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Exploring Student Representations of Biodiversity in Science Education in Morocco: A Didactic Perspective

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Abstract: In teaching, students' representations could constitute an obstacle to the construction of scientific knowledge and are often considered stable cognitive structures whose organization is sought to be inferred through questionnaires and interviews. This study aims at identifying and analyzing high school students' representations related to the concept of biodiversity. To meet this objective, a semi-structured interview and a questionnaire were used to collect data. 202 Moroccan students participated in this survey (46.5% from rural areas and 53.5% from urban areas of the "Direction Provinciale" of education of Guelmim city in Morocco). The results of the interview indicated that only 1.82% of the students gave a definition that consists of the three biodiversity dimensions, namely the species, the ecosystems, and the genetic diversity. The questionnaire results revealed a low to medium correlation between their representations and their acquired knowledge related to the concept of biodiversity dealt with in Moroccan school programs (from the discipline of "scientific activity" in the primary cycle and that of "life and earth sciences" in the secondary cycle). The results further indicated a low presence of supervised activities related to biodiversity within the school and therefore a low degree of influence on the students' representations. It was concluded that there was no effective transmission or adequate assimilation of the concept of biodiversity among the students surveyed.

Keywords: *Biodiversity, school program, secondary school, students' representation.*

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Introduction

Biodiversity is a very complex concept (Barbault, 2011) used during the preparation of the Convention on Biological Diversity in 1992 (United Nations, 1992). The term "biodiversity" has become one of the most commonly used terms in debates about the protection of the living world; it can be the subject of scientific and social controversies, especially when it comes to its scholarly use (Barroca-Paccard, 2022). Several approaches to biodiversity can be identified, like the one that considers biodiversity as a specific ecosystem and genetic diversity (Wilson, 2000) or the one that presents biodiversity as a component of the sustainable development of natural diversity (Lange, 2011a). Hence, the study of biodiversity helps to better understand the environmental pressures that influence biodiversity and, therefore, condition its evolution (Maris, 2018; Raffin, 2005). In terms of schooling, the concept of biodiversity is delivered in the Moroccan school program by addressing its different dimensions in a graduated and progressive form, from primary to high school (Id Babou et al., 2020).

Some research provides us with essential insights to address the question of students' representations of biodiversity. They addressed the way younger generations perceive and interact with the natural world around them from different angles, providing valuable insight into the factors that influence the way students understand biodiversity. For example, a study of White et al. (2018) highlights the crucial importance of actively involving children in local biodiversity observation and environmental action to foster their understanding and engagement. Furthermore, in the current context of unprecedented decline in biodiversity, a recent study focused on biodiversity education in Latin America emphasizes the crucial importance of understanding and targeting socio-ecological complexities, thereby

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reinforcing the need for social transformation to preserve our mutual and interconnected bond with biological diversity, with significant implications for environmental education (Bermudez et al., 2022).

However, it is important to study students' representations of biodiversity because they allow us to explore what young people conceive when we lecture them about biodiversity (Maris, 2010). Through this, teachers can better understand the representations of students that hinder the construction of new scientific knowledge and help them learn more effectively (Voisin, 2017). In addition, the study of students' representations provides teachers with resources to facilitate their teaching, create meaningful projects with students (Ha et al., 2023; Kaifa et al., 2023; Smith et al., 2022), and understand the global implications of learning about biodiversity (Maris, 2018).

Representation primarily involves student activity, which depends not only on the student's cognitive associations in memory but also on specific barriers in each conceptual domain, on the students' understanding of the situation, and on interindividual interactions (Orange & Ravachol, 2013). Accordingly, we point out the importance of the didactic transposition of the concept of biodiversity. The teacher should pay attention to students' representations to be able to guide them toward a "reconceptualization" (Astolfi et al., 2008) of the scientific knowledge related to the three biodiversity dimensions. We also stress that students' "obstacles" often reflect their lack of in-depth analysis (Astolfi, 1990). For this reason, we emphasize the importance of studying the biodiversity representations of the students of the second-year high school (baccalaureate) in Morocco, the "Direction Provinciale" of education in Guelmim city. The students have studied the concept of biodiversity in the program of the discipline of "scientific activity" in primary school (primary cycle) and the discipline of "sciences of life and earth" in high school (secondary cycle). This study aims to provide answers to the following questions:

- What are students' representations of the concept of biodiversity?
- Is there a relationship between students' representations and the conception of biodiversity in school programs?
- How does the knowledge acquired related to the concept of biodiversity influence the students' representations?

Literature Review

Science didactics has long been concerned with the fundamental role of mental representations in the learning process. Jean Migne was the pioneer of the introduction of the concept of "representation" at the didactic level in 1969 in the journal "Education Permanente" (Orange & Ravachol, 2013). He has used this term to address scientific learning issues in teaching situations (Astolfi et al., 2008). Since then, research in this area has shown that students' representations are a central part of their understanding of scientific concepts. Students' representations are not isolated entities but are rooted in fields such as developmental psychology, epistemology, social psychology, and psychoanalysis (Astolfi et al., 2008; Gaston Bachelard, 1938; Kerlan, 1985; Moscovici, 1961). Representations are not simply intellectual acts but also cognitive organizations in memory, influenced by specific obstacles related to the understanding of concepts and interindividual interactions (Astolfi et al., 2008). Students use their prior knowledge to interpret new learning situations, and their pre-existing conceptions can sometimes conflict with established scientific knowledge (Clément, 2014).

Students' representations, as discussed in the scientific didactic literature, play a central role in how they perceive complex scientific concepts such as biodiversity. Existing literature acknowledges that biodiversity is a multifaceted and difficult scientific topic. Most authors recognize three organizational levels of living beings: genetic, specific, and ecological, based on the work of naturalists (Girault & Alpe, 2011; Ramade, 1994). However, Francesco di Castri has expanded this narrow definition by stating that diversity encompasses all levels of organization of living beings, including the molecular, individual, population, and community levels (Arnould, 2006). Biodiversity is governed by an entire system of interaction networks between species and ecosystems (United Nations, 1992). It also refers to ecological services and the protection of the natural balance, to man as an actor in its dynamics, and to the sustainable development of human societies (Barbault, 2011). Biodiversity is studied at multiple dimensions and the interactions between them, but some scientists tend to focus on three dimensions: ecosystem diversity, species diversity, and genetic diversity (Wilson, 2000). These three interconnected biodiversity dimensions are then not separate but embedded in each other. Additionally, Tilman adds "functional diversity". It focuses on the interactions within and between these three dimentions (Tilman, 2001). The link between biodiversity and species evolution has also been the subject of much research (Barroca-Paccard, 2022; Blandin, 2011; Girault & Alpe, 2011), exploring how species interact and evolve and how human activities such as deforestation, pollution, and climate change affect this process (Maris, 2018). So, the preservation of biodiversity is essential to support species evolution and maintain ecosystem balance and stability (Raffin, 2005). Unquestionably, biodiversity remains a crucial element of the environment; it is linked to human activities and behaviors such as agriculture, deforestation, and urbanization that have caused a considerable loss in recent decades (Raffin, 2005). Research revealed that human activities, such as agriculture, significantly impacted ecosystem fitness (Ngom, 2021). Moreover, human activities such as overfishing, pollution, and the introduction of exotic species can alter the natural balance and cause an ecological disturbance. However, there are also human behaviors that can contribute positively to the conservation of biodiversity (Maris, 2018). For example, studies (Bull et al., 2014; Tilman, 2001) showed that agroforestry improves agricultural production while also increasing biodiversity by allowing animal and plant species to coexist in the same environment. For this reason, the implementation of sustainable development education in schools may contribute to biodiversity preservation by developing positive attitudes toward nature (Lange, 2011b).

However, current research on concepts and representations of biodiversity focuses primarily on raising awareness among the general public, undergraduate students, and pre-service teachers (Arbuthnott & Devoe, 2014; Buijs et al., 2008; Dikmenli, 2010; Fiebelkorn & Menzel, 2013; Fischer & Young, 2007; Id Babou et al., 2023; Morón-Monge et al., 2020). In these studies, the adult population is the main target group. Despite its significance for biodiversity education, only a small body of research has focused on how teenagers perceive and conceptualize biodiversity. As a result, our current study has tracked how Moroccan secondary school students perceive biodiversity.

Methodology

Investigation Tools

To provide answers to our research questions, we opted for a mixed approach. To do this, we collected qualitative data using a semi-structured preparatory interview guide, previously prepared, validated, and pre-tested, in order to collect students' representations of the term biodiversity. We also collected quantitative data via a questionnaire designed and pre-tested by the authors and validated by experts. Subsequently, we performed a reliability test on the questionnaire via principal component factor analysis (SPSS V26) and analyzed the collected data using descriptive and graphical statistical tests as well as correlation tests (XSTAT 2023).

Characteristics of the Sample

Before starting the results of the various AFCP tests, it is interesting to present the characteristics of the sample that was the subject of the confirmatory study. The sample of students surveyed had a gender distribution of 59.2% males and 143.7% females, for a total of 202 respondents. They had a rural or urban educational background (Table 1) and a grade level of 2nd year Baccalaureate (Table 2).

Table 1. Socio-Demographic Characteristics of the Respondents

No	Demographic Characteristics	Students	
		Total	%
1.	**Gender**		
	Male	59	29.2
	Female	143	70.8
2.	**School environment**		
	Rural	94	46.5
	Urban	108	53.5

Table 2. Grade Level of the Sample of the Respondents

Grade Level	Students	
	Total	%
2nd year Baccalaureate in Life and Earth Sciences	56	27.7
2nd year Bac physical sciences	143	70.8
2nd year Baccalaureate in Mathematics	3	1.5

Sample and Data Collection

To conduct this qualitative study, we randomly selected six secondary schools of the provincial management of Guelmim, urban and rural areas combined, in May 2022. The exploratory study is conducted through semi-directive interviews, the saturation threshold of which is obtained from a sample of 23 students. The confirmatory study is conducted using a questionnaire. The total population was 1348 students, with a representative sample of 300 students. In this respect, we administered 300 questionnaires, of which we were able to collect only 202 responses, which represents a rate of 67%. The time chosen to distribute the questionnaire is related to the end of the school curriculum followed by the students interviewed. This is a random sample of 202 undergraduate students who were able to study all units of the program with their SVT teachers. Students interviewed first answered the questions of the semi-directive preparatory interview, which aims to identify students' representations of the concept of biodiversity. Subsequently, they completed the questionnaire, which aims to evaluate students' understanding of the concept of biodiversity, covering the three dimensions of biological diversity taught in primary and secondary school curricula. The questionnaire is validated by an SVT inspector, a trainer, a primary care teacher, and a research teacher. All the work was carried out in explanatory workshops co-sponsored with SVT teachers from the group of students participating in the survey. The questions were explained one by one. All papers are collected at the end of the workshop. Participation in the study was voluntary. Students could withdraw from the workshop without any consequences, and the anonymity of participants was guaranteed. The information collected will only be used for research purposes.

It is important to note that we have taken specific steps to ensure the validity and reliability of our questionnaire. These measures have been taken to ensure that the data collected is valid and that the responses are reliable.

Data Analysis

The data analysis for the confirmatory phase of our study was conducted using SPSS v26. We identified two tests: first, dimensionality to verify that the variable "students' knowledge of the biodiversity concept" accepts the factor analysis; and second, the internal reliability test via the Cronbach alpha to check the representativity of the items of that variable. The thematic coding of this variable is done through three subvariables (species classification, ecology, and genetics) based on the scales of measurement. The fourth subvariable (biodiversity information source) is studied through multiple-choice questions. In terms of data analysis, KMO index values above 0.7 admit that factor analysis as a main component is feasible. In terms of internal reliability, the Cronbach Alpha values are greater than 0.7, so we can conclude that all items are significant.

The statistical analysis of the collected data required statistical software that allowed us to accomplish both quantitative and qualitative analyses. To do this, we used the statistical analysis software XLSTAT 2023, which allowed us to perform descriptive and graphical statistical tests as well as data correlation tests. Furthermore, we used several attributes for the variables in the data collected on an Excel file (Table 3). We have kept these attributes in the graphs and tables of our survey results in the paragraphs below.

Table 3. Description of Attributes Used in Data Collection

Attributes	**Descriptions**
V_Div Esp	Dimension of "specific diversity" of biodiversity
V_Div Ecosys	Dimension of "ecosystem diversity" of biodiversity.
V_Div Gen	Dimension of "genetic diversity" of biodiversity.
V-Class-score	Results of the diagnostic test on the "specific diversity" of biodiversity
V-Eco-score	Results of the "Ecosystem Diversity" Biodiversity Diagnostic Test
V-Gen-score	Results of the Diagnostic Test on the "genetic diversity" of biodiversity
V_access_courses	Means of accessing information on biodiversity in high school: courses
V_access_ presentations	How to access information on biodiversity in high school: presentations
V_access_museum	Means of accessing information on biodiversity in high school: museums
V_access_cultural_week	How to access information on biodiversity in high school: Culture Week
V_access_school_clubs	How to access information on biodiversity in high school: School clubs
V_access_homework	High School Biodiversity Information Access Tool: Homework
V_access_laboratory equipment	Means of accessing the information on biodiversity at the high school: Laboratory equipment
V_access_library	Means of accessing information on biodiversity in high school: library
V_access_journal	Means of accessing information on biodiversity in high school: school newspaper
V_access_manual	Means of accessing information on biodiversity in high school: textbook
V_access_other	Means of accessing information on biodiversity in high school: Other

Results

Biodiversity in The School Program

Based on an analysis of the Moroccan school program (Id Babou et al., 2020), we have determined the extent to which the three dimensions of biodiversity (Wilson, 2000) are integrated into the Moroccan school curriculum. This analysis focused on the "scientific activity" discipline in primary schools and the "sciences of life and earth" discipline in high schools.

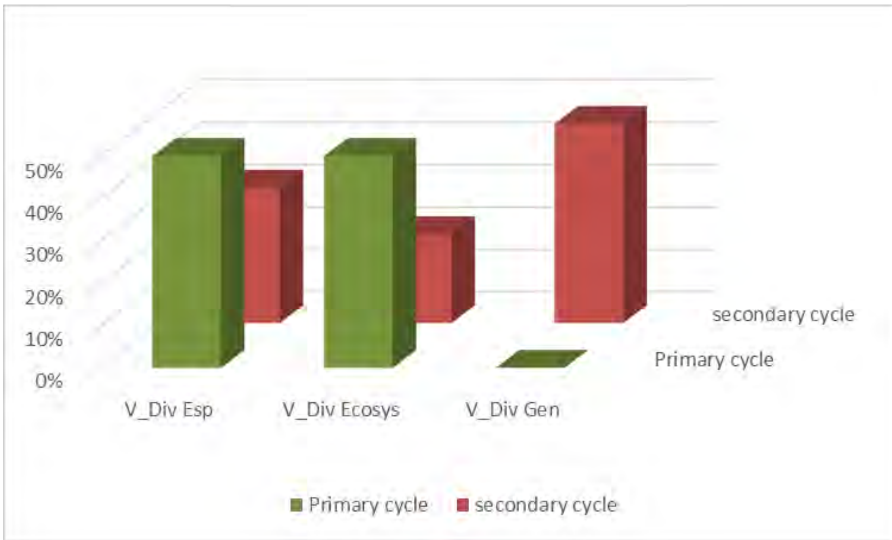
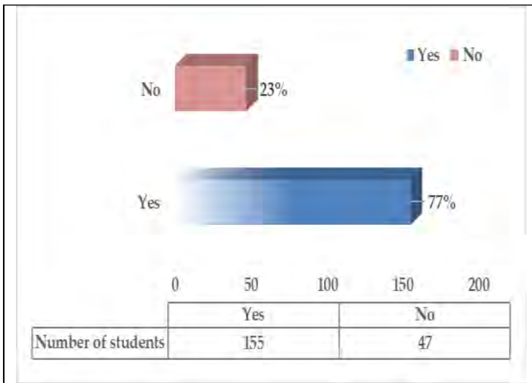


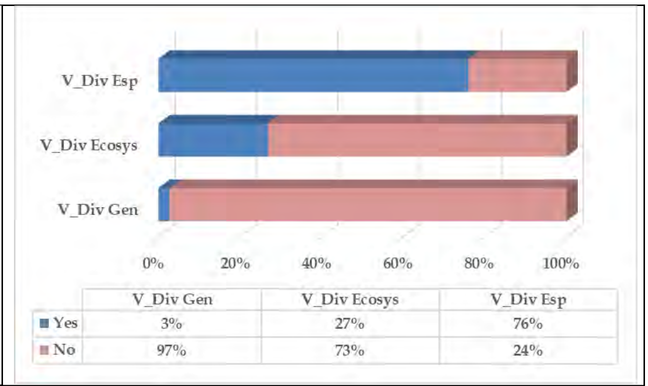
Figure 1. Degree of the Presence of the Three Dimensions of the Biodiversity Concept in the Moroccan School Program

According to Figure 1, the two dimensions of species and ecosystem diversity are the first to be delivered to students in the primary cycle with an equal degree of presence. Moreover, the dimension of genetic diversity is treated in the secondary cycle. In the following paragraphs, we present the results of the survey in which we adopted the definition of biodiversity with three levels of organization of living beings to analyze the collected data about students' representations relative to the concept of biodiversity.

Students' Representations of The Term Biodiversity

The survey carried out aims to identify students' representations of the concept of biodiversity. For this purpose, we rely on the definition of Wilson (2000) regarding biodiversity and its three dimensions of diversity as variables for analyzing the students' responses. The results of the answers to the two questions (*"Have you ever heard of the term biodiversity?" / "What does the term "biodiversity" mean to you?"*) of the preparatory semi-directive interview are presented in Figure 2 below.





(a)	(b)

Figure 2. Results of Students' Responses to the Questions a and b

According to graphs (a) and (b) in Figure 2, 77% of the students stated that they had already heard the term "biodiversity". In the meantime, the majority of them (76%) defined the concept of biodiversity as a diversity of species. However, 27% mentioned ecosystem diversity in their definition, while only 3% cited genetic diversity.

By applying a qualitative analysis using a thematic coding approach to students' responses, we identified six major themes that reveal how they perceive and define biodiversity, going beyond simple isolated quotes:

- Perception of biodiversity: Some students define biodiversity as the diversity of species, especially animals and plants. Others rarely consider other forms of life, such as bacteria, fungi, or viruses. According to one student, "biodiversity is the diversity of life on earth, including plants and animals."
- Scope of biodiversity: Some students believe that biodiversity is only about the diversity of ecosystems, especially wilderness areas. They recognize that biodiversity can also exist in cities, gardens, or farms, and that humans are one of the components of nature that interact with it. A student explains, "Biodiversity is the living

beings of our planet, and it covers several natural environments and several forms of life and their interactions."

- Dimensions of Biodiversity Organization: Some students view biodiversity as specific and ecosystem diversity as an interaction. They do not mention genetic diversity as one of the three levels of organization in the definition of biodiversity. The majority of participants spoke of the links that may exist between species and their living environments, while a minority spoke of the links between living environments, their components, and humans. One surveyed student says, "It is the diversity of species and genes within each species, as well as the organization and distribution of ecosystems."
- Quantitative approach to diversity: Students often think of diversity in terms of quantity. They use phrases such as "there are many" to emphasize the number of elements or species in a given ecosystem. One student points out, "There are many living species on earth."
- Variability within biodiversity: Students use terms such as "diversity of", "different types of" and "variety of" to express variability within biodiversity. These terms emphasize the idea that biodiversity contains different species and elements that vary from ecosystem to ecosystem.
- Biodiversity as a unit: Students use phrases such as "is the multiplicity of", "refers to the set of" and "refers to the variability of" to describe biodiversity as a unit. These terms emphasize the idea that, despite species diversity and variability, biodiversity is a coherent and interconnected entity. One student states "It is the sum total of all living things on earth.".

Combinations of Analysis of the Students' Representations

Analysis of the students' responses to the question, *"What does the term 'biodiversity' mean to you?* allowed us to identify the different combinations of responses classified in Table 2. These combinations (Table 4) allow us to determine the percentage of students who mentioned one, two, or three biodiversity dimensions in their responses (Figure 3):

Table 4. Analysis of Combinations of Collected Responses from the Participants

Combination's	V_Div Esp	V_Div Ecosys	V_Div Gen
	Yes	Yes	Yes
	Yes	Yes	No
	Yes	No	Yes
	Yes	No	No
	No	No	No

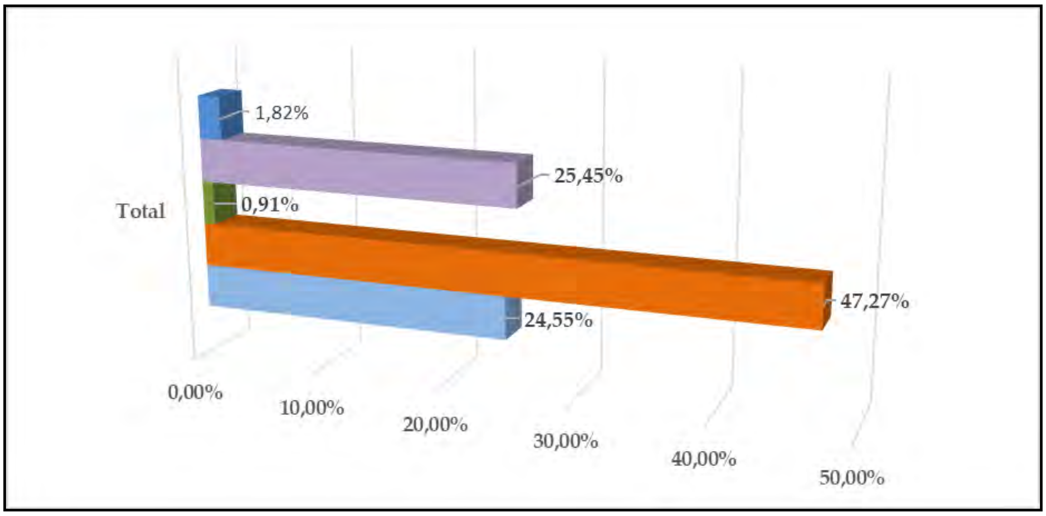


Figure 3. Combinations From the Responses of Students' Biodiversity Representations

Figure 3 shows that 47.27% of the participants stated that biodiversity is limited to species diversity, while 25.45% indicated both species and ecosystem diversity when discussing biodiversity. Meanwhile, only 1.82% of the participants mentioned all three biodiversity dimensions. This motivated us to assess students' knowledge of the three dimensions of biodiversity, with particular emphasis on the genetic dimension, which constitutes 50% of the school curriculum (Figure 1).

Results of the Questionnaire on the Biodiversity Concept

After presenting some descriptive statistics of our sample, we specify that the variable object of the analysis, “students' knowledge of the biodiversity concept” is evaluated through four subvariables: Three subvariables (species classification, ecology, and genetics) are tested by items on a scale of 1 to 5, and the "sources of information on the concept of biodiversity" subvariable is dealt with in a descriptive way (textual). The following tables show the quality of representation of items in each subvariable as well as the reliability of items for the different subvariables.

- *Dimensionality of "Classification of Species"*

Table 5. KMO Index and Bartlet's Test "Classification of Species"

KMO Index and Bartlett Test		
Kaiser-Meyer-Olkin Index for sampling quality measurement.		.718
Bartlett Sphericity Test	Chi-square approx.	513.889
	DDL	10
	Significance	.000

Table 6. AFCP Results for the "Classification of Species"

	Representational Qualities			
	Raw		**Standardized**	
	Initials	**Extraction**	**Initials**	**Extraction**
ACQEL1	1.279	.872	1.000	.682
ACQEL2	1.414	1.227	1.000	.868
ACQEL3	1.600	1.311	1.000	.819
ACQEL4	2.006	1.685	1.000	.840
ACQEL5	1.917	1.684	1.000	.878

Explained Total Variance					
Component	**Initial eigenvalues**			**Sums extracted from the load square**	
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**
1	4.898	59.606	59.606	4.898	59.606
2	1.881	22.888	82.494	1.881	22.888
3	.671	8.169	90.662		
4	.493	5.998	96.660		
5	.274	3.340	100.000		

When examining the data in Table 5, it is evident that the KMO index is 0.718, indicating a significant correlation among the items. This KMO value meets the recommended standard, which suggests that it should be above 0.5. Additionally, the variance explained reaches 59.606% (Table 6).

- *Internal Reliability of "Classification of Species"*

Table 7. Internal Reliability Test "Classification of Species"

Cronbach's Alpha	**Number of Items**
.824	5

Internal reliability for the constructs in each item is assessed using Cronbach's alpha test, which should exceed 0.7 for reliability. In our case, as shown in Table 7, the Cronbach's alpha test yielded a total value of 0.824 for the questionnaire. This result indicates that our questionnaire meets the required level for internal reliability, confirming that the various constructs within the variables are retained.

- *Dimensionality of "Ecology"*

Table 8. KMO Index and Bartlet's Test "Ecology"

KMO Index and Bartlett Test		
Kaiser-Meyer-Olkin Index for sampling quality measurement.		.809
Bartlett Sphericity Test	Chi-square approx.	586.227
	ddl	10
	Significance	.000

Table 9. AFCP Results for the "Ecology "

	Representational Qualities			
	Raw		Standardized	
	Initials	**Extraction**	**Initials**	**Extraction**
ACQEL1	1.443	.820	1.000	.569
ACQEL2	1.636	1.114	1.000	.681
ACQEL3	1.408	1.082	1.000	.769
ACQEL4	1.423	1.059	1.000	.744
ACQEL5	1.290	.799	1.000	.619

Explained Total Variance					
Component	**Initial eigenvalues**			**Sums extracted from the load square**	
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**
1	4.875	67.702	67.702	4.875	67.702
2	1.119	15.537	83.239		
3	.536	7.446	90.684		
4	.395	5.489	96.173		
5	.276	3.827	100.000		

Reviewing the data presented in Table 8, it becomes evident that the KMO index is 0.809, indicating a significant correlation among the items. This value aligns with the KMO index standards, which typically require a value greater than 0.5. Furthermore, there is a variance value of 67.702%, as indicated in Table 9.

- *Internal Reliability of "Ecology"*

Table 10. Internal Reliability Test "Ecology"

Cronbach's Alpha	Number of Items
.879	5

The internal reliability of the constructs for each item is assessed using the Cronbach's alpha test, which should ideally exceed 0.7. In our study (as shown in Table 10), the Cronbach's alpha reliability test yielded an overall value of 0.879, indicating that our questionnaire meets the required standards. Consequently, we can confidently assert that the internal reliability has been confirmed, and the various constructs of the variables are retained.

- *Dimensionality of "Genetic"*

Table 11. KMO Index and Bartlet's Test "Genetic"

KMO Index and Bartlett Test		
Kaiser-Meyer-Olkin Index for sampling quality measurement.		.774
Bartlett Sphericity Test	Chi-square approx.	382.491
	ddl	10
	Significance	.000

Table 12. AFCP Results for the "Genetic"

	Representational Qualities			
	Raw		Standardized	
	Initials	**Extraction**	**Initials**	**Extraction**
ACQES1	1.511	.824	1.000	.545
ACQES2	1.422	.858	1.000	.604
ACQES3	1.700	1.294	1.000	.761
ACQES4	1.350	.597	1.000	.442
ACQES5	1.478	.808	1.000	.547

Table 12. Continued

Component	Explained Total Variance				
	Initial eigenvalues			Sums extracted from the load square	
	Total	% of Variance	Cumulative %	Total	% of Variance
1	4.381	58.715	58.715	4.381	58.715
2	1.410	18.895	77.610		
3	.587	7.868	85.477		
4	.570	7.642	93.120		
5	.513	6.880	100.000		

Reading the data displayed in the Table 11, we see that the KMO index is .774, justifying an interesting correlation between the items. This value respects the standards of the KMO index, which must be more than 0.5. A variance also has a value of 58.715% (Table 12).

- *Internal Reliability of "Genetic"*

Table 13. Internal Reliability Test "Genetic"

Cronbach's Alpha	Number of Items
.818	5

The internal reliability of the constructs for each item is verified by Cronbach's alpha test, which must exceed 0.7. In our case (Table 13), the Cronbach's alpha reliability test statistical result of the questionnaire gave a total value of .818. This puts our questionnaire at the right level. This makes it possible to say that the internal reliability is checked and that the different constructs of the variables are retained.

- *Degree of Assimilation of the Biodiversity Concept Among Surveyed Students*

The questionnaire we developed to assess students' understanding of the three dimensions of the biodiversity concept contains questions with a scoring system ranging from 0 to 5 points for each dimension. The results are presented in Figure 4, which illustrates the degree of assimilation of the biodiversity concept among the surveyed students.

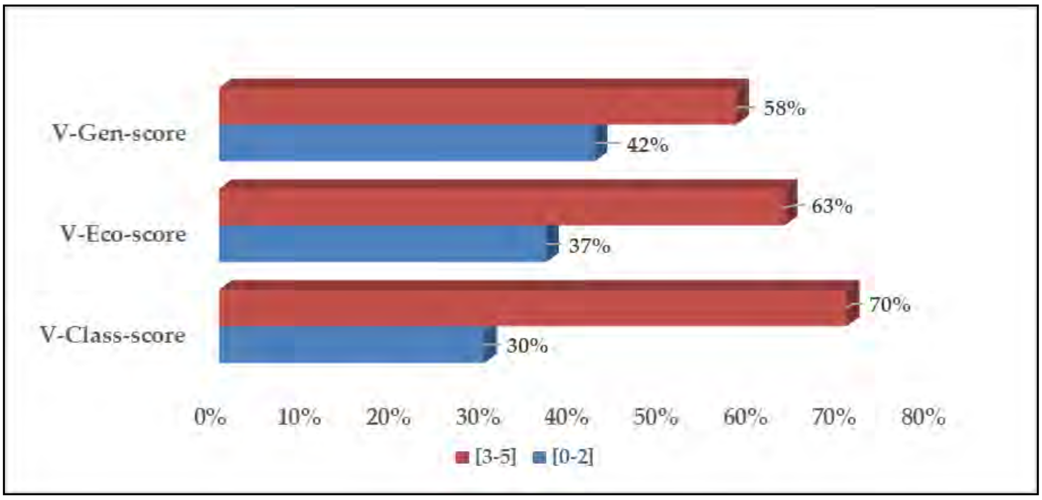


Figure 4. Degree of Assimilation of the Biodiversity Concept Among Surveyed Students

[0-2]: score between 0 and 2 points on 5 points; [3-5]: score between 3 and 5 points out of 5 points.

Our findings reveal that the participants have acquired a satisfactory level of knowledge about specific, ecosystem, and genetic diversity, as depicted in Figure 4. The majority of responses indicate a strong assimilation of knowledge related to the dimensions of biodiversity, with over 60% of participants scoring above average. These results, as shown in Figures 3 and 4, prompt us to conduct a correlation study, the findings of which we will discuss in the following paragraph.

Correlations

To establish the independent relationship between the variables in the diagnostic test and the participants' representations of the biodiversity concept, we conducted a correlation test using the statistical software EXSTAT 2023. The results of this test are presented in the Table 14 below:

Table 14. Correlation Table of Variables Related to Students' Representations and the Diagnostic Test

Variables	V-Class-score	V-Eco-score	V-Gen-score	V_Div Esp	V_Div Ecosys	V_Div Gen
V-Class-score	1*	.085	.297*	-.020	.006	-.043
V-Eco-score	.085	1*	.377*	.043	.159*	-.004
V-Gen-score	.297*	.377*	1*	-.099	-.141*	-.075
V_Div Esp	-.020	.043	-.099	1*	.485*	.093
V_Div Ecosys	.006	.159*	-.141*	.485*	1*	.140*
V_Div Gen	-.043	-.004	-.075	.093	.140*	1*

Values with "" are different from 0 at significance level alpha=*.05

We observed a weak correlation of -0.141 between students' representations of ecosystem variability and their knowledge score on genetic diversity. This correlation suggests that there is a negative trend between students' representations of ecosystem diversity and their knowledge of genetic variability. In other words, students with representations that are more focused on ecosystem diversity tend to have a less developed knowledge of genetic variability. This observation is essential for the pedagogy and perception of biodiversity, highlighting the need to integrate these two components of biodiversity in a more coherent way in education. A weak correlation of 0.159 was observed between students' representations of the dimension of ecosystem diversity and their knowledge of ecosystem diversity. It is pertinent to note that, although 63% of students scored well on the diagnostic test on their knowledge of ecosystem diversity, only 27.27% of them mentioned ecosystem diversity in their biodiversity-related representations. This correlation indicates a mismatch between students' knowledge of ecosystem diversity and how they represent it, suggesting a need for pedagogical reflection. A weak correlation of 0.140 is also observed between the variables related to students' representations of the dimension of ecosystem and genetic diversity. This result is in agreement with the results presented in Figure 3, where only 1.82% of students correlated these two variables in their representations. This suggests a relative independence between these two aspects of biodiversity in the minds of students. It should also be noted that there is a medium correlation between the variable relating to students' representations of the dimension of species diversity and that relating to students' representations of the level of ecosystems (0.485). This suggests that students tend to link these two aspects of biodiversity more closely in their representations. This correlation analysis highlights a number of important trends, including the fact that students appear to have a more robust knowledge of genetic diversity and that their representations of biodiversity do not always reflect this knowledge.

Means of Acquiring Biodiversity Information from Participants

During the survey, participants were questioned about their sources of information regarding biodiversity. The results are outlined in Table 15, showcasing the varying degrees of students' participation in biodiversity-related events across different environments, including school, friendly environments, family, and associations.

Table 15. Degrees of Students' Participation in Biodiversity-Related Events in Different Environments

Grade Level	Students
	%
School	30.7
Friendly environment	25.2
Family	53.5
Association	18.8

- School: School seems to be an important space for students' participation in biodiversity-related activities. About 30.7% of students participated in such activities in school. This suggests that school programs and educational activities have an impact on students' engagement with biodiversity;
- Friendly environment: One-quarter of the students have participated in biodiversity-related activities in a friendly environment, which showed that social interactions and group activities among friends could encourage students to become more interested in biodiversity and take part in biodiversity-related events;
- Family: The family appears to be the most influential context for participants' involvement in biodiversity-related activities, with 53.5%. This percentage indicates that the environmental education and values transmitted within the family have significantly impacted students' engagement with biodiversity. The family has a key role in raising awareness and interest in environmental and biodiversity issues among students;
- Associations and clubs: Associations and clubs appeared to be a less common field for students' participation in biodiversity-related events with only 18.8%. However, associations can provide more specialized and targeted participation opportunities for interested students in specific biodiversity topics.

Biodiversity-Related Activities in Schools

In order to gain a better understanding of how students acquire information about biodiversity and their level of participation in biodiversity-related activities at school, we collected responses to questions pertaining to both in-class and out-of-class activities. The data extracted from these responses is presented below (Figure 5):

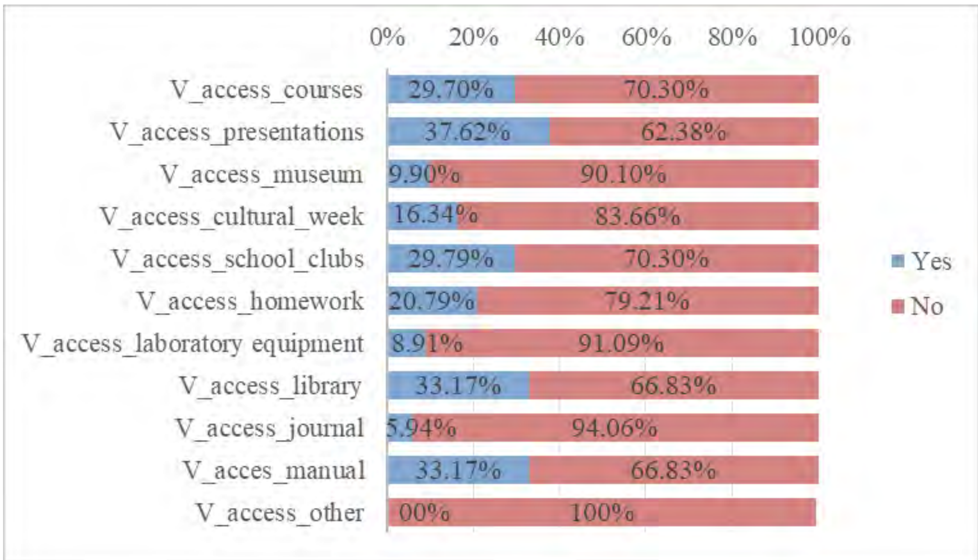


Figure 5. Degrees of Participants' Access to Biodiversity-Related Activities at School

Based on the data presented in Figure 5, approximately 30% of the participants have obtained information about biodiversity via:

- Classroom activities via presentations, textbooks, in-class lectures, and homework assignments;
- Activities outside the classroom or related to school life through the use of the school library, school club activities such as exhibitions, and national and international celebration days.

On the other hand, between 15% and 20% of the participants have accessed biodiversity information through other classroom and school life activities, homework, and annual events organized in the schools. Other classroom and school life activities that students have benefited from to access biodiversity information at less than 10% are the school museum, the laboratory, and the wall newspaper.

Discussion

Representations of the Students Surveyed Regarding the Biodiversity Concept

According to our survey, the meaning attributed to the term "biodiversity" seems to vary from one learner to another (Figure 3). We limited our discussion to the analysis of students' representations based on the three dimensions of the of biodiversity concept. Interestingly, some of the students' representations refer to the three dimensions of the concept of biodiversity, which is in line with the results of other studies (Ngom, 2021; White et al., 2018).

However, it should be pointed out that these findings differ from the German study conducted in 2019, where high school students had a fragmented understanding of the scientific concept of biodiversity, mostly equivalent to species diversity (Schneiderhan-Opel & Bogner, 2019). These variations could be influenced by cultural and contextual factors, such as differences in curricula and pedagogical approaches between countries. Similarly, a study conducted in 2021 with Spanish primary school students aimed to assess their understanding of the natural, geological, and anthropogenic components of their environment (Morón-Monge et al., 2021). The results revealed that children's understanding of biodiversity was limited and that their perceptions of the environment were often influenced by factors such as where they lived and their personal experiences. These cultural and contextual factors play a major role in shaping students' representations of biodiversity. It is also relevant to note that the correlation between students' representations and their academic knowledge of biodiversity was weak in our study (Table 14). This weak correlation could be due to the fact that representations are closely related to students' mental organization, which can be influenced by cultural and contextual factors. In this way, students from different parts of the world can approach biodiversity in a distinct way because of their experiences and cultural environment.

These variations underscore the need to adapt curricula and teaching methods to take into account cultural and contextual differences that influence students' representations of biodiversity. One size does not fit all, and teachers need to be sensitive to these factors to promote a more comprehensive understanding of the concept of biodiversity.

Relationship Between Students' Representations and the Conception of Biodiversity in School Programs

The weak correlation we observed between students' representations and their academic knowledge of biodiversity (Table 14) highlights the need for more integrated biodiversity education to help students better understand and adequately represent the different aspects of biodiversity. This suggests that cultural and contextual factors may also play a major role in how students integrate these concepts into their understanding. This finding is consistent with the results of other studies conducted around the world. For example, a study conducted in Australia in 2020 showed significant variations in how Indigenous and non-Indigenous students understand biodiversity, highlighting the impact of cultural contexts on individual perceptions (Smith et al., 2022).

It is crucial to take these cultural and contextual differences into account when designing educational programs. By acknowledging the diversity of perspectives and experiences, we can create more inclusive and effective learning environments. Students need to be able to sort, eliminate, readjust, organize, reorganize, and coordinate data that can enable them to properly assimilate biodiversity knowledge (Astolfi et al., 2008). Students therefore need new didactic strategies to change their representations (Kilinc et al., 2013). Teachers then have a critical role to play in adapting their pedagogical methods to reflect these cultural and contextual realities, thus fostering a more holistic understanding of biodiversity.

The Means of Acquiring Information at the School Related to Biodiversity Concept

Regarding ways to acquire information about biodiversity at school, our results (Table 15) reveal that students' participation in biodiversity-related events is influenced by their family, school, and social environment. This finding is consistent with previous research conducted in a variety of cultural contexts. For example, a study conducted in Central Europe in 2018 showed that students were more likely to get involved in biodiversity awareness activities when they were supported by their families and school (Kelemen-Finan et al., 2018). These findings underscore the importance of mobilizing the entire education community, including families, schools, and groups of friends, to promote biodiversity awareness. Educational programs and awareness-raising initiatives can be strengthened by leveraging these social networks and promoting student participation in biodiversity-related activities.

In our own study, we identified similar challenges related to the availability of educational resources and access to biodiversity-related activities. However, we have also observed that biodiversity associations and clubs have been able to provide more targeted resources and engagement opportunities for a limited number of students (Morón-Monge et al., 2021). These organizations can play a crucial role in bridging some of the gaps and providing more individualized learning experiences. By adapting our educational approaches to this diversity, we can help shape a generation that is more informed and committed to preserving biodiversity on a global scale.

Conclusion

Representations are seen as internal cognitive strategies that students rely on and on which differentiated pedagogy must rely to facilitate students' acquisition of positive thinking and behavior. Indeed, it is necessary to help students understand biodiversity by rationalizing their initial representations. However, the definition of the concept of biodiversity given by each of the participants in this study shows that their representations are not influenced by the acquisitions of the school curriculum. It will therefore be necessary to guide students to reconceptualize their knowledge of biodiversity and mobilize it. Comparing our findings to previous studies conducted around the world, we found that students' representations and engagement with biodiversity vary depending on their cultural and contextual environment. These differences highlight the need to adapt curricula and pedagogical approaches to reflect this diversity. However, barriers to participation remain, including socio-economic and cultural factors. Future studies should address these barriers and explore strategies to overcome them. By fostering a holistic approach to biodiversity education, integrating classroom knowledge with hands-on experiences, and encouraging active participation, we can inspire a new generation of individuals committed to biodiversity conservation globally. Ultimately, biodiversity education is not just about imparting knowledge, it also involves creating a deep connection between students and nature, taking into account their culture and context. This approach will help address today's environmental challenges and ensure a more sustainable future for our planet.

Recommendations

The results of this study highlight the critical importance of improving biodiversity education (Van Weelie & Wals, 2002) in schools. To this end, we make a number of recommendations. First of all, it is essential to encourage critical thinking in students by encouraging them to ask questions and analyze current biodiversity issues (Clément, 2014). It is also crucial to increase supervised biodiversity-related activities in school curricula, providing students with concrete opportunities to explore and apply their knowledge (Chodkowski et al., 2022). Increased involvement of the educational community and families is needed to increase awareness of biodiversity. We also encourage the development of educational resources adapted to Moroccan reality and the promotion of research in biodiversity education to contribute to a better understanding of this complex concept among students and to the achievement of the United Nations Sustainable Development Goals (United Nations, n.d.). In addition, we advocate for the implementation of in-service training for teachers focused on effective pedagogical approaches to address biodiversity in the classroom (Yli-Panula et al., 2018). Finally, to further substantiate these recommendations to improve biodiversity education discussed above, it is essential to conduct additional studies involving teachers. These studies will examine whether students' representations are related to teachers' own conceptions of the concept of biodiversity and their interests and values related to biodiversity education. This research will provide valuable insights into aligning teachers' and students' perspectives on biodiversity education.

Limitations

Despite working with an exhaustive sample from the Guelmim Province, it is necessary to confirm or refute the obtained results through further research extending to other regions and countries. The limitations of this study therefore include the limited generalizability of the findings to broader contexts. To better understand the extent and scope of the conclusions, it would be beneficial to expand the investigations to more diverse populations and varied environments.

Ethics Statements

Once we received approval for our authorization request from the Regional Academy of Education in the Guelmim Oued Noun region, we were granted access to the high schools. This, in turn, facilitated the efficient distribution of questionnaires and the conducting of interviews as integral components of our research.

Authorship Contribution Statement

Conceptualization and methodology, A.I.B., and A.A.; formal analysis, A.I.B., A.A., N. B., and S. S.; investigation, A.I.B., A.A., and M.Z.; writing—original draft preparation, A.I.B. writing, review and editing, A.A., and S.S.; supervision, A.A. and S.S.; project administration, A.A. and M.Z. All authors have read and agreed to the published version of the manuscript.

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