EDeR

Educational Design Research

Volume 9 | Special Issue 1 | 2025 | Article 78

Contribution Academic Article

Title **The importance of refining design principles when conducting educational design experiments on biodiversity in Latin America**

Authors **Pollyana de Andrade Sales**
Rural Federal University of Pernambuco
Brazil

Helaine Sivini Ferreira
Rural Federal University of Pernambuco
Brazil

Abstract This research aims to develop and refine a design process to approach the concept of biodiversity from an integral and polysemic perspective, contemplating real problems in the context of practice. The teaching and learning sequences proposed in this article originate from different design principles, structured considering pedagogical guidelines that emerged from the Model of Educational Reconstruction (MER). The design principles formulated sought to deal with the diversity of perceptions that students have about the concept of biodiversity in the North and Southeast regions of Brazil and to provide different possibilities of action for teachers. It became evident from the process of refining design principles that the sequence drawn about biopiracy was not aligned with the reality experienced by students in the North region. For this context, it was essential to consider that students do not develop knowledge about biodiversity only through the school curricula, especially those immersed in a sociocultural context rich in indigenous and local knowledge about biodiversity, and topics like illegal

exploration and impacts of mining would be much better. It is expected that this study can help fill research gaps related to the relevance, understanding, application, and effectiveness of design principles in the practice of local contexts and offer a sensitive glimpse at the multiple nuances that permeate the scientific approach to the concept of biodiversity in Latin America.

Keywords Design-based research
Design principles
Heuristic tool
biodiversity

DOI dx.doi.org/10.15460/eder.9.1.2156

Citation Sales, P. D. A., Ferreira, H. (2025). The importance of refining design principles when conducting educational design research experiments on bio diversity in latin america. *EDeR - Educational Design Research*, *9*(1), 1-26. http://dx.doi.org/10.15460/eder.9.1.2156

The importance of refining design principles when conducting educational design experiments on biodiversity in Latin America

Pollyana de Andrade Sales, Helaine Sivini Ferreira

1.0 Introduction

In educational design research, understanding the term “design principles” is fundamental for structuring its processes. However, some studies reveal gaps in the development of conclusive and refined principles (Gundersen, 2021). Despite attempts to clarify the term, it is often unclear how design principles are specifically articulated, who they target, and how to apply them in practice (Bakker, 2019; Baumgartner & Bell, 2002; Van den Akker, 1999). According to Gundersen (2021), actual descriptions of design principles and their transformations are often omitted in Design-Based Research (DBR) publications.

However, formulating principles considered useful by professionals, applying them in practice after understanding them theoretically, and identifying how to revise them based on experience gained in real-life interventions are challenging tasks, although they are objectives that the DBR seeks to achieve. In some cases, instead of producing relevant and robust guidelines for educators and researchers to test and apply in their practices, DBR tends to generate idealized descriptions of design principles. This is counterproductive since one of DBR’s central ambitions is precisely to provide such guidelines.

Furthermore, it is essential to consider the negotiations necessary for the application of the initially planned designs, as there are multiple subjects involved in the process and different educational scenarios that can create unexpected situations, often at odds with the initial objectives. Dissonances that arise during the research process are part of the nature of DBR. They should not be considered a negative aspect but rather a basic condition when educational researchers explore design principles and their possible applications in practical contexts.

However, the difficulties highlighted accentuate the importance of exploring the lack of transparency and the connection between design principles and practice contexts, so in this article, the research question is: How to develop a process for proposing design principles for developing teaching and learning sequences about biodiversity that address real problems in practice contexts?

To this end, the research is based on studies by Silva (2019), who applied the Model of Educational Reconstruction to the concept of Biodiversity, and on studies by Hanghøj et al. (2022), who proposed a heuristic tool intending to refine proposals designed from the DBR perspective.

Thus, this research aims to develop and refine a design process to approach the concept of biodiversity from an integral and polysemic perspective, contemplating real problems in the context of practice.

2.0 Real challenges in the context of practice: Biodiversity in Latin America

There is a vast biological and cultural diversity in Brazil. It manifests through particularities in its traditions, heritage, ties, and knowledge in different regions. Furthermore, the country has several ecosystems, climates, and landscapes, including savannas, caatingas, Cerrado, beaches, tropical forests, and other environments. This rich diversity places Brazil in a prominent position regarding its heritage protection and conservation. Although the Brazilian territory is rich in biodiversity and unique ecosystems, there is widespread criticism due to the lack of effective conservation and environmental preservation actions. Unfortunately, continued exploitation, fires, and destruction of biodiversity have been an alarming and increasingly worrying reality.

Environmental perception can be a valuable tool in discussing and developing socioenvironmental strategies. Through social, cultural, economic, and other factors, this approach allows for a better understanding of knowledge related to the environment. Given this, several Brazilian researchers have dedicated themselves to investigating students' perceptions of biodiversity across the country, aiming to deepen knowledge and propose effective pedagogical approaches for socioenvironmental conservation.

The study developed by Franzolin, Garcia, and Bizzo (2020) investigated the perception of students from different geographic regions of Brazil regarding the concept of biodiversity. According to data collected in interviews, more than half (50.4%) of the students residing in the Amazon region expressed interest in learning about local plants and animals, while approximately 33.1% demonstrated the same level of curiosity in the Southeast region. The Northeast region also stood out with the second highest relative number of respondents motivated to learn about the diversity of organisms in their region, reaching a percentage of 46.9%.

In this study, it was possible to verify that both students from the Amazon region and those from the Southeast of Brazil show great value in participating in actions to protect the environment (Table 1). This can be observed by the combined results of high disagreement with some statements such as: "Environmental problems are exaggerated" (C41) and "It is the responsibility of rich countries to solve the world's environmental problems" (C38). On the other hand, they showed high agreement on statements such as: "People should be

more concerned about protecting the environment" (C31) and "I think each of us can make a significant contribution to environmental protection" (C35).

Table 1

Perceptions of students from the North and Southeast regions of Brazil about conservation actions based on the study developed by Franzolin, Garcia, and Bizzo (2020)

North Region	**Southeast Region**
Items with the highest level of agreement	
C31– People should be more concerned about protecting the environment	
C30 – We can still find solutions to our environmental problems	C35 – I think each of us can make a significant contribution to environmental protection
C35 – I think each of us can make a significant contribution to environmental protection	C30 – We can still find solutions to our environmental problems
C33 – The natural world is sacred and should be left alone	C29 – I can personally influence what happens to the environment
C29 – I can personally influence what happens to the environment	C33 – The natural world is sacred and should be left alone
E65 – I am willing to solve environmental problems even if it means sacrificing many goods	
C32 – I am optimistic about the future	
Items with the highest level of disagreement	
C41 – Environmental problems are exaggerated	E54 – Science and technology can solve almost all problems
E54 – Science and technology can solve almost all problems	C41 – Environmental problems are exaggerated
C38 – It is the responsibility of rich countries to solve the world's environmental problems	C28 – Science and technology can solve all environmental problems
C28 – Science and technology	C38 – It is the responsibility of

can solve all environmental problems	rich countries to solve the world's environmental problems
C34 – People worry too much about environmental problems	
C40 – Threats to the environment are none of my business	C37 – Environmental problems should be left to experts
C37 – Environmental problems should be left to experts	C40 – Threats to the environment are none of my business

Source: Adapted from Franzolin, Garcia, & Bizzo (2020).

Therefore, even if there are discrepancies in interest regarding the inclusion of environmental issues in study plans, students from both regions have a unanimous position regarding their role in the struggle concerning environmental issues. They demonstrate a vehement refusal to the idea that it is only up to rich countries to solve all the planet's environmental challenges and present a growing dissent about discourses that underestimate environmental issues. These two patterns may be related and, thus, deserve to be investigated in depth.

This research was based on statistics and used national samples. The results show that, despite significant differences in students' level of interest between the North and Southeast regions, there is a common commitment to engaging in conservation actions. In line with the literature, prior knowledge about biodiversity is one fundamental factor in increasing interest in conservation actions. It is worth highlighting that students' knowledge about biodiversity is not limited to school content; for example, students who live in the Amazon region are immersed in a sociocultural context rich in indigenous and local knowledge about biodiversity that needs to be highlighted.

Although the topic is of great importance, there are several gaps in knowledge about the concept of biodiversity and environmental perception. The recently released Brazilian national report on youth, environment and climate change JUMA (Juventudes, Meio Ambiente e Mudanças Climáticas, 2023) reveals that around 36% of the 5,150 young Brazilians interviewed do not know which biome they live in. This data highlights the urgency for actions that expand knowledge about biological, cultural, and geographic diversity since this understanding awakens a feeling of belonging and responsibility for the environment around them.

Therefore, primary/elementary and secondary education must undergo significant transformations, including the introduction of the study of the knowledge of local indigenous peoples about native fauna and flora. When reflecting on the universality of the sociocultural aspects of indigenous peoples, an approach that was distant from the reality experienced by students was identified. For example, Brazilian curricula lack a polysemic approach to the concept of biodiversity so that greater integration of knowledge can occur. In other words, the content learned defines the region as an ancient forest that encompasses diverse plants and animals, but sociocultural aspects such as

its potential for the development of medicines, agricultural activities, indigenous myths, and their relationship with nature are not explored (Bermudez & Lindemann-Matthies, 2020).

Although many students share the concern for environmental preservation, it is necessary to note that there are distinct environmental issues in different realities (Schwarz, André, & Sevegnani, 2012). In the Southeast region, for example, air pollution is an alarming environmental challenge that has been widely debated, while in the North, it is common to identify issues such as deforestation and illegal exploration. There is a need to promote distinct approaches to the concept of biodiversity for students in different regions of Brazil that are articulated with the values and beliefs of the local community to promote participatory approaches toward conservation.

3.0 The design principles

Design principles are developed in the hope that it will be possible to transform theoretical assumptions into specific guidelines capable of addressing pedagogical resources, teaching methodologies, or specific student tasks. Thus, design principles establish objective and descriptive intentions that can be implemented through interventions such as teaching and learning sequences, resulting in specific knowledge.

It is possible to divide the studies applied to design-based research into two types: validation studies, which aim to validate and develop theories about the teaching and learning process, and development studies, which elaborate design principles for their practical application (Van den Akker, 1999; Nieveen, McKenney & Van den Akker, 2006). Therefore, design principles can arise from a theory to be validated or developed from an existing context.

Design principles have two fundamental aspects. The first is linked to the characteristics that emerge from interventions developed at the beginning of the design process and enable the generation of ideas for the subsequent design stages (substantial). The second aspect relates to how the project should be developed or the characteristics of the project approaches, such as its objectives, resources, and actors involved (procedural). According to Van den Akker (1999), the articulation between these two aspects enhances the creation of principles that allow the description, discussion, and reflection of knowledge based on dialogicity, which can be systematized using the following structuring pattern of design principles:

If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics A, B, and C [substantive emphasis], and to do that via procedures K, L, and M [procedural emphasis], because of arguments P, Q, and R. (Van den Akker, 1999, p. 9).

This structure favors dialogicity between the aspects presented previously since the substantive emphasis highlights the characteristics

of the intervention, such as the descriptive principles, and the procedural emphasis highlights the procedures to be conducted, such as the prescriptive principles. Therefore, their articulation can offer a more effective application of design practice and methodological rigor in research.

On the other hand, Baumgartner and Bell (2002) state that the usefulness of design principles arises from their generative nature; they enable the creation of new designs based on well-structured guidelines. To achieve this, the authors reinforce the importance of establishing criteria to evaluate the usefulness and value of these principles. Furthermore, it allows researchers to address fundamental aspects such as characterization and applicability.

Based on the above, the key questions can help elucidate the characteristics and purpose of the principles: What are the characteristics of this principle? Why is it relevant? Who should apply it and when? How should it be applied? What are the elements that validate the effectiveness of its application? (Hanghøj et al., 2022) These aspects explore the usefulness and relevance of the proposed principles, providing opportunities for their reformulation or the emergence of new proposals. Therefore, the heuristic tool promotes articulation and reflection based on guiding questions that enhance the viability of approaching these principles.

4.0 Methodology

The present investigation is a development study (Sarmento et al., 2013) with a qualitative bias. The educational guidelines defined by Silva (2019) were used to address the concept of biodiversity, relying on the Model of Educational Reconstruction (MER) as a theoretical and methodological structure. The choice for the concept of biodiversity arises from analyses and reflections on its relevance to the Brazilian and international context, its investigative gaps, and challenges for its integral and polysemic approach. Furthermore, the students' multiple perceptions regarding the concept of biodiversity, discussed previously, reveal the difficulties inherent in the construction of clear design principles applicable to the different contexts of practice that permeate the regions of the country.

In this way, the methodological path aims to design two teaching and learning sequences adapted to the contexts of the North and Southeast regions of Brazil. As previously presented, local diversity promotes distinct student perspectives regarding biodiversity. Therefore, the objective is to develop sequences that reflect the reality and perceptions of students in different Brazilian regions.

Therefore, the first stage consists of selecting the educational guidelines (OE) developed in a study by Silva (2019) that portray various social, environmental, and economic aspects (Table 2). From the application of the Model of Educational Reconstruction, the researcher

signaled similarities and differences between scientific conceptions and those of students regarding the concept of biodiversity, which allowed her to identify the pedagogical potential of this dialogue. The educational guidelines function as tools for teaching planning and guide the development of principles.

Table 2

Educational guidelines on biodiversity based on Silva's (2019) study

Educational guidelines on the concept of biodiversity	
OE1	It is essential to understand the meaning of each of the levels of organization of biodiversity, recognizing that it can be analyzed through these levels.
OE2	It is important to comprehend that there are interactions between the levels of organization of biodiversity and that these interactions allow an evolutionary view of biodiversity.
OE3	It is crucial to understand that biodiversity can be analyzed in more detail through its attributes and components and that they interact with each other, giving an ecological interpretation to biodiversity.
OE4	It is essential to recognize that in the sociocultural context, biodiversity can be treated from different dimensions, which are not independent of each other, and pursue the same objective: to analyze how biodiversity is conserved in society.
OE5	It is essential to understand that the sociocultural discussion of the concept of biodiversity allowed different values and interpretations to be added to biodiversity over time.
OE6	It is important to build values linked to biodiversity when seeking to prepare individuals committed to its preservation and conservation.
OE7	It is crucial to discuss the concept of biodiversity through its two discussion contexts, understanding that both are equally important for understanding the concept of biodiversity. Therefore, one context should not overlap the other.
OE8	It is necessary to understand the conceptual breadth of biodiversity in both its discussion contexts.
OE9	The concept of biodiversity must be discussed through a wide

	repertoire of scenarios, which provides students with varied ways of thinking about biodiversity.

Source: Adapted from Silva (2019).

For the North region, the educational guidelines were chosen based on the need to address specific aspects related to local biodiversity, highlighting the importance of understanding how the attributes and components of biodiversity interact ecologically (**OE3**), in addition to incorporating diverse sociocultural values into the concept of biodiversity (**OE5**) and promote the formation of values linked to environmental conservation (**OE6**).

On the other hand, for the Southeast region, the guidelines were selected to address the multiple sociocultural dimensions of biodiversity. It is important to recognize that these dimensions are interdependent and contribute to the understanding of how biodiversity is conserved in society (**OE4**). Furthermore, it highlights the discussion of the concept of biodiversity through different discussion contexts and scenarios (**OE7**, **OE8**, and **OE9**).

Based on this, the design principles were proposed and formulated following the systematization guidelines (Van den Akker, 1999; Duit et al., 2012). Based on the principles, the Meetings (E), Didactic Actions (AD), and methodological suggestions were structured. Once the sequences were structured, aspects of the heuristic tool were applied to identify the proposed principles' usefulness, value, and applicability (Hanghøj et al., 2022).

The first didactic sequence explores the ecoengineering bias in the Southeast region through the development of microhabitats in bioreceptive and self-sustainable panels that can improve vertical urbanization processes and the climate in their surroundings (Mustafa, Prieto, & Ottele, 2021). The proposal to use bioreceptive panels has pedagogical potential but has not yet been widely used in teaching and learning environments. For this reason, the use of these panels as a central element in a teaching and learning sequence could provide students with an integral and polysemic view of the concept of biodiversity, in addition to developing preservation actions and environmental awareness. As a teaching methodology, Challenge-Based Learning intends to increase student engagement through technologies and a culture of innovation to solve challenges (Santos, 2016; Sales, 2022). Thus, students are immersed in questions that help them plan to identify challenges, gather evidence-based solution proposals, and validate them to make constant improvements.

For the development of the second didactic sequence, it was decided to use the theme of biopiracy in Brazil as central in the discussion. Biopiracy is the illegal obtaining of biological resources such as animals, plants, and even the knowledge associated with them. Further-

more, it involves the use and commercialization of these resources without due authorization (Serotini & Vitoi, 2022; Aviz, 2022). It has a negative impact on biodiversity since excessive collection of these resources can lead to a reduction in species populations and loss of biodiversity, which can trigger severe consequences for ecosystems and human health (Farias & Muniz de Carvalho, 2022; Danley, 2012).

As it is a topic that generates controversies and has complexities, as it involves debates related to intellectual property, access to biological resources, and the preservation of biodiversity, it was decided to use the Socioscientific Issues Questionnaire (SSI-Q) as a teaching methodology. The SSI-Q approach encourages argumentation on scientific, technological, and social aspects. Furthermore, it can stimulate interaction between individuals, decision-making, critical positioning, and evidence-based data.

5.0 Results and Discussion

To develop design principles aligned with the different possibilities of action in educational contexts, the selected educational guidelines made it possible to understand the conceptual complexity of biodiversity. From this, the teaching and learning sequences developed aim to approach the concept of biodiversity (BD) in an integral and polysemic way, considering the different contexts in which students live. To this end, the North and Southeast Brazilian regions were selected as possible locations for applying the sequences structured in this study, as they present different realities and needs.

Considering the pedagogical guidelines selected for the North and Southeast regions previously mentioned in the methodology, design principles were developed, and they guide the construction of teaching and learning sequences (Table 3) based on the pedagogical needs and potential identified by Silva (2019).

Table 3

Design principles that guided the design of biodiversity teaching and learning sequences

Design principle that guides the design of the teaching sequence on biopiracy in Brazil
Design Principle 1: Within an integral and polysemic perspective, the objective is to promote reflections on the social, cultural, economic, and environmental aspects that permeate the concept of biodiversity (BD) through socioscientific questions about biopiracy in Brazil. To better understand the concept, there must be a dialogue between its different contexts (scientific and sociocultural) – and the socioscientific issues enable this multidimensional approach (Silva, 2019). The proposal has been guided by studies on biopiracy

in Brazilian regions since the uncontrolled exploitation of plants generates an immense loss of biodiversity in the Amazon (Aviz, 2022; Farias & Muniz de Carvalho, 2022; Danley, 2012). However, in the educational context, this theme has gaps, and despite its pedagogical potential, there are no records of its use in teaching and learning environments. In this way, students can articulate sociocultural knowledge and scientific arguments to understand the impacts of illegal exploitation of biodiversity in the Brazilian territory and develop a critical and reflective stance in the face of the above.
Design principles that guided the design of the teaching sequence on ecoengineering
Design Principle 1: From the perspective of the ecological dimension of biodiversity, to promote a broad view of the attributes and components of BD, a teaching and learning sequence inspired by the construction of bioreceptive and self-sustaining plates was developed because these can assist in discussions about the analysis of biodiversity in a region through various attributes and components. This proposal has been guided by studies on the development of microhabitats in bioreceptive panels that enable the increase in biodiversity and preservation actions. In this way, students can establish an integral and polysemic approach to the concept of biodiversity based on experiences that bring them closer to understanding the ecological dimension of BD.
Design Principle 2: From the perspective of the sociocultural context of biodiversity, the objective was to establish a reflective dialogue with students through the articulation between the social, economic, cultural, ethical, and environmental dimensions to promote students' socioenvironmental awareness and leadership through actions of biodiversity preservation. For this, bioreceptive panels were used due to their effectiveness in ecoengineering and the benefits found for the biodiversity of a region (Mustafa, Prieto, & Ottele, 2021). Furthermore, it allows discussions with students about the urbanization process, creation of green spaces, benefits, and resources of BD through practical and contextualized activities.

Source: The authors (2024).

The teaching and learning sequences were structured after formulating the design principles. The proposals were divided into Meetings (E) and Didactic Actions (ADs), with methodological suggestions that enable a flexible implementation path for educators (Figure 1). The didactic actions developed seek to promote interaction, iteration, collaboration, and flexibility and are contextualized according to the educational scenario. For Wang and Hannafin (2005), these charac-

teristics are considered fundamental in design-based research and present theoretically and methodologically based principles. Furthermore, the author highlights the limitations found in the application of design-based research in teaching and learning environments, such as the applicability and feasibility of the methodology.

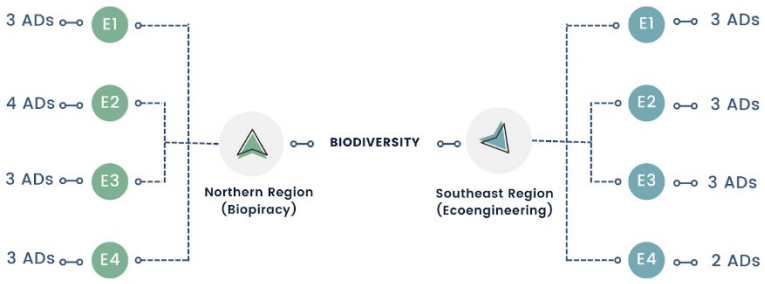

Figure 1. Structure of teaching and learning sequences about biodiversity

Source: The authors (2024).

In the first meeting of both sequences, didactic actions focus on promoting moments of individual reflection and collective activities to encourage student participation during the activities and value their perceptions. Furthermore, it encourages autonomy, self-reflection, and an investigative approach on the part of the students when developing research and recording their experiences. It is essential to highlight that the sociocultural repertoire is integrated with the content, enriching the construction of knowledge.

In this sense, in the first sequence (biopiracy), students are encouraged to carry out prior research on the concept of “biodiversity” and “biopiracy” using interactive and didactic resources provided by the educator to develop a critical and investigative stance. Students’ prior knowledge is valued, and a collaborative wall was built to gather information in different formats, such as images, news, and videos. In the ecoengineering sequence, students were also invited to explore concepts of biodiversity, green walls, and microhabitats in advance, using interactive resources and texts from the ecology area. Then, they were instructed to create an infographic about the challenges and benefits of green walls for biodiversity, reflecting on possible solutions.

To highlight the essence of the proposals developed, we chose to exemplify the second meeting of both teaching and learning sequences (Table 4) since the context of practice already implies a sig-

nificant differentiation in didactic actions. This moment proposes deepening the social, economic, cultural, ethical, and environmental dimensions to encourage a broader view of the biodiversity contexts. To this end, the didactic actions developed will enable investigation, socialization, and collection of evidence on the topics covered to promote a new glimpse at biodiversity. In this way, students can use their sociocultural repertoire to help understand economic, social, and cultural aspects and enhance their perception of biodiversity and its multiple dimensions.

Table 4

Didactic actions of the second meeting of the teaching and learning sequences

Didactic actions of the second meeting – biopiracy (North region)	
AD1	It is recommended to develop an activity in which students can list, write, or draw their thoughts on the topic to awaken students' prior knowledge. To do this, the teacher can question the students about what was covered in the previous class: "*About the previous meeting, list, write, or draw what was most interesting*." Based on the answers, it is possible to develop a brief discussion on what they understand about biopiracy in Brazil and how this relates to local biodiversity.
AD2	Presentation and collective reading of the case "**Açaí: Amazon Treasury under threat from biopiracy**," highlighting essential aspects related to biodiversity and its conservation. **Case "Açaí: Amazon Treasury under threat from biopiracy":** Açaí is a fruit native to the Amazon region and has long been consumed by local populations. With its growing popularity around the world, it has become a valuable commodity, especially in the food and nutritional supplement industry. However, its growing demand has led to the illegal practice known as biopiracy in the Brazilian Amazon. Many foreign companies have infiltrated the region, collected samples of the fruit, and took it out of the country without authorization. The Brazilian Amazon is one of the most biodiverse regions in the world, home to around a third of the planet's plant and animal species. The impacts of biopiracy are devastating for biodiversity, economy, and local culture and can lead to an environmental imbalance worldwide as it affects the entire ecosystem. It includes the loss of species, such as the palm trees that are the source of açaí, and the disruption

	of essential ecological processes such as pollination and seed dispersal. Furthermore, the region's culture is also affected, as the practice of biopiracy violates the knowledge and rights of indigenous and riverside communities, who often depend on açaí as a source of food and for medicinal use. Therefore, the balance between economic development and biodiversity protection is crucial to guarantee a sustainable future for the Amazon region and its communities.
AD3	After reading the case, the students can be organized into groups to discuss the guiding questions. At this point, it is worth defining the students' roles within the group, such as one person responsible for mediating the discussion and another for keeping records. It is important to promote a space for welcoming and sharing ideas, provoking questions related to the concept of biodiversity and the practice of biopiracy. It is worth reinforcing that the moment can address the different contexts in which biodiversity can be found, such as scientific and sociocultural. **Guiding Questions:** 1. How important is açaí to local communities in the Amazon, and how have they been affected by biopiracy? 2. What are the environmental impacts of excessive and illegal exploitation of açaí, and how can this affect biodiversity? 3. How can biopiracy harm the culture and economy of local communities? 4. What measures can be taken to prevent biopiracy and promote sustainable use of biological resources? 5. How can valuing common knowledge contribute to the conservation of biodiversity? 6. How can we balance economic needs with protecting and conserving local biodiversity?
AD4	To end the meeting, sharing the discoveries made by the group is an option for sharing students' perceptions on the topic. Then, the educator can provoke an individual reflection at home: "How is biodiversity present in your routine?" They may be asked to register their portfolios in the format they

	wish.
Didactic actions of the second meeting – ecoengineering (South-east region)	
AD1	Here occurs the socialization of the infographics developed at the previous meeting and review of the main points, using an integral and polysemic approach to the concept of biodiversity. At this point, the teacher can lead a reflection on the main preservation actions and the role of biodiversity in the sociocultural context. Some discussions can be raised, such as the urbanization process, the creation of green spaces, ecoengineering, and ecological interactions. Students must have the opportunity to understand the different values and interpretations attached to biodiversity.
AD2	Here occurs the presentation of the proposal for the construction of bioreceptive and self-sustaining panels for the school environment. Then, students can develop a collaborative mural highlighting the main doubts, difficulties, and potential of applying self-sustainable panels. It is worth highlighting the importance of developing a link between the social, economic, cultural, ethical, and environmental dimensions to understand the values linked to biodiversity.
AD3	Here occurs the preparation and initial construction of bioreceptive panels with students. At this point, their participation in the entire development of the material is essential, from the separation of materials to their application. Students will build panels using a previously developed 3D mold, following the protocol described by the teacher, and will then be able to record their reflections and learning in their portfolios. It is important to highlight that at this stage, it is essential to encourage an integral and polysemic approach to the concept of BD with students, outlining discussions about creating green spaces and ecoengineering with the benefits and resources of BD. Finally, the students' perspectives for the next meeting can be noted, highlighting their expectations regarding the application of bioreceptive plates in the school environment.

Source: The authors (2024).

The third meeting corresponds to the stage in which students develop solutions in the school environment to promote criticality and a multidimensional approach to the concept. In this way, environmental awareness and leadership are developed through didactic actions via

practical, investigative, and reflective activities, building a dialogical relationship between the dimensions and contexts of biodiversity.

In this meeting, in the sequence of biopiracy, students review the points discussed previously and share their reflections. They are then organized into groups to create mental maps that highlight the impacts of biopiracy on the sociocultural, economic, and environmental dimensions of Brazilian biodiversity, aiming for a critical analysis and multidimensional approach. The mind map serves as a visual tool for organizing information concisely, allowing students to explore and structure their ideas.

The sequence on ecoengineering allows the application of bioreceptive plates in the school context. Students need to prepare the cultivation of microhabitats using a paste made from mosses that permits the development of living beings. During the process, students must make photographic records and assumptions about the plates, analyzing aspects such as fungal colonization, color variation, and identification of living beings. They should also observe weather variations or other changes that may impact results, carrying out weekly observations and recording their findings in their portfolios. It is important to highlight that students play a fundamental role, from the construction of the plaques to the reflection on the discoveries. In this sense, from the construction of bioreceptive panels to reflection on the consequences of biopiracy on the economy and the environment, students can use their sociocultural repertoire to enhance their understanding of the concept of biodiversity.

The objective of the last meeting is to systematize learning about the concept of BD in its integral and polysemic perspective. This moment contributes to the development of actions that promote questions about the articulation between economic needs and the conservation of local biodiversity. It is worth highlighting that the pedagogical intention offered in the last meetings of the teaching and learning sequences aims to promote an assessment of learning in different formats and respect the students' individualities. Furthermore, design principles offer support to guide teachers in the application of teaching and learning sequences, dialoguing with their contexts and pedagogical needs.

In this sense, in the biopiracy sequence, students develop biodiversity conservation strategies based on knowledge about biopiracy, using the problem and solution tree technique. After the discussion, a welcoming environment is provided for them to express their perceptions and evaluate the teaching sequence, highlighting positive and negative points and suggestions for improvement, followed by self-evaluation and reflection on learning. For the ecoengineering sequence, the proposal was for students to conduct assessments, present their discoveries, and propose solutions based on data and evidence, promoting critical and investigative thinking.

After the presentation of the drawings and the different perceptions, the refinement process began, articulating the needs of local contexts. Hanghøj et al. (2022) argue that design researchers must be able to articulate and transform detailed principles into iterative and flexible processes for the emergence of eventual challenges and ideas. To improve the proposed principles, we adopted a refinement protocol. Initially, it is necessary to reflect on some key questions that can help to elucidate the characteristics and purpose of the principles (**Step 1 – Initial approach**). Next, the elements that stand out and contribute to the effectiveness of the guidelines and the elements that can be improved for a more satisfactory performance are identified (**Step 2 – Opportunity mapping**). Finally, the main aspects highlighting the usability and importance of the proposed principles, enabling a new perspective for the proposal, are identified (**Step 3 – Analysis of the practice context**).

To this end, the heuristic tool, structured by them and presented in Figure 2, was used to explore the articulation between the proposed principles and the contexts of practice based on some key questions that can help in evaluating the usefulness, value, and applicability: **What are the characteristics of this principle? Why is it relevant? Who should apply it and when? How should it be applied? What are the elements that validate the effectiveness of your application?** (Hanghøj et al., 2022).

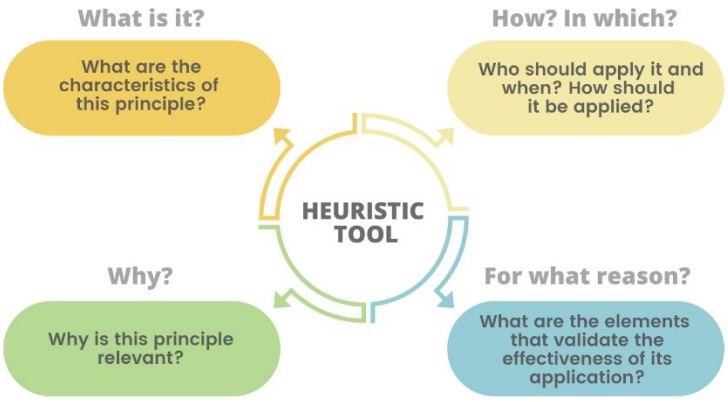

Figure 2. Heuristic Tool

Source: Adapted from Hanghøj et al. (2022).

Based on the questions raised, a set of elements were identified that require careful reflection to align the design of the proposed sequence with the local context. In the North region, the most prominent environmental problem is the practice of illegal exploration. It can be highlighted that the Brazilian Amazon represents around 15% of all biodiversity on the planet and has several unknown species (Pivetta, 2019). Furthermore, the territory encompasses a diversity of indige-

nous peoples who reside in the area and are committed to defending themselves against frequent and violent attacks aimed at their survival and cultural heritage. The illicit exploitation of natural resources and biodiversity triggers a series of social and environmental consequences. The Yanomami represent one of the indigenous peoples harmed by this practice, facing the impacts of mining since the 1970s, including mercury contamination, malnutrition, and hunger (Villén-Pérez et al., 2022). In other words, it is possible to establish a direct connection between environmental devastation and the maintenance of human life.

From this, the heuristic tool was used to explore the articulation between the proposed principle and the contexts of practice based on key questions that can help evaluate the usefulness, value, and applicability of the proposal on biopiracy (Table 5). Given this, it is possible to identify that refinement provides an objective understanding of the elements that guide educational practice, ensuring a relevant and constantly improved approach.

Table 5

Application of the heuristic tool in the design principle on biopiracy (initial approach)

Key questions	**Design principle analysis**
What are the characteristics of this principle?	The principle promotes reflection on biodiversity, integrating social, cultural, economic, and environmental aspects. Furthermore, it uses socioscientific questions about biopiracy.
Why is it relevant?	It is relevant because the practice of biopiracy negatively impacts biodiversity, local communities, and the economy, being essential to promote awareness about illegal exploitation and preservation of the environment.
Who should apply it and when? How should it be applied?	Teachers must apply this principle during their pedagogical practices involving environmental and social issues. It is applied through discussions, case studies, projects, and practical activities that integrate ecological, social, economic, ethical, and environmental aspects.
What are the elements that validate	Based on students' understanding of the impacts of biopiracy and the development

the effectiveness of its application?	of a critical and reflective stance, in addition to valuing traditional knowledge and the rights of local communities.

Source: The authors (2024).

By applying the heuristic tool to the design principle and the structured sequence on biopiracy, some essential aspects were identified that must be considered in the second stage: ecological (reflections on the impacts of biopiracy on the diversity of species and ecosystems), social (addressing sociocultural issues related to traditional knowledge, local community resources, and quality of life), economic (analysis of illegal trade in biological and intellectual resources and the negative economic impacts on the community), ethical (actions to discuss community rights and environmental conservation), and environmental (development of sustainable approaches to mitigate the effects of biopiracy on the preservation of BD and its resources). Therefore, although biopiracy is crucial for biodiversity conservation, it is not a widely discussed and publicized subject. When reflecting on the universality of the aspects considered for the design of the proposal and their relationships with the context of practice, it was identified that the designed sequence is not fully aligned with the reality experienced by students in the region.

After analyzing the relationship between the proposed principles and practical contexts, using the heuristic tool as a guide, it became evident that the issue of illegal exploitation is especially relevant to the region. Based on this finding, we chose to restructure the teaching and learning sequence, incorporating the issue of illegal exploitation in the Yanomami region. This measure aims to meet the specific demands of this scenario and strengthen the relevance and effectiveness of the proposed educational approach (Table 6).

Table 6

Socioscientific questions of the didactic sequence for the North Region

The Yanomami, an indigenous community that inhabits the Amazon region, is characterized by a unique biodiversity and an intrinsic relationship with nature. Their livelihoods depend on the sustainable use of natural resources while preserving their cultural practices and traditional knowledge. In recent years, the Yanomami region has been the target of illegal exploitation, including activities such as mining, deforestation, and animal trafficking. The search for precious minerals, such as gold, has led to constant invasions of indigenous lands, resulting in conflicts, environmental degradation, and threats to the safety and health of the Yanomami.

Impacts on Biodiversity:

- Deforestation: Illegal exploitation is associated with deforestation, compromising natural habitats and contributing to the loss of biodiversity.
- Water Contamination: Mercury in gold mining pollutes rivers and streams, affecting aquatic fauna and threatening the food security of the Yanomami, who depend on fishing.
- Interruption of Natural Cycles: The constant presence of invaders interferes with the region's natural cycles, harming the reproduction of several species and impacting ecological dynamics.

The Yanomami have actively resisted illegal exploitation, seeking legal and international support to protect their lands. Furthermore, indigenous leaders have promoted awareness of environmental impacts, highlighting the importance of preserving biodiversity for ecological balance and sustainability of their community. The case of the Yanomami illustrates the vital interconnection between indigenous communities, illegal exploitation, and biodiversity. The preservation of the rich biological diversity of the Amazon is intrinsically linked to respect for territorial and cultural rights of indigenous peoples. The search for sustainable solutions must consider the importance of protecting biodiversity and also the communities that depend on it for survival and prosperity.

Guiding questions:

- How important is biodiversity for local communities in the Amazon, and how have they been affected by illegal exploitation?
- What are the environmental impacts of excessive and illegal exploitation, and how can this affect biodiversity?
- How can illegal exploitation harm the culture and economy of local communities?
- What measures can be taken to prevent the illegal exploitation of biodiversity in the North region and promote sustainable use of biological resources?
- How can valuing popular knowledge contribute to the conservation of biodiversity?
- How can we balance economic needs with the protection

and conservation of local biodiversity?

Source: The authors (2024).

Concerning the second teaching and learning sequence, the heuristic tool was also applied to articulate the proposed principles with the key questions (Table 7). Given this, it is possible to identify that the refinement reveals a multidimensional approach to the concept of biodiversity. The use of bioreceptive panels and contextualized practical activities enable an understanding of the attributes and components of biodiversity, social and economic impacts, and socioenvironmental awareness and leadership.

Table 7

Application of the heuristic tool in ecoengineering design principles (initial approach)

Key questions	**Design principle analysis**
What are the characteristics of this principle?	Principle 1 focuses on the ecological dimension of biodiversity, using bioreceptive panels to analyze attributes and components of biodiversity.
	Principle 2 integrates sociocultural dimensions, using the same panels to discuss social, economic, cultural, ethical, and environmental issues.
Why is it relevant?	Principle 1 is relevant because it promotes an in-depth understanding of the ecological dimension of biodiversity, such as the interactions between living beings and their natural environments.
	Principle 2 is relevant for promoting socioenvironmental awareness and leadership, integrating the creation of urban green spaces, and discussing their benefits for biodiversity.
Who should apply it and when? How should it be applied?	Principle 1 can be applied by teachers through projects that involve students in the construction and analysis of bioreceptive panels.

	Principle 2 can be applied by teachers through practical activities and discussions that integrate the multiple dimensions of biodiversity and the urbanization process.
What are the elements that validate the effectiveness of its application?	Based on students' understanding of the components and attributes of biodiversity and the benefits of ecoengineering. And analysis of the development of socioenvironmental awareness, leadership, and environmental preservation and/or conservation actions.

Source: The authors (2024).

The application of the heuristic tool to the principles and the proposed teaching and learning sequence for the Southeast Region (with ecoengineering as a central element based on bioreceptive panels) reveals in the second stage that, although the context is not usual in educational proposals, it allows the interweaving of several aspects: **ecological** (development of microhabitats that can be colonized by macroorganisms, microorganisms, and plants), **social** (understanding the role of human beings in ecological systems and reflections on social responsibility), **economic** (reflections on how BD assets and resources are related to economic development, approach to ecoengineering and the urbanization process), **ethics** (actions to value all species for the integration and conservation of BD), and **environmental** (understanding the relationships between living beings and environments). In this context, the economic focus can also be highlighted by encouraging the development of sustainable business models and entrepreneurial practices to face the challenges of the urbanization process. Therefore, the heuristic tool explained a good articulation between the elements that validate the principles and their applicability with the local practice context.

The aspects presented previously were explored to help direct and align with the needs of real-life teaching and learning contexts, considering different perceptions about the concept of biodiversity. This practice consists of refining the design principles proposed for the development of teaching and learning sequences about the concept of biodiversity, seeking to propose relevant and robust guidelines for educators and researchers to implement in their practice contexts.

6.0 Final considerations

Design-based research in education offers promising paths, as it allows researchers to validate theories and concepts in actual teaching and learning environments, which contextualizes their applicability. Despite its potential, the use of design principles in practice faces

some challenges: discrepancy between what was idealized and applied in practice, lack of success criteria and detailed guidelines, and relevance and applicability of the principle. In this way, the heuristic tool presented in this study is a proposal to refine and create design principles useful for educators and aligned with practice contexts.

The teaching and learning sequences proposed in this article originate from different design principles, structured considering pedagogical guidelines that emerged from the MER. The design principles formulated sought to deal with the diversity of perceptions that students have about the concept of biodiversity in the North and Southeast regions of Brazil and to provide different possibilities of action for teachers. The structured teaching actions were aimed at recognizing the students' individualities and respecting their interests, preconceptions, perspectives, and experiences.

From the process of refining design principles, there is a need to increase the emphasis on cultural diversity when designing teaching and learning sequences for different sociocultural contexts since it tends to encourage pedagogical practices and curricula with a Eurocentric bias. This difficulty became evident in the sequence drawn about biopiracy. For this particular context, it was essential to consider that students do not develop knowledge about biodiversity only through the school curricula, especially those immersed in a sociocultural context rich in indigenous and local knowledge about biodiversity.

It is expected that this study can help fill research gaps related to the relevance, understanding, application, and effectiveness of design principles in the practice of local contexts and offer a sensitive glimpse at the multiple nuances that permeate the scientific approach to the concept of biodiversity in Latin America.

Acknowledgments

We would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the financial support.

7.0 References

Aviz, A. D. S. (2022). *Biopirataria e contrabando da biodiversidade amazônica: a cartografia dos crimes ambientais no Estado do Pará*.

Bakker, A. (2019). Design principles in design research: A commentary. *Unterrichtsentwicklung macht Schule: Forschung und Innovation im Fachunterricht*, 177-192.

Baumgartner, E., & Bell, P. (2002, April). *What will we do with design principles? Design principles and principled design practice*. Annual Meeting of the American Educational Research Association, New Orleans, LA, USA.

Bermudez, G. M. A., & Lindemann-Matthies, P. (2020). "What matters is species richness" – high school students' understanding of the components of biodiversity. *Research in Science Education*, *50*(6), 2159-2187.

Danley, V. (2012). Biopiracy in the Brazilian Amazon: Learning from International and Comparative Law Successes and Shortcomings to Help Promote Biodiversity Conservation in Brazil. *Florida A & M University Law Review*, *7*(2), 8.

Duit, R., Gropengiesser, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction – A framework for improving teaching and learning science. In *Science education research and practice in Europe* (pp. 13-37). Brill.

Farias, A. C. F., & Muniz de Carvalho, A. A. (2022). Biodiversity, biopiracy and intelligence. *CEP*, *71*, 50.

Franzolin, F., Garcia, P. S., & Bizzo, N. (2020). Amazon conservation and students' interests for biodiversity: The need to boost science education in Brazil. *Science Advances*, *6*(35). https://doi.org/10.1126/sciadv.abb0110

Gundersen, P. B. (2021). *Exploring the challenges and potentials of working design-based in educational research*.

Hanghøj, T., Händel, V. D., Duedahl, T. V., & Gundersen, P. B. (2022). Exploring the messiness of design principles in design-based research. *Nordic Journal of Digital Literacy*, 4, 222-233.

JUMA (2023). *Pesquisa Juventudes, Meio Ambiente e Mudanças Climáticas – 1ª edição*.

Mustafa, K. F., Prieto, A., & Ottele, M. (2021). The role of geometry on a self-sustaining bio-receptive concrete panel for facade application. *Sustainability*, *13*(13), 7453.

Nieveen, N., McKenney, S., & Van den Akker, J. (2006). Educational design research: the value of variety. *Educational design research*, 151-157.

Pivetta, M. (2019). A floresta da chuva: a Amazônia leva umidade para as demais regiões do Brasil e até outros continentes. *Pesquisa Fapesp*, 285.

Sales, P. D. A. (2022). *Influência do Projeto Incentífico no engajamento discente para a resolução de desafios socioambientais* [Master's thesis, Universidade Federal de Pernambuco].

Santos, A. R. D. (2016). *Um método de aprendizagem baseada em desafios: um estudo de caso em ambientes de desenvolvimento de aplicativos* [Doctoral dissertation, Pontifícia Universidade Católica].

Sarmento, A. C. D. H., Muniz, C. R. R., Silva, N. R. D., Pereira, V. A., Santana, M. A. D. S., Sá, T. S. D., & El-Hani, C. N. (2013). Investigando princípios de design de uma sequência didática sobre metabolismo energético. *Ciência & Educação (Bauru)*, 19, 573-598.

Schwarz, M. L., André, P., & Sevegnani, L. (2012). Children's representations of the biological richness of the mata atlântica biome. *Ciência & Educação (Bauru)*, 18, 155-172.

Serotini, A., & Vitoi, R. T. (2022). Reflexões sobre a biopirataria no Brasil. *Revista Eletrônica da Faculdade de Direito de Franca*, *17*(1).

Silva, M. G. (2019). *O modelo de reconstrução educacional como aporte teórico e metodológico para o design de uma sequência didática sobre o conceito de biodiversidade em uma perspectiva integral e polissêmica* [Doctoral dissertation, Universidade Federal Rural de Pernambuco].

Van den Akker, J. (1999). Principles and methods of development research. In J. van den Akker, R. M. Branch, K. Gustafson, N. Nieveen, & T. Plomp (Eds.), *Design Approaches and Tools in Education and Training* (pp. 1-14). Springer, Dordrecht. https://doi.org/10.1007/978-94-011-4255-7_1

Villén-Pérez, S., Anaya-Valenzuela, L., da Cruz, D. C., & Fearnside, P. M. (2022). Mining threatens isolated indigenous peoples in the Brazilian Amazon. *Global Environmental Change*, 72, 102398.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational technology research and development, 53*(4), 5-23.

Author Profiles

Helaine Sivini Ferreira, Dr., Prof is a Professor of Didactics of Science at the Department of Education and Graduate Program in Science Teaching at the Federal Rural University of Pernambuco. She teaches and researches in the areas of construction of meanings in formal and non-formal learning spaces, digital media as well as Design-Based Research. https://ufrpe.br

Pollyana de Andrade Sales, is doing her PhD at the Federal Rural University of Pernambuco, with research focused on Educational Design. She holds a master's degree in Education in Science and Mathematics, with an emphasis on student engagement and educational innovation. She is a teacher of active methodologies and is working with pedagogical practices that integrate technologies and active strategies to promote learning. https://ufrpe.br

Author Details

Helaine Sivini Ferreira
Federal Rural University of Pernambuco
Dom Manoel de Medeiros Street
Brazil
+55 81 98185 9900
helaine.ferreira@ufrpe.br

Pollyana de Andrade Sales
Federal Rural University of Pernambuco
Dom Manoel de Medeiros Street
Brazil
+55 81 99527 7302
pollyana.sales@ufrpe.br

Editor Details

Prof. Dr. Tobias Jenert
Chair of Higher education and Educational Development
University of Paderborn
Warburgerstraße 100
Germany
+49 5251 60-2372
Tobias.Jenert@upb.de

Journal Details

EDeR – Educational Design Research
An International Journal for Design-Based Research in Education
ISSN: 2511-0667
uhh.de/EDeR
#EDeRJournal (our hashtag on social media services)

Published by

Hamburg Center for University Teaching and Learning (HUL)
University of Hamburg
Schlüterstraße 51

20146 Hamburg
Germany
+49 40 42838-9640
+49 40 42838-9650 (fax)
EDeR.HUL@uni-hamburg.de
hul.uni-hamburg.de

In collaboration with

Hamburg University Press
Verlag der Staats- und Universitätsbibliothek Hamburg – Landesbetrieb
Von-Melle-Park 3
20146 Hamburg
Germany
+49 40 42838 7146
info.hup@sub.uni-hamburg.de
hup.sub.uni-hamburg.de