components. Accordingly, the actualization of the aesthetic and worldview level intellectualizes, aestheticizes, expands, deepens and interprets the existing deep lyophilic, existential and emotional and emotional perception of the planet Earth and nature as special values, meanings and images, transforming them into stereotypes of actions and behavior and

Table 4
Centroids of 3 clusters determined using the K-Means method.

Question number	Cluster 1	Cluster 2	Cluster 3
Q1	2	1	2
Q2	2	1	2
Q3	2	1	1
Q4	3	1	2
Q5	3	1	2
Q6	2	1	2
Q7	3	1	2
Q8	2	0	1
Q9	2	0	1
Q10	3	1	2

Table 5
Distribution of data by 3 clusters using the K-Means method.

Cluster number	Distribution of data by clusters
1	50 (30%)
2	70 (42%)
3	46 (28%)

Table 6

Centroids of 4 clusters determined using the K-Means method.

Question number	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Q1	2	2	1	1
Q2	1	2	2	1
Q3	1	2	2	1
Q4	2	3	1	1
Q5	2	3	2	1
Q6	2	2	2	1
Q7	2	3	2	1
Q8	1	2	1	0
Q9	1	2	1	0
Q10	1	3	3	1

Table 7

Distribution of data by 4 clusters using the K-Means method.

Cluster number	Distribution of data by clusters
1	70 (42%)
2	46 (28%)
3	8 (5%)
4	42 (25%)

psychological attitudes. Accordingly, this level of ecologization is called aesthetically harmonizing.

For the objects of Cluster 1 (42%) and Cluster 4 (25%), we consider the strategy of ecologization relevant, in which the leading aspect is the idea of harmonization aimed at “constructing” at the mental level a harmonious and existentially oriented interaction with the environment and revealing the cognition of the high meanings of Gaia (Earth) and biophilia. This is the initial condition for the further development of ecophilic tendencies of consciousness. We call this level of ecologization existentially harmonizing.

Let’s analyze the results of clustering the objects obtained in the course of testing using the “Fedorets’ Questionnaire for Determining Ecophilic Tendencies of Consciousness” based on the Canopy method. In the process of applying the Canopy method, the division of objects into 3 clusters did not give optimal results in terms of interpretation, so the study presents the division of objects into 4 clusters using the Canopy method (table 8 and table 9).

Let’s analyze the results of clustering using an integrative humanitarian and environmental approach. Cluster 1 has the following centroids according to the answers to the test questions and question

Table 8

Centroids of 4 clusters determined using the Canopy method.

Question number	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Q1	1	3	1	2
Q2	1	3	1	2
Q3	1	1	1	2
Q4	1	3	0	3
Q5	1	3	1	2
Q6	1	3	1	1
Q7	1	3	1	2
Q8	1	3	0	2
Q9	1	3	0	2
Q10	1	3	1	2

Table 9

Distribution of data by 4 clusters using the Canopy method.

Cluster number	Distribution of data by clusters
1	76 (46%)
2	42 (25%)
3	36 (22%)
4	12 (7%)

numbers: 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1 (table 8). The algorithm assigned 76 data instances to the cluster, which is 46% of the answers. This cluster reflects the dominant group. At the same time, in this group, the dominant ecophilic intentions and values are characterized by the lowest degree of manifestation (or intensity). Therefore, we consider them unstable. Thus, despite the dominance of ecophilic tendencies of consciousness, but with low intensity, manifested in a significant quantitative representation in the specified cluster, it may indicate: a real but not yet sufficiently sustainable effect that has arisen due to the education and promotion of environmentally acceptable behavior and values, as well as a tribute to the fashion for “ecological behavior”. Therefore, considering that in this cluster, which makes up almost half of the entire sample, this ecophilic tendency can be disaccommodated under the influence of certain factors (economic, political) under the influence of minor economic, psychological or socio-cultural influences. This indicates the need for targeted cultural and educational influences in order to develop ecophilic tendencies of consciousness.

Cluster 2 has the following centroids: 3, 3, 1, 3, 3, 3, 3, 3, 3, 3, 3 (table 8). This cluster contains 25% of the data, which is 42 instances. The cluster reveals a rather stable ecophilic orientation of consciousness with a high degree of intensity of manifestation. One fourth of the individuals in the study sample to some extent reflects the attributive features of a human being as a highly developed intellectually and morally species characterized by love and good attitude towards the world and living beings. That is, this number can to some extent be interpreted as a manifestation of human nature, which has an ecophilic nature, and not only and not so much the influence of education and society.

Cluster 3 was formed on the basis of the following centroid answers to the questionnaire: 1, 1, 1, 1, 0, 1, 1, 1, 0, 0, 1. The cluster was formed on the basis of answers of 36 people (22%). The cluster represents a group of people who have both an ecophilic orientation of consciousness with a low degree of intensity of manifestation and people who have no or low level of ecophilicity. Almost a quarter of the sample reflects a variety of reactions, which includes both minor ecophilic tendencies and their absence. This, to some extent, as well as the previous Cluster 1, illustrates the specifics of the distribution of traits in the population. That is, there is a group characterized by quite pronounced ecophobic tendencies (25%) (Cluster 2) and, to some extent, the opposite group of people with insufficiently pronounced and/or absent ecophilic tendencies (22%) (Cluster 3). The risk of people in this group (Cluster 3) is that they may transform into ecophilic neutrals or ecophobes as a result of external influences.

Cluster 4 is based on the following answers to the questionnaire: 2, 2, 2, 2, 3, 2, 1, 2, 2, 2, 2. This cluster combines the answers to the questions of 12 people and makes up 7%. This cluster unites people who have both distinct ecophilic tendencies of consciousness (answer – 3, 2) and relatively non-intense ones (answer – 1). We consider it a “transitional” cluster between Cluster 1 and Cluster 2. This is due to the fact that it contains features of both of these clusters (Cluster 1 and Cluster 2). Cluster 4, which is transitional and relatively significant in quantitative terms (7%), reflects an important trend – the active dynamics of the formation of ecophilic consciousness under the influence of socio-cultural (including educational) factors, which is caused by global processes of ecologization.

The presence of a relatively large group of 25% of people who form Cluster 2 and, accordingly, have stable tendencies of ecophilic consciousness and the transitional group represented by Cluster 4 (7% of all respondents), which indirectly reflects the trend of development of ecophilic tendencies of consciousness, indicates the need to apply such strategies and technologies for ecologization, which include distinct aesthetic and worldview components. We call this level (or aspect) of ecologization

aesthetically harmonizing.

For the representatives of Cluster 1 (46%) and Cluster 3 (22%), we consider the strategy of ecologization relevant, in which the leading aspect is the idea of harmonization aimed at “constructing” at the mental level a harmonious and existentially oriented interaction with the environment and cognition of the high meanings of Gaia (Earth). This is the initial condition for the further development of ecophilic tendencies of consciousness. We call this level (or aspect) of ecologization existentially harmonizing.

The above cluster model, like the previously discussed one, with the formation of 4 clusters, contributes to the structuring of ecologization as an educational meta-strategy with the allocation of two levels (or directions) in it – existentially harmonizing and aesthetically harmonizing.

A comparative analysis of the cluster models obtained by applying the K-Means and Canopy methods (table 6 and table 7, table 8 and table 9) shows quite similar results. The similarity is manifested in the structure of the distribution by clusters and in the architecture of the clusters themselves, which indicates the correctness and adequacy of the methods used. These two cluster models, in which objects are structured into 4 clusters, complement and extend the cluster system obtained by applying the K-Means method with a division into 3 clusters.

We consider the above aspects of ecologization – existentially harmonizing and aesthetically harmonizing – to be complementary and view them as independent paths or as successive stages. We consider the existentially harmonizing aspect of ecologization to be related to the coexistence of man and the Earth (“natural existence”). This aspect is understood as aimed at revealing the understanding of oneself as: an integral part of the Earth’s space; the Earth as a home, the value of Earth’s landscapes, elements and “kingdoms” (minerals, animals and plants); a sense of oneself as a spatial being harmonized with Earth’s landscapes.

The aesthetic and harmonizing aspect of ecologization is based on the dominant aesthetic dimension, within which the Earth and Earth landscapes, elements and “kingdoms” of plants and animals are understood as: a special natural earthly and cosmic harmony and aesthetics (“natural beauty”); as an aspect of inspiration. This aspect is understood not as “pure” creativity or aestheticism, but as an aesthetic intention aimed at preserving the Earth. These aspects (existentially harmonizing and aesthetically harmonizing) can be presented in greening strategies in a more distinctive or integrated way.

The results of the study of ecophilic tendencies of consciousness are used to formulate and implement strategies and practices of greening, as well as to develop environmental competence and soft skills in the educational process of higher education, including education in the field of information technology, teacher training, and postgraduate education.

Let us consider examples of strategies for applying the results of the study to the ecologization of university students. For the greening of future teachers of mathematics and computer science and students of information technology, the primary is the actualization of the rational dimension of consciousness, which primarily includes the disclosure of the harmony and beauty of the world through ecological and aesthetic reflection on mathematical, information and environmental phenomena and works of art. That is, the aesthetic and harmonizing direction of ecologization is primary as “external” (aimed at cognition of the external world), the actualization of which subsequently contributes to the manifestation of the existential and harmonizing direction, which is essentially internal. This approach to ecologization is inherently both intellectualized and aestheticized. An important aspect of the disclosure of the student’s ecological knowledge and intellectual potential is mathematical and informational knowledge and ideas that illustrate and reveal ecological phenomena at the level of mathematical rationality. In this case, mathematical knowledge and information algorithms act as procedural and operational ones, which, being part of environmental knowledge, make it possible to represent and comprehend environmental phenomena and represent them as regularities, processes, harmony, disharmony, compliance or non-compliance with certain aesthetic and environmental “ideals”. The specificity of ecological knowledge is also that it is formed as ethically and value-oriented, not as irrelevant or “ethically and aesthetically neutral”. The value, ethical and aesthetic orientation of environmental knowledge is largely determined by its procedural and operational components, which in turn reflects primarily its mathematical and informational dimensions (both in actual, formalized and contextual formats).

In order to develop the health-preserving competence of physical education teacher in postgraduate education, namely the formation of its anthropocultural component, in the system of which the ecological aspect is defined as significant, we apply both existentially harmonizing and aesthetically harmonizing directions of ecologization. The existentially harmonizing direction of ecologization is especially important, the possibility of realization of which is determined by existential specificity of motor activity and the possibility of actualization of existentials of corporeality, spatiality, temporality in the process of physical culture. This direction is largely reflexive, existential and cognitive, internal (directed at oneself) and introverted (largely directed at oneself and self-knowledge) and contextual, as well as connected with the subconscious dimension of the psyche and the collective unconscious. Accordingly, this direction is realized by means of physical culture and can be formally represented as “Cognition and dialogue with the planet Earth through physical activity, mastery of the landscape and self-knowledge”. The aesthetically harmonizing direction is dominated by external, extroverted (directed to the outside world), emotional and cognitive orientation. It is both rational and emotional, and accordingly, it is revealed and realized through the cognition of earthly landscapes in the process of moving in space and through the actualization of visuality and visual culture. That is, physical culture reveals the aesthetics of the outside world through motor activity, while additionally using the means of art.

4. Discussion

Let us consider the work of some researchers in relation to our scientific developments.

The use of cluster analysis to identify groups of students who differ in specific, group-specific characteristics is a technique that we have used effectively in many studies, including the Canopy method [24]. Also, for example, Galati et al. used fuzzy clustering methods to study students' behavior in purchasing products in environmentally friendly packaging [10].

The use of mathematical statistics methods, according to many authors, is appropriate for studying environmental awareness [7, 14, 24], and our results confirm that determining the level of “environmental potential” will make it possible to outline the directions of its formation and development. In particular, the results of our research on recommendations for increasing the level of ecophilic consciousness correlate with the results of other researchers, in particular, with the study of Lian et al. [11], Mulrow et al. [9], Arya and Kumar [12] that it is necessary to raise students' awareness of the environment in order to better understand the risks.

Saboya de Aragão and Alfinito [4] point out the insufficient understanding of the relationship between human values and environmental behavior of consumers. Comparing the ideas presented in this study with our findings, it can be noted that the existential and harmonizing aspect of greening identified by us can be considered as a strategy for shaping consumer environmental behavior based on the actualization of human values.

Pu et al. [5] studying the impact of COVID-19 on environmental sustainability and development, identify the qualities of creativity, innovation, altruism, and compassion. We consider these qualities to be cognitive, behavioral and emotional prerequisites for the ecophilic orientation of a personality, as well as cognitive and behavioral factors of the existential and harmonizing aspect of greening.

Zhen, Yue and Yulong [6], who study the formation of ecological physical education of college on the basis of actualization of multidisciplinary approach consciously or intuitively deal essentially with the development of ecophilic tendencies of consciousness (orientation, values, etc.). This indicates the conceptual proximity of these studies.

Peters [39], who proposes to integrate artificial intelligence technology and environmental design to improve the quality of urban space, develops his concept in relation to the aesthetic and harmonizing strategy (or aspect) of greening that we have identified. Peters [39] and Brien [40] essentially proposes to integrate the aesthetic and environmental (in the format of ecodesign) and cognitive, which largely corresponds to the ideology of NBIC-convergence, which corresponds to the 6th technological mode.

Arya and Kumar [12], based on the application of the theory of normative value behavior to study

the environmental behavior of university students, conclude that the presence of altruistic and egoistic values and responsibility significantly predict pro-environmental behavior. These ideas of Arya and Kumar [12] correlate with the existential harmonizing aspect of ecologization presented by us, which can also be considered as a strategy. Within the framework of the existential harmonizing aspect of ecologization, the actualization of existential values and relevant types of behavior and behavioral stereotypes (and character traits; more broadly, according to A. Paccei, human qualities), namely altruism and responsibility, is crucial. In this aspect, it is significant that the phenomenon of responsibility is one of the central ones in the existential approach. The presence of responsibility indicates the existential completeness and maturity of the individual and his/her ability to form ecological meanings that are lived and understood in a deep and existential way – as existential meanings. Accordingly, this determines environmental or pro-environmental behavior.

5. Conclusion

The anthropological and psychological basis for the implementation of the Sustainable Development Goals is the development of relevant ecologically oriented human qualities, which are a prerequisite for ecologically oriented behavior. This study emphasizes the importance of the existential and harmonizing aspect of ecologization, which can be presented as a purposeful strategy.

The overarching idea of the research is the study of psychological, value, cognitive and behavioral factors in the development of environmental consciousness and human behavior. The psychological prerequisite for the formation of these human qualities is the ecophilic tendencies of consciousness, which determines the need for their digital and mathematical modeling using systems of methods. In the study, we used the methods of system analysis, cluster analysis, methods of mathematical statistics, digital modeling, digital data visualization, etc.

In order to determine the optimal number of clusters, we used the Hubert index and its graphical representation, hierarchical clustering with Ward's minimum variance method (Ward D and Ward D2) and its visual representation, distance matrix and visualization based on it. Using these methods, it was diagnosed that the optimal number of clusters is 3 clusters. However, in the course of the study, we decided to divide the set of objects into 4 clusters in order to lose the unique structure of the cluster for diagnosing the ecophilic intentions and values of university students.

We clustered the objects using two clustering methods – K-Means and Canopy. The use of these two methods is justified by the structure and types of data and the features of the algorithms. Based on the results of clustering using these two methods, cluster models were formed. The obtained models for dividing objects into 4 clusters are similar, which indicates the effectiveness of the K-Means and Canopy algorithms with such data structures and confirms the adequacy of the constructed cluster structures.

Based on the study of ecophilic tendencies of consciousness using cluster modeling with the help of K-Means and Canopy methods, the 3rd and 4th clusters were formed. In our opinion, 4 cluster models are more representative clustering models. These models are dominated by clusters with a slight development of ecophilic tendencies of consciousness (42-46%). The “ecophilic” clusters (25-28%) with a medium and high level of ecophilic tendencies of consciousness is defined as the system-organizing one. In quantitative terms, this feature is quite significant, indicating the formation of a “stratum” of modal individuals who are active “carriers” of the ecological idea, which is relevant for socio-cultural ecological transformations. The “transitional” clusters (5-7%) is also identified, which indicates the presence of “ecological potential” in the cluster with the lowest level of ecophilic tendencies of consciousness. The presence of this clusters, which is determined by structuring into 4 clusters using different methods, also reflects the effectiveness of existing educational and cultural influences aimed at ecologization. This structure of clusters also reflects the presence of humanistic and democratic traditions in the system of which ecologization is implemented in a “soft” intellectualized way, aestheticized as a cultural and educational trend, and not as an indoctrination of an ideological doctrine. This is in line with the ideology of the Sustainable Development Goals aimed at unlocking human potential.

University students are a dynamic and socially active group and, accordingly, they can act as agents

of environmentally oriented changes in the socio-cultural, professional and scientific dimensions. Therefore, an important social and socio-psychological aspect of modeling ecophilic tendencies of consciousness is the analysis of the formation of these tendencies in university students with the corresponding development of ecologization strategies. The results of the study of ecophilic tendencies of consciousness are taken into account in the development of strategies for the ecologization of higher education students. Two directions of ecologization are conceptualized, which can be simultaneously represented at the same level – existentially harmonizing and aesthetically harmonizing.

The existentially harmonizing direction of ecologization is largely reflective, existentially cognitive, internal (directed at oneself) and introverted (largely directed at oneself and self-knowledge) and contextual, as well as connected with the subconscious dimension of the psyche and the collective unconscious. The aesthetically harmonizing direction is dominated by external, extroverted (directed to the outside world), emotional and cognitive orientation. It is both rational and emotional. At the methodological and metacognitive levels, the process of ecologization is structured on the basis of the above directions (existentially harmonizing and aesthetically harmonizing) and is used to develop ecophilic tendencies of consciousness, in particular, of future mathematics teachers, students of information technology and to improve the health-saving competence of physical education teachers, in the system of which the ecological aspect is a significant factor for health preservation.

Declaration on Generative AI: The authors have not employed any Generative AI tools.

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