Evidencing the Involvement of Physical Mechanisms in Urban Ecology Dynamics for a Meaningful Learning

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Abstract

Modern learning emphasizes first of all the creation of meanings, it is a learning focused on understanding and comprehension rather than rote memorization or surface-level understanding. Educational, learners aim to make connections between new information and their existing knowledge, thus deepening their understanding and ability to apply what they've learned in various contexts. It is the case of educational programs aimed at conserving biodiversity and forming pro-environmental attitudes for urban ecology; their operationalization requires transdisciplinary syntheses and overcoming the monodisciplinary level of biology, chemistry, physics, economy, etc. The present study, circumscribed by these trends, aims to evaluate to what extent the students understand and integrate the mechanisms of physics in an ecological context. On 7-point Likert scales, 90 students of scientific, technical and humanities specializations are asked to evaluate the degree to which some mechanisms, physical in their essence – e.g. the change in the permeability of the soil caused by asphalting, soil erosion, the quality of electric lighting, the absorption of sounds, dust sedimentation, etc. - are involved in the dynamics of conservation and urban ecology. The results obtained are heterogeneous - different specializations perceive in different ways the existing connections between the biological layer and the laws that govern the physical world. Some mechanisms are perceived and evaluated only by the aesthetic benefits and not by the effects they produce on the urban ecology. The practical utility of these results consists in updating the urban ecology curriculum by introducing some elements that allow deepening the meaning and causalities of the studied mechanisms, through informational bridges from the field of physics.

Keywords: *physical mechanisms, meaningful learning, making sense, urban ecology*

1. Introduction

Modern learning focuses on developing higher cognitive skills and critical thinking, rather than on mechanical memorization of information. It emphasizes deep understanding of subjects and concepts over superficial memorization. In this regard, students are encouraged to make connections between ideas, analyze information, and apply it in various contexts. An important role of learning is also the construction of personal meanings, motivating students to see the applicability and relevance of the knowledge acquired in their daily lives. Another element is the contextualization of learning in relevant and authentic situations. Thus, students can see the applicability and relevance of information in their daily lives, helping them transfer the acquired knowledge to various contexts.

Educational programs aiming at biodiversity conservation and the formation of pro-environment attitudes for urban ecology align with modern learning. These programs need to be transdisciplinary to address the complexity of environmental issues and offer sustainable and effective solutions. They must integrate knowledge from monodisciplinary fields such as biology, chemistry, physics, economics, urban planning, and sociology to tackle the complex problems of biodiversity conservation and urban ecology. These programs should also promote students' critical and analytical thinking so that they can evaluate different perspectives and develop creative and innovative solutions to environmental problems [1]. The knowledge gained from these programs needs to be applied in various practical contexts such as field activities, research projects, collaboration with local environmental organizations, or volunteering in biodiversity conservation projects.

Such a transdisciplinary educational program aims to form a generation of responsible citizens who are aware of their impact on the environment and can promote biodiversity conservation and sustainability in the urban environment.

This study, aligned with these trends, aims to evaluate the extent to which students understand and integrate the mechanisms of physics into the dynamics of urban ecology. Urban ecology is an interdisciplinary field of environmental sciences that deals with the study of urban ecosystems and the interactions between biotic and abiotic factors in the urban environment. It examines how the urban environment is influenced by human activities, infrastructure, and urban development, as well as the impact that the urban environment has on urban health, biodiversity, and overall quality of life. Through appropriate solutions and strategies, urban ecology can contribute to the creation and management of healthy, sustainable, and resilient urban environments that support the health and well-being of the urban community.

2. Abiotic Factors in the Context of Urban Ecology

In the context of urban ecology, abiotic factors play a crucial role in determining the structure and functioning of urban ecosystems, as well as influencing the lives and health of residents. Abiotic factors are those non-living environmental factors that influence the lives of organisms without being affected by these organisms themselves [2]. It is important for students to understand the concepts of physics that influence the dynamics of the urban environment and biodiversity conservation [3], [4].

Air pollution is one of the environmental factors that can have a significant impact on urban biodiversity, affecting plants, animals, and humans alike. Nitrogen oxides, sulfur dioxide, fine particles, and other pollutants can impact residents' health, plant growth and development, and reduce visibility.

Soil quality is crucial for supporting biodiversity in urban environments. Factors such as soil chemical composition, nutrient levels, and compaction can influence the types of plants and animals that can live in a particular urban area.

Light pollution, as an abiotic factor, through excessive artificial lighting, can affect natural light and dark cycles and influence the behavior of animals and plants in urban environments. Light pollution can disrupt the migratory orientation of birds, reproductive and feeding cycles of many species. Some animal species are attracted to artificial lights, which can expose them to additional risks such as predators or traffic. Additionally, light pollution can disturb species sensitive to light, such as nocturnal species, which may be disrupted in their usual feeding and hunting activities. In some cases, light pollution can lead to a reduction in biodiversity in urban environments, as certain species may be more susceptible to the negative impact of artificial light than others. This can lead to changes in the composition and structure of plant and animal communities in cities.

Global climate change has a major impact on urban biodiversity, influencing temperatures, precipitation, and local climate patterns. These changes can affect species distribution, migration phenomena, and resource availability.

Urban infrastructure, such as buildings, streets, parks, and green areas, can affect biodiversity by modifying natural habitats and fragmenting ecosystems. Urban planning and proper management of infrastructure can play an important role in conserving urban biodiversity. Construction of buildings, roads, and other infrastructure can fragment natural habitats and isolate populations of plants and animals. Habitat fragmentation can lead to a decrease in biodiversity by reducing the size and quality of available habitats and by making it difficult for species to move and migrate. Urban development can also lead to the destruction or degradation of natural habitats such as forests, marshes, and wetlands. The loss of natural habitats reduces the availability of resources for plants and animals and can lead to a decrease in the number and diversity of species in the urban environment. Urban infrastructure can be designed and managed sustainably to support biodiversity. Ecological innovations such as green roofs, urban green areas, and ecological corridors can contribute to increasing biodiversity in the urban environment by providing additional habitats and connections between green spaces.

Temperatures and humidity in urban environments, other abiotic factors, can vary significantly depending on local conditions and climate changes. These factors can influence the distribution and behavior of species, as well as the dynamics of urban ecosystems. Temperature and humidity influence the distribution of plant and animal species in the urban environment. Certain species are better adapted to specific ranges of temperature and humidity and can thrive in specific conditions. Changes in temperature and humidity can affect urban biodiversity by modifying habitats and available resources [5].

Noise represents a form of acoustic pollution and can have a significant impact on biodiversity and wildlife in cities. It can come from various sources such as road traffic, construction, machinery, airplanes, industry, and human activities.
Wind, which is a physical force of nature, can have a significant impact on the environment and living organisms and also favors the phenomenon of soil erosion. The climate and local temperatures can be influenced by wind, including temperatures and humidity levels, as well as particle transport. These abiotic factors are just a few of the important ones that can influence biodiversity in urban environments. Understanding these factors and their interactions is essential for managing and conserving biodiversity in cities.

3. Methods of Evidencing the Knowledge of Physics' Involvement in the Context of Urban Ecology

The present study, circumscribed by these trends, aims to evaluate the degree of awareness, understanding and integration of physics mechanisms in an ecological context by the students of the Cluj Napoca Technical University, from the Northern Baia Mare University Center (Romania). We assume that the students, who come from various university specializations, will have different understandings of the physics concepts involved in the dynamics of urban biodiversity conservation and characterization. Students represent an important, dynamic category, open to changes in the community, which will have an important decision in social dynamics. By ensuring that they have a solid understanding of how the mechanisms of physics apply in the dynamics of conservation and urban ecology, we are preparing a generation capable of tackling complex environmental challenges with effective solutions. University education is a favorable moment for the introduction of interdisciplinary concepts. Students, by updating the university curriculum, can integrate the knowledge of physics, ecology, biology and other fields to understand environmental problems and to develop comprehensive and sustainable solutions.
In this study, the students answered some questionnaires to evaluate their degree of interest, awareness and knowledge regarding urban biodiversity conservation issues. By evaluating students' understanding of these concepts, we can identify gaps in knowledge and skills and adapt the university curriculum to improve their training. When evaluating the level of knowledge of the influence of physical mechanisms on urban biodiversity, we followed the degree of understanding of the basic concepts related to abiotic factors and urban biodiversity. This includes an understanding of key terms as well as the ability to explain associated concepts and processes. We also looked at whether students can analyze and interpret information related to the influence of abiotic factors on urban biodiversity, including here their ability to interpret data and identify patterns and trends. The subjects of the study come from various specializations, namely, biology, engineering and economic sciences. Their field of study is both bachelor's and master's. All respondents, 90 in number, are over 19 years old and their confidentiality was ensured, their names not being associated with the questionnaire. Each questionnaire was assigned a number.
The 7-point Likert scale questionnaire contained the following statements:
1. The term urban biodiversity is a well-known term.
2. The term abiotic factor is a known term.
3. Public lighting influences urban biodiversity
4. Anthropogenic (man-made) changes in environmental temperature and humidity have a major impact on biodiversity in urban environments.
5. The quality of the soil, the air and the dispersion of dust particles are not important in urban biodiversity.
6. Urban infrastructure (such as buildings, streets and green areas) influences biodiversity in the urban environment.
7. Climate change can reduce urban biodiversity.
8. The creation of green areas and urban parks contributes to the improvement of biodiversity in the urban environment.
9. Noises and vibrations have no impact on the urban environment.
10. Soil permeability is influenced by the paving of some urban areas.

The task of the respondents was to mark on a scale from 1 to 7 the degree of personal agreement/disagreement with the proposed statement (1 = express total disagreement with the statement, 7 = total agreement with the statement)

4. Analyzes and Results

The analysis of the results obtained in the Likert questionnaires was done with the help of the SPSS 17 (Statistical Package for the Social Sciences 17) program for the statistical analysis of the data [6].
The objectives of the study were the following:
A first objective pursued was to establish the general knowledge level of the respondents. The average scores of the answers to all the subjects of the questionnaire have relatively close values, between 4.73 and 6.16, so that the differences are not significant between the average values of the answers (tab. 1.). By analyzing the average difference, relatively high values are found (>>0.05), which means that there is *relatively homogeneous knowledge in each of the subjects proposed in the questionnaire*

Table 1. *Descriptive statistics for the average tendency of respondents' answers to the subjects in the questionnaire*

Subject	*N (respondents)*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
i_1	*90*	*1*	*7*	*5.16*	*1.555*
i_2		*1*	*7*	*4.73*	*2.090*
i_3		*1*	*7*	*4.59*	*1.978*
i_4		*1*	*7*	*6.08*	*1.351*
i_5		*1*	*7*	*6.16*	*1.280*
i_6		*1*	*7*	*5.70*	*1.561*
i_7		*2*	*7*	*6.33*	*1.202*
i_8		*1*	*7*	*5.34*	*1.758*
i_9		*1*	*7*	*5.01*	*2.157*
i_{10}		*1*	*7*	*5.62*	*2.132*

The second objective of the study was ii) establishing the influence that the students' specialization (biology, engineering, economic sciences) has on their general knowledge about the physical mechanisms involved in biodiversity. Similarly, the study aims iii) to analyze the influences that the level of study (bachelor's, master's) has on the understanding of the involvement of physical mechanisms in biodiversity
The calculation carried out to achieve these objectives is the uni-factorial analysis of variance (ANOVA). Tables 2 and 3 summarize these results.

Table 2. The influence that the followed specialization of the subjects has on the understanding of the physical mechanisms involved in biodiversity (ANOVA)

Subject	Specialization	N (respondents)	Mean	Std. deviation	F	p
i_1	engineering	25	5.20	1.399	0.016	0.984
	biology	31	5.12	1.900		
	economics	34	5.18	1.362		
i_2	engineering	25	4.60	2.010	2.898	0.062
	biology	31	5.48	1.896		
	economics	34	4.14	2.172		
i_3	engineering	25	3.95	2.282	1.462	0.239
	biology	31	4.80	1.683		
	economics	34	4.86	1.957		
i_4	engineering	25	6.25	1.118	2.137	0.126
	biology	31	5.64	1.868		
	economics	34	6.36	0.780		
i_5	engineering	25	5.70	1.895	1.140	0.326
	biology	31	5.64	2.271		
	economics	34	5.54	2.236		
i_6	engineering	25	6.45	0.686	0.272	0.763
	biology	31	5.88	1.691		
	economics	34	6.21	1.166		
i_7	engineering	25	5.55	1.669	0.085	0.919
	biology	31	5.88	1.810		
	economics	34	5.64	1.254		
i_8	engineering	25	6.25	1.070	1.251	0.292

	biology	31	6.40	1.258		
	economics	34	6.32	1.278		
i_9	engineering	25	5.40	1.789	0.036	0.965
	biology	31	4.48	2.330		
	economics	34	5.21	2.217		
i_{10}	engineering	25	4.95	1.791	1.214	0.303
	biology	31	5.76	1.332		
	economics	34	5.25	2.030		

The values of F and p in table 2 (p > 0,05) indicate that the three specializations analyzed have a comparable level of knowledge; the specialization pursued (at least in the present cases where all specializations assume a scientific and technical approach) does not significantly influence the level of knowledge of general physical mechanisms with tangents on biodiversity.

Table 3. The differences induced by the study level on the understanding of the different physical mechanisms involved in biodiversity (ANOVA)

Subject	Study level	N (respondents)	Mean	Std. deviation	F	p
i_1	bachelor degree	70	5.05	1.616	1.492	0.226
	master degree	20	5.60	1.242		
i_2	bachelor degree	70	4.67	2.155	0.184	0.670
	master degree	20	4.93	1.870		
i_3	bachelor degree	70	4.33	1.941	5.221	0.025*
	master degree	20	5.60	1.844		
i_4	bachelor degree	70	6.00	1.463	1.045	0.310
	master degree	20	6.40	0.737		
i_5	bachelor degree	70	5.76	2.029	1.260	0.265
	master degree	20	5.07	2.492		
i_6	bachelor degree	70	6.14	1.249	0.119	0.731
	master degree	20	6.27	1.438		
i_7	bachelor degree	70	5.60	1.716	1.051	0.309
	master degree	20	6.07	0.594		
i_8	bachelor degree	70	6.33	1.145	0.000	0.987
	master degree	20	6.33	1.447		
i_9	bachelor degree	70	5.05	2.081	0.087	0.769
	master degree	20	4.87	2.503		
i_{10}	bachelor degree	70	5.12	1.836	4.726	0.033*
	master degree	20	6.20	1.082		

The results contained in Table 3. indicate that the vast majority of the physical mechanisms involved in maintaining biodiversity are known to a comparable extent by bachelor students as well as by those in the master's cycle. These values indicate a high level of knowledge, the averages obtained (means) being in the upper quarter of the variation range of the scale. Exceptions to these trends are made by two analyzed physical mechanisms: "public lighting" (i_3) and "soil permeability and asphalting" (i_{10}). For these, the variant analysis indicates significantly higher averages of those in the master's level compared to those in the bachelor level (Fi_3= 5.221 and a p=0.025 and Fi_{10}=4.726 for a p=0.033) If the other analyzed mechanisms are already well identified mechanisms as having a logic connection with biodiversity, the

influence of public lighting and paving seems not to be completely understood for implication in biodiversity until master degree.
In order to nuance the results obtained, we resorted to an additional coding of the answers, respectively we divided the group of respondents according to the level of general knowledge of the concepts of biodiversity (i1) and of the concept of abiotic factors (I_2) - as an indicator of the degree of familiarization with the problems and mechanisms of biodiversity. The coding was carried out in the following way: we formed three categories of respondents
1 - low level - with those who awarded 1 or 2 points for subject i_1 and i_2
2 - medium level - with those who awarded 3, 4 or 5 points for subject i_1 and i_2
3 - high level - those who awarded 6 or 7 points for subject i_1 and i_2
Objective iv) we set out to analyze to what extent the level tested at i_1 (knowledge of the concept of biodiversity" influences the level of understanding of the connection of different physical mechanisms with biodiversity. The answers to the analysis of the variant carried out on this topic are contained in Table 4.

Table 4. The influence of the level of knowledge of the concept of "biodiversity" on the understanding of the connections that physical mechanisms have in biodiversity

Subject	categories of respondents for i_1	N (respondents)	Mean	Std. deviation	F	p
i_3	low level	6	4.20	1.924	1.019	0.366
	medium level	36	4.24	1.640		
	high level	48	4.90	2.198		
i_4	low level	6	4.00	2.828	10.485	0.000**
	medium level	36	5.86	1.125		
	high level	48	6.51	0.942		
i_5	low level	6	4.60	2.881	1.466	0.238
	medium level	36	5.86	1.060		
	high level	48	6.59	.910		
i_6	low level	6	4.60	2.881	7.993	0.001**
	medium level	36	5.86	1.060		
	high level	48	6.59	0.910		
i_7	low level	6	4.40	2.302	2.396	0.098
	medium level	36	5.59	1.659		
	high level	48	5.95	1.317		
i_8	low level	6	5.80	2.168	2.567	0.084
	medium level	36	6.03	1.322		
	high level	48	6.62	0.877		
i_9	low level	6	4.20	3.033	0.777	0.464
	medium level	36	5.34	1.696		
	high level	48	4.87	2.353		
i_{10}	low level	6	5.20	1.789	5.422	0.006**
	medium level	36	4.59	2.163		
	high level	48	5.92	1.133		

** significance threshold p below 0.01

Table 4 contains three physical mechanisms whose knowledge is sensitive to the influence of the factor "general level of knowledge of the concept of "biodiversity": "Anthropogenic (man-made) changes in environmental temperature and humidity have a major impact on biodiversity in urban environments" , "Urban infrastructure (such as buildings, streets and green areas) influences biodiversity in the urban environment" and "Soil permeability is influenced by the paving of some urban areas" [7]. For all of these, the significance thresholds recorded are below 0.05 (equivalent to saying that the level of knowledge of the concept of biodiversity influences, without any assumed error, the degree of understanding of the involvement of three physical mechanisms in the mechanisms of biodiversity [8].
Similarly, the analysis of the way in which the understanding of physical mechanisms are involved in biodiversity is influenced by the knowledge of the concept of "abiotic" and is carried out through variant analysis. The results are summarized in Table 5:

Table 5. The influence of the level of knowledge of the "abiotic" concept influences the level of understanding of the physical mechanisms connected with biodiversity

Subject	categories of respondents for i_2	N (respondents)	Mean	Std. deviation	F	p
i_3	low level	20	4.65	1.869	0.071	0.932
	medium level	28	4.45	1.896		
	high level	42	4.65	2.130		
i_4	low level	20	5.88	2.828	2.937	0.060
	medium level	28	5.64	1.125		
	high level	42	6.47	.942		
i_5	low level	20	5.53	2.881	0.814	0.447
	medium level	28	6.09	1.060		
	high level	42	5.35	0.910		
i_6	low level	20	5.76	2.881	1.521	0.226
	medium level	28	6.09	1.060		
	high level	42	6.41	0.910		
i_7	low level	20	4.94	2.302	3.719	0.029*
	medium level	28	5.59	1.659		
	high level	42	6.15	1.317		
i_8	low level	20	5.88	2.168	1.591	0.211
	medium level	28	6.41	1.322		
	high level	42	6.50	0.877		
i_9	low level	20	4.94	3.033	0.013	0.988
	medium level	28	5.05	1.696		
	high level	42	5.03	2.353		
i_{10}	low level	20	4.76	1.789	2.917	0.061
	medium level	28	5.00	2.163		
	high level	42	5.85	1.133		

* significance threshold $0,01 < p<0,05$

Table 5 indicates that the predictive value for the variation in the level of understanding of the physical mechanisms connected with biodiversity is much lower in the case of the knowledge of the "abiotic" concept than in the case of the knowledge of the "biodiversity" - only the understanding of one of the physical mechanisms analyzed is influenced by the degree of knowledge of the concept of "abiotic factor", namely "Climate change can reduce urban biodiversity" for a significance threshold p=0,029. Ignorance of the term abiotic factors and its meaning causes a misunderstanding of the link between climate change and urban biodiversity

5. Conclusions

These data indicate that the understanding of the existing connections between the mechanisms of physics and those of biodiversity presuppose knowledge at least at a medium-high level of the basic concepts in the field of biodiversity. The more general the concepts in the field of biodiversity, the greater their predictive value for the understanding / misunderstanding of the physical mechanisms attached to biodiversity.

The assessments made by the respondents demonstrate that there are no significant differences between the averages of the groups. However, it is found that each specialization group knows better its field of specialization and does not recognize related specializations as well. This is related to the acquisition over time of some knowledge and notions that characterize a non-multidisciplinary learning, resulting in imbalances in the general evaluation of the interdisciplinary aspect related to the application of physics mechanisms in environmental issues. The results obtained are heterogeneous - different specializations perceive in different ways the existing links between the biological layer and the laws that govern the physical world. Some mechanisms are perceived and evaluated only by the aesthetic benefits and not by the effects they produce on the urban ecology.

The practical utility of these results consists in updating the urban ecology curriculum by introducing elements that allow deepening the meaning and causalities of the studied mechanisms, through informational bridges in the field of physics. It is necessary to develop teaching methods that emphasize the interconnection between physics and ecology, such as case studies or interdisciplinary research projects, as well as the use of simulations and modeling software to illustrate ecological and physical mechanisms.
The interdisciplinary knowledge and skills developed by learning the application of physics methods in ecology can open career opportunities in various fields, including research, environmental management, engineering, public policy and education. Assessing and improving these concepts in students is crucial to ensure that they are well equipped to contribute to solving current and future ecological challenges. It is important to have continuous feedback to adjust the curriculum and teaching methodologies. Additionally, to include the latest discoveries and technologies in the field of physics applied to ecology, periodic curriculum review is necessary.
The application of physical mechanisms in urban ecology and biodiversity conservation is essential for the development of innovative and effective solutions to contemporary ecological problems. Understanding these mechanisms encourages a proactive approach to biodiversity conservation and natural resource management. Training a new generation of professionals capable of addressing ecological challenges with an interdisciplinary perspective can contribute to the implementation of sustainable development.

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