REVIEWED ARTICLE

Biodiversity: What do students know about it?

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Introduction

Through the graphic images presented via the media, we are exposed to a variety of environmental concepts in our daily lives. Major ideas such as global warming, ecological sustainability, greenhouse emissions and biodiversity are regularly discussed in the media. Both at home and at school, students start to learn about these ideas and form opinions on their importance. Working with staff from a local Environmental Education Centre, final year science education students from Charles Sturt University were invited to explore the level of school student understanding about one of these major ideas: biodiversity. Establishing the current level of understanding of a scientific concept is an important strategy for teachers who are concerned with providing quality teaching and learning experiences for their students. The recently released *Quality Teaching in NSW Public Schools* document from the NSWDET (2003) identifies the need for students to actively construct deep knowledge and understanding of concepts through the provision of quality learning environments where learning is meaningful and based on a real world context.

This study sought to identify the current level of understanding about biodiversity in a group of students as part of a critical review of the range of environment focussed activities designed by teaching staff at the Environmental Education Centre. Before reporting on what the students know about biodiversity, a précis of what scientists currently consider as essential attributes of the concept of biodiversity, is presented. Additionally, the incidence of reference to biodiversity found in the New South Wales Science and Technology Stages 1-3, Science Years 7-10 and Stage 6 Biology, Earth and Environmental Science and Senior Science syllabuses is identified.

A scientific understanding of biodiversity

The term 'biodiversity' came to prominence after the National Forum on Biodiversity held in Washington, D.C. on September 21-24 1986 (Wilson, 1997). Understanding and managing biodiversity has since become one of the most critical issues facing the global science and political communities.

Biodiversity is simply an abbreviation for 'Biological diversity' as suggested by Welsh (2004) and at a basic level can be thought of as the variety of life on earth. The diversity of life was traditionally considered in terms of the number of species in a given area. However, the increasing depth of scientific knowledge on biodiversity has rendered this simplistic definition inadequate to cover the enormity of the biodiversity concept. Heywood and Baste (1995) give a more comprehensive definition as the 'variability among living organisms from all sources and the ecological complexes of which they are a part'. Within this framework biodiversity includes multiple levels of organisation and primary attributes. That is, interconnected spheres of **compositional**, **structural** and **functional** biodiversity each encompassing organisational levels such as: *ecosystem, community, species, and genetic* (Noss, 1990).

For example **functional** attributes of biodiversity can be analysed at:

- an ecosystem level that may include disturbance processes such as flooding or nutrient flows;
- a community level that might be a measure of biomass production, parasitism and predation rates;
- a species level that may include population density, abundance, and fertility and mortality rates; and,
- a genetic level that may encompass gene flows, genetic drift and inbreeding.

Biodiversity is not evenly distributed on the surface of the earth. A characteristic pattern of biodiversity is a general increase in the numbers of species with proximity to the equator. Maximum species densities of land habitats are found in tropical rainforests and in aquatic habitats in tropical and sub-tropical coral reefs (Krebs, 2001).

School level understanding of biodiversity

To gain an indication of the level of understanding at which the concept of biodiversity is taught, a popular New South Wales senior biology text was consulted. Heinemann's textbook *Biology* defined biodiversity as follows:

> 'Biodiversity is the variety of all living organisms found on earth. This variety has three components:
> 1. at the genetic level there is variation in the genes found within a species;

2. at the species level there is variety in the types of plants, animals and micro-organisms found; and.
3. at the ecosystem level there is a variety of different environments that support different species.' (Mudie and Brotherton, 2000)

Although this senior school science textbook definition does not fully encompass the scientific understanding, it none-the-less does provide a moderate understanding of biodiversity.

Biodiversity and the NSW Science Syllabuses

The concept of biodiversity is found in a number of science based syllabuses of the Office of the Board of Studies in New South Wales. However, the quantity and quality of the learning experiences varied depending on the teaching stage. These references to biodiversity are shown below.

Stage 3 – Science and Technology K-6 Syllabus

- Living things depend on other living things to survive.
- Plants and animals live in environments that supply their needs.
- Change occurs throughout the lifetime of living things.

Stage 4 – Science 7-10 Syllabus

- 4.10 a) describe some adaptations of living things to factors in their environment.
- 4.10 b) describe how producers, consumers and decomposers in Australian ecosystems are related, using food chains and food webs.
- 4.10 c) describe the role of photosynthesis and respiration in ecosystems.

Stage 5 – Science 7-10 Syllabus

- 5.10 a) distinguish between biotic and abiotic features of the local environment.
- 5.10 b) describe the importance of cycles of materials in ecosystems.
- 5.10 d) discuss strategies used to balance human activities and needs in ecosystems with conserving, protecting and maintaining the quality of the environment.

Stage 4 and 5 Science – 7-10 Syllabus: Optional content

- Discuss the Convention on Biodiversity with particular reference to Article 8 and 10.

Stage 6 – Biology Syllabus

8.2 A Local Ecosystem

- The distribution, diversity and number of plants and animals found in ecosystems are determined by biotic and abiotic factors.
- Each local aquatic or terrestrial ecosystem is unique.

Stage 6 – Senior Science Syllabus

8.3 Plants

- The maintenance of diversity in plants is important for the genetic health of the planet.

5.5 Local Environment

- The distribution, diversity and number of plants and animals found in ecosystems are determined by biotic and abiotic factors.
- Each local aquatic or terrestrial ecosystem is unique.

Stage 6 – Earth and Environmental Science Syllabus

8.3 The Local Environment

- The properties of local soils affect the local biological environment.
- Biodiversity assists in keeping the dynamic balance in the biosphere.

4.4 Water Issues

- Interacting sub-systems of the Earth that together produce a unique biome.

Methodology

For the purposes of this study, the operational definition of biodiversity incorporated the three organisational levels mentioned above as the primary mode of analysis to interpret students' responses. These three organisational levels of biodiversity were identified as: i) genetic level; ii) species level; and, iii) ecosystem level.

The method of obtaining data in this study employed the 'interview about instances' procedure suggested by Osborne and Gilbert (1979). This method is based on the idea that a particular concept held by a student can be explored by asking the person to distinguish between instances or non-instances of the scientific concept.

Interviews were conducted individually with students to investigate the student's understanding of the concept 'biodiversity'. A total of 26 students

participated with 12 students from Stage 6 (Year 11), and 14 students from Stage 3 (Years 5 and 6). The participating students attended different schools that were visiting the Environmental Education Centre.

Using the three organisational levels of biodiversity described above, a set of 13 cards was designed. The first 12 cards focussed on genetic, species and ecosystem level instances. Four cards addressed each of these three levels, showing 2 'positive' and 2 'negative' examples. Each card was presented to the student during the interview and the student was asked these two questions for each card:

Question 1: *"Is this an example of biodiversity?"*
Question 2: *"Why do you believe it is/is not?"*

The first question provided a 'Yes' or 'No' response which indicated if the student categorised the instance as an 'example' or 'non-example' of the concept. The second question elicited the student's reasoning on each card. Students' responses were recorded for later analysis.

The final thirteenth card presented a comparison between two instances of biodiversity at the ecosystem level. For this final card students were asked: 'In your opinion which image is more biodiverse, or are they the same?'

The images depicted on the 13 cards were as follows:

Genetic level cards

1. Pictures of various dog breeds. (This is a positive instance)
2. Pictures of people from various nations and cultures. (This is a positive instance)
3. A set of twin girls. (This is a negative instance).
4. A landscape of a canola field. (This is a negative instance)

Species level cards

5. Pictures of many different animals. (This is a positive instance)
6. Various coloured flowers. (This is a positive instance)
7. A large group of bats all of the same species. (This is a negative instance)
8. One lizard. (This is a negative instance)

Ecosystem level cards

9. Picture of a rainforest. (This is a positive instance)
10. Desert landscape. (This is a positive instance)
11. A moonscape image. (This is a negative instance)
12. Landscape of city buildings. (This is a negative instance)

Comparison card

13. One image presented the rainforest and the second image presented the desert.

Frequency tables representing students' responses to each card were generated as well as tables contrasting Stage 3/Stage 6 and Female/Male responses (Tables 1 – 4). A summative table of the reasons provided to support the decision by each student on whether that card was an instance or non-instance of biodiversity was also presented (Table 5). The framework for analysis of students' responses to each of the first 12 cards classified their response into one of three categories. These were:

- Generalised reason. eg. 'Different people around the world' (Card 4); 'They are all the same.' (Card 7).
- Scientific reason which used the appropriate level of organisation as part of the response. eg 'Shows different climates that the world can have.' (Card 10); 'It's all one species of plant.' (Card 4).
- Non-scientific reason. e.g. 'Nothing green or living.' (Card 10); 'Different kinds of lifestyles.' (Card 2).

Finally, the students' responses to card 13, the comparative ecosystem level images, were summarised in Table 6.

Results

Exploring initial responses

When the responses from each student were collated and analysed, a series of tables was generated that summarised the findings. Table 1 presents the overall response patterns for Question 1 to the first 12 cards. Some percentage figures in the tables have been rounded off.

From Table 1, no student was able to identify every instance correctly. Cards 5, 6 and 9 were correctly identified as instances of biodiversity by most students. Using the three levels of organisation concerning biodiversity to analyse the students' responses:

- 63% of responses correctly identified instances representing the genetic level of organisation about biodiversity (cards 1 – 4);

Table 1. Aggregated students' responses to cards 1-12

Student's Responses (n=26)			
Card	**Yes**	**No**	**Unsure**
1 (+)	18 (69%)	8 (31%)	0
2 (+)	18 (69%)	7 (27%)	1 (4%)
3 (-)	8 (31%)	17 (65%)	1 (4%)
4 (-)	14 (54%)	12 (46%)	0
5 (+)	24 (92%)	2 (8%)	0
6 (+)	22 (85%)	4 (15%)	0
7 (-)	13 (50%)	13 (50%)	0
8 (-)	14 (54%)	12 (46%)	0
9 (+)	23 (88%)	2 (8%)	1 (4%)
10(+)	14 (54%)	12 (46%)	0
11 (-)	11 (42%)	15 (58%)	0
12 (-)	10 (38%)	15 (58%)	1 (4%)

(+) this card represents an instance of the concept
(-) this card represents a non-instance of the concept

- 69% of responses correctly identified instances representing the species level of organisation about biodiversity (cards 5 – 8); and,
- 65% of responses correctly identified instances representing the ecosystem level of organisation about biodiversity (cards 9 – 12).

In Table 2 the frequency of students' responses that correctly identified all 4 cards at each level of organisation concerning biodiversity is presented.

Overall, the results show a low level of correct responses to each set of 4 instances. Stage 6 students responded more often correctly to the ecosystem level of organisation. In the next table, response patterns for Stage 3 and Stage 6 students are reported.

Table 2. Frequency of students correctly responding to all cards at each organisational level

	Stage 3 (n=14)	**Stage 6 (n=12)**	**Total**
Genetic level	4	2	6
Species level	4	2	6
Ecosystem level	1	5	6

Table 3. Stage 3 and Stage 6 students' responses

Stage Three (n=14)				Stage Six (n=12)		
Card	**Yes**	**No**	**Unsure**	**Yes**	**No**	**Unsure**
1 (+)	9 (64%)	5(36%)	0	9 (75%)	3 (25%)	0
2 (+)	10 (72%)	3 (21%)	1 (7%)	8 (67%)	4 (33%)	0
3 (-)	5 (36%)	8 (57%)	1 (7%)	3 (25%)	9 (75%)	0
4 (-)	8 (57%)	6 (43%)	0	6 (50%)	6 (50%)	0
5 (+)	14 (100%)	0 (0%)	0	10 (83%)	2 (17%)	0
6 (+)	11 (79%)	3 (21%)	0	11 (92%)	1(8%)	0
7 (-)	6 (43%)	8 (57%)	0	7 (58%)	5 (42%)	0
8 (-)	8 (64%)	5 (36%)	0	5 (42%)	7 (58%)	0
9 (+)	11 (79%)	2 (14%)	1 (7%)	12 (100%)	0 (0%)	0
10 (+)	7 (50%)	7 (50%)	0	6 (50%)	6 (50%)	0
11 (-)	9 (64%)	5 (36%)	0	2 (17%)	10 (83%)	0
12 (-)	9 (64%)	4 (29%)	1 (7%)	1 (8%)	11 (92%)	0

(+) This card represents an instance of the concept.
(-) This card represents a non-instance of the concept

Using the three levels of organisation, comparative data for Stage 3 and Stage 6 was generated:

- at the *genetic* level, 59% of Stage 3 students compared to 67% of Stage 6 students correctly identified these cards;
- at the *species* level, 68% of Stage 3 students compared to 69% of Stage 6 students correctly identified these cards; and,
- at the *ecosystem* level, 49% of Stage 3 students compared to 81% of Stage 6 students correctly identified these cards.

Key findings to emerge from these data include:
i) all Stage 3 students correctly identified card 5;
ii) all Stage 6 students correctly identified card 9.
Using a criterion of 80% correct identification, more Stage 6 students correctly identified instances than Stage 3 students. Stage 6 students were more frequently able to identify non-instances at the ecosystems level.

The final comparative analysis explored whether gender based differences were evident. These results are reported in Table 4.

Some findings from Table 4 were that all male students correctly identified card 5. Female students correctly responded more frequently to positive instances of biodiversity than male students. Overall responses patterns when analysed at the three levels of organisation were remarkably similar.

- At the *genetic* level, 68% of females vs 57% of males correctly identified these instances,
- At the *species* level, 69% of females vs 68% of males correctly identified these instances, and,
- At the *ecosystem* level, 65% of the females vs 64% of the males correctly identified these instances.

Exploring the reasons provided

The second part of the analysis of the data collected from the interviews with each of the 26 students focussed on the reasons provided by the students to each of the 12 cards to support their decision whether the card represented an instance or non-instance of biodiversity. This analysis is reported in Table 5. To undertake this analysis, the operational definition and the three levels of organisation within biodiversity described earlier in this report were the framework against which each student's response was classified.

From Table 5 a number of observations about the reasons provided to the cards at each of the three levels of organisation of

Table 4. Female vs Male responses

	Female (n=15)			Males (n=11)		
Card	**Yes**	**No**	**Unsure**	**Yes**	**No**	**Unsure**
1 (+)	11(73%)	4 (27%)	0	7 (64%)	4 (36%)	0
2 (+)	13(86%)	1 (7%)	1 (7%)	5 (45%)	6 (55%)	0
3 (-)	4 (26%)	10 (67%)	1 (7%)	4 (36%)	7 (64%)	0
4 (-)	9 (60%)	6 (40%)	0	5 (45%)	6 (55%)	0
5 (+)	13 (87%)	2 (13%)	0	11 (100%)	0 (0%)	0
6 (+)	14 (93%)	1 (7%)	0	8 (73%)	3 (27%)	0
7 (-)	9 (60%)	6 (40%)	0	4 (36%)	7 (64%)	0
8 (-)	7 (47%)	8 (53%)	0	7 (64%)	4 (36%)	0
9 (+)	14 (93%)	0 (0%)	1 (7%)	9 (82%)	2 (18%)	0
10 (+)	7 (47%)	8 (53%)	0	6 (55%)	5 (45%)	0
11 (-)	6 (40%)	9 (60%)	0	4 (36%)	7 (64%)	0
12 (-)	5 (33%)	9 (60%)	1 (7%)	5 (45%)	6 (55%)	0

(+) This card represents an instance of the concept.
(-) This card represents a non-instance of the concept

Table 5. Analysis of students' level of understanding

	All students (n=26)						Stage 3 students (n=14)						Stage 6 students (n=12)					
	General		Scientific		Non scientific		General		Scientific		Non scientific		General		Scientific		Non scientific	
Card	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1 (+)	11	42	3	12	12	46	8	57	0	0	6	43	3	25	3	25	6	50
2 (+)	14	54	1	4	11	42	7	50	0	0	7	50	7	59	1	8	4	33
3 (-)	7	27	6	23	13	50	5	36	1	7	8	57	2	16	5	42	5	42
4 (-)	12	46	3	12	11	42	7	50	1	7	6	43	5	42	2	16	5	42
Subtotal *Genetic*	44	42	13	13	47	45	27	48	2	4	27	48	17	35.5	11	23	20	41.5
5 (+)	17	65	6	23	3	12	10	72	2	14	2	14	7	58	4	33	1	8
6 (+)	14	54	5	19	7	27	9	64	1	7	4	29	5	42	4	33	3	25
7 (-)	7	27	8	31	11	42	2	14	5	36	7	50	5	42	3	25	4	33
8 (-)	2	7	8	31	16	62	2	14	2	14	10	72	0	0	6	50	6	50
Subtotal *Species*	40	38	27	26	37	36	23	41	10	18	23	41	17	35.5	17	35.5	14	29
9 (+)	12	46	3	12	11	42	4	29	2	14	8	57	8	67	1	8	3	25
10 (+)	9	35	2	7	15	58	4	29	1	7	9	64	5	42	1	8	6	50
11 (-)	12	46	1	4	13	50	5	36	0	0	9	64	7	59	1	8	4	3
12 (-)	8	31	1	4	17	65	3	21	0	0	11	79	5	42	1	8	6	50
Subtotal *Ecosystem*	41	39	7	7	56	54	16	29	3	5	37	66	25	52	4	8	19	40
Total *all levels*	125	40	47	15	140	45	66	39	15	9	87	52	59	41	32	22	53	37

biodiversity can be made. These are provided firstly for each level of organisation and secondly from a summative perspective.

Genetic level:

- Most students gave either a general or non scientific reason to support their decision about whether each of cards 1 – 4 represented an instance or non-instance of biodiversity.
- More Stage 6 students than Stage 3 students (23% vs 4%) provided a scientific reason that used genetic level reasoning to support their decision about each card representing a genetic level example of biodiversity.

Species level:

- The overall pattern of reasons provided to support the students' decision on each of cards 5 – 8 indicated that all students were distributed relatively uniformly between general, scientific and non-scientific reasons. This pattern suggested a level of uncertainty was evident.
- More Stage 6 students than Stage 3 students (35% vs 18%) were able to provide a scientifically accurate reason to support their decision about each of cards 5 – 8.

Ecosystem level:

- Overall, most students (54%) gave a non scientific reason to support their decision on each of cards 9 – 12.
- Very few students at either Stage 6 or Stage 3 (8% vs 5%) were able to provide a scientifically accurate reason at the ecosystem level to support their decisions on cards 9 – 12. However, more students at Stage 6 opted for a generalised reason to support their decision compared to Stage 3 students (52% vs 29%).

Finally, some overall observations based on the patterns of responses to all 12 cards were:

- About 3 in 8 Stage 6 students used non scientific reasons to support or justify their decision on each card; and
- About 2 in 5 Stage 3 and Stage 6 students' responses used a generalised reason to support their decision on cards 1 – 12.

Comparing biodiversity

The final card (card 13) asked students to analyse two images and decide if one or both images depicted biodiverse environments. The results are presented in Table 6 below.

Table 6. Students' responses to card 13

Responses	All students (n=26)	Stage Three (n=14)	Stage Six (n=12)
Rainforest over Desert	21	11	10
Desert over Rainforest	1	1	0
They are the same	2	2	0
No answer	2	0	2

The majority of students (81%) thought that the rainforest was more biodiverse than desert. The analysis of students' responses suggested that the reasoning algorithm of 'lots of difference, greenness, and lots of plants and animals' was frequently used to respond to this card.

Discussion and conclusion

It is encouraging to see that many students, regardless of Stage, were able to identify strong positive examples of biodiversity (e.g. cards 5 and 9). Furthermore, the majority of Stage 6 students demonstrated the ability to identify instances and non-instances of biodiversity at the ecosystem organisational level.

However, through analysing the reasons for each choice rather than the simple Yes/No response provided, teachers can identify where strengths and omissions in their students' reasoning is evident. Generalising from the analyses described above, students of either stage infrequently use specific scientific reasoning to justify their yes/no response. This result was partly expected with the young Stage 3 students but was unanticipated with the Stage 6 students. Furthermore, the results indicate that students employed a generalised set of algorithms to judge instances and non-instances of biodiversity. Their reasoning pattern often consisted of these rules or algorithms: '*if there are differences, it shows biodiversity*' especially in relation to cards 1 – 4. Indicative students' responses included: '*shows all different kinds*' (Female Stage 6); or '*they are different cultures*' (Female Stage 6); or '*people from different countries*' (Male Stage 3). The second rule or algorithm used by most students was: '*if there is lots of colour (green), or there are lots of plants and animals present, it shows biodiversity*' especially in relation to cards 5 – 12. Indicative students' responses included: '*Different colours, shapes and animals*' (Male Stage 3); or '*It's a rainforest – there are a large number of native plants*' (Male Stage 6); or '*All different types of animals and insects in different habitats*' (Female Stage 3). Additionally, students at Stage 6 employed the rule that: '*if an object (plant or animal) could live in that environment, it shows biodiversity*'. Stage 6 students' comments that supported this algorithm included: '*It shows how trees can live in the desert*' (Female Stage 6); or '*A heap of animals in one area living together, cooperating*' (Male Stage 6). These rules or algorithms, although not incorrect, indicate a surface level understanding of biodiversity.

Moreover, at the Stage 6 level, a lack of deeper understanding was evident. This finding suggests that a range of targeted strategies focussing on developing students' deeper understanding of biodiversity could be implemented. Possible strategies to enhance students' development of deep knowledge and understandings could include using pictorial images, similar to those cards used in this study. Another possible strategy is to initiate class discussion and encourage students to engage in

critical analysis and reflection on the main identifying attributes of biodiversity. Additionally teachers can focus on enhancing intellectual quality of the content being studied during the teaching sequence as a means of promoting real world, contextualised applications of biodiversity.

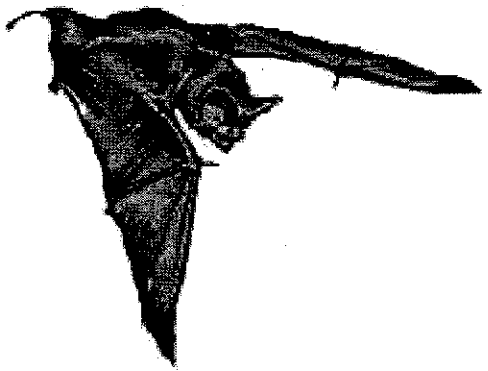
This report has affirmed the value of using the interview about instances as a teaching strategy. For the classroom teacher, this strategy can be used to identify the students' entry level knowledge and understandings. Additionally, the strategy provides some insights into the reasoning used by their students to justify their decision about instances of the concept.

Students' responses to the instances and non-instances of biodiversity presented to them in this study do not indicate that they have the detailed and sophisticated level of understanding that is implicit in the learning outcomes statements present in the Stage 6 syllabuses.

At the practical teaching level, the results of this study indicate that each teacher should take the time to start with the commonly held algorithm and expose some of the problems inherent within its application. The set of cards used in this study would provide a good initial discussion point. The teacher can then proceed to explore the three levels of organisation implicit in the concept of biodiversity in explicit ways so that the students develop the metalanguage, deep knowledge and understandings that are expected in the Stage 6 syllabuses.

Request for the cards

An electronic copy of the cards is available from Colin Boylan through emailing him at: cboylan@csu.edu.au



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