Secondary stage biological courses in KSA: "Content analysis in the light of NGSS"

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Abstract: The present study aims to reveal the reality of biological courses content of secondary school in KSA in the light of Next Generation Science Standards (NGSS). To achieve this the researcher prepare a list of standard specifications for the life sciences in high school in light of NGSS. The study also determines the availability of standard specifications in high school biology courses content in Saudi Arabia. A descriptive research approach was used in defining the next generation standards and content analysis of biological courses for high school in the light of these standards to see availability in those courses. Research sample consisted of high school biology books (first and second semester) for the academic year 2012 in Arabic Edition. The results showed that there was a deficiency in the inclusion of Next Generation Science Standards in the field of life sciences with secondary school courses. The study results have suggested that development of courses should address this deficiency through the content of the proposed biological courses of the secondary level. A proposed framework for developing biological courses content in secondary stage in Saudi Arabia according to NGSS where suggested.
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Introduction:

Biological science is considered as a broad and overlapping field and it is now being taught extensively as compared to the past. Students in high school develop understanding of key concepts that help them make sense of life science. The ideas are building upon students' science understanding of disciplinary core ideas, science and engineering practices, and crosscutting concepts from earlier grades (National Research Council, 2012). The school curriculum is more in touch with developments in biological science and there is increase in the public salience of biology (Jenkins, 2016). Vision and change in education related to biology education has outlined five core concepts that include; evolution, structure and function, information flow, exchange, and storage, pathways and transformations of energy and matter, systems (Brownell, Freeman, Wenderoth, & Crowe 2014). The need of developing high school biology courses in the light of science education standards (NSES) has been confirmed by (Binns & Bell, 2015). Fakeehe (2009) conducted a study to evaluate biology content in the light of suggested standards indicating low content included as per standards.

Next generation science standards (NGSS) aimed at teaching certain process that covers many facts to focus on core ideas and comprehensive concepts. These ideas and concepts can be used to explain phenomena in life and solve problems by engaging in scientific and engineering practices. This integration of ideas, concepts, and practices is the core criteria of NGSS that are termed as three dimensional (3Ds) (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014). It is believed that the criteria followed by NGSS is considered complementary to the previous standards, and was built on a strong foundation of research findings and previous studies. NGSS provides a conceptual framework from kindergarten to the end of secondary school (K-12). It considered as an extension to the science education standards (NSES) (NGSS, 2013). Application of NGSS presented an unprecedented opportunity to change science education for all students. The concepts of previous standards were separated from the processes; however, NGSS was distinguished from its predecessor as it expects the students to develop their understanding of science and scientific practices to develop new knowledge (Penuel, Harris, De Barger, 2015).

The fundamental changes in science curricula tends to improve and develop strategies to cope up with the technological and scientific advancements encountered across the globe. In the light of new standards, the potential challenges for students does not in what they should know in the field of biology. Rather the biggest challenge lies in what should be able to be observed clearly, cleverly observed, counted meticulously, explained convincingly, results formulated clearly, and their ability to link neighborhoods with realistic examples. It is important to evaluate the biology course and content for the intermediate/secondary stage in Saudi Arabia. Therefore, the study aims to prepare a list of standard

specifications for the life sciences in high school in light of NGSS using content analysis. It has also determined the range of availability of standard specifications in high school biology courses content in Saudi Arabia.

The study results would be significant in identifying the degree of correspondence between main policies of biology books and actual content of science books curricula as it will provide list of standard specifications for the life sciences in high school in light of NGSS. The study will also provide information about standard specifications of (NGSS) in high school biology courses content in Saudi Arabia and create awareness among teachers regarding standard specifications of NGSS in high school biology courses content. Moreover, this will increase the level of understanding among the teachers and guide them towards the development of student's capacity to produce models and explanations and engaging in biology practices. This study would be beneficial for developers and planners of biological courses in secondary schools, along with the researchers who are interested in analyzing scientific content. The research questions addressed in this study are as follows;

1. What standard specifications for the life sciences in high school in the light of NGSS?
2. What is the availability of standard specifications in high school biology courses content in Saudi Arabia?
3. What is suggested framework for developing biological courses content in secondary stage in Saudi Arabia according to NGSS?

Then the objectives of this study are as follows:

1. Prepare a list of standard specifications for the life sciences in high school in light of (NGSS).
2. Determine the availability of standard specifications in high school biology courses content in Saudi Arabia.
3. Proposed a framework for developing biological courses content in secondary stage in Saudi Arabia according to NGSS.

Contribution to the knowledge:

1. Provide a list of standard specifications for the life sciences in high school in light of (NGSS).
2. Know how standard specifications of (NGSS) in high school biology courses content in Saudi Arabia verifier.
3. Provide a suggested framework for developing biological courses content in secondary stage in Saudi Arabia according to NGSS.
4. Improve the awareness of teachers with standard specifications of (NGSS) in high school biology courses content.
5. Help teachers to increase their understanding on how to promote and develop the capacity of students to produce models, explanations and engaging in biology practices.
6. This research will benefit developers and planners of biological courses in secondary schools In the Gulf.
7. This research will benefit researchers who are interested in analyzing scientific content.

Material and Methods

The study has employed descriptive research approach in defining the next generation standards and content analysis of biological courses for high school to observe availability in those courses (Christensen & Turner, 2011). For content analysis, subject division was adopted to focus on main topics and ideas. There was a list of categories of analysis corresponding to content standards for biology (DCI) that has already been written in the light of high school considering the NGSS.

The study sample consisted of high school biology books (first and second semester) for the academic year 2012 in Arabic Edition which was published by Obeikan under agreement with the McGraw-Hill Companies (Biggs, Holliday, Kapicka, Lundgren, MacKenzie, & Zike, 2009). Table (1) has provided information about the high school biology books. The percentages determined for books availability at different levels have been illustrated in (table 2).

Table (1): Information for high school biology books (sample analysis)

Books	Semester	Number of subjects	Number of units	Number of pages
First secondary	1	10	5	134
	2	12	4	139
Second secondary	1	14	6	178
	2	13	6	161
third secondary	1	18	6	215
	2	13	5	165
Total	6	80	32	992

Table (2): The method of calculating the availability of (NGSS) in high school biology courses content

Percentage	Availability
75 and over	High
7550 -less than	Average
Less than 50	Low

Statistical Analysis

Statistical Package of Social Sciences (SPSS) was used to calculate statistical redundancy and percentages for identifying the availability standards of NGSS in high school biology courses content.

Results

The results have depicted a list of standard specifications (National Academy of Sciences, 2013) that consists of 4 fields of standards by DCI and 24 performance expectations (Appendix 1). The content of biology course was analyzed in the light of list of standard specifications and availability of determined category to depict the range of availability of standard specifications in high school biology courses content in Saudi Arabia. The results of content analysis showing total redundancy and percentages for high school biology courses content has been illustrated in (table 3).

Table (3): Total redundancy and percentages for high school biology courses content by four standards by DCI

Standards by DCI	first grade		Second grade		Third grade		Total	
	R	%	R	%	R	%	R	%
1-From Molecules to Organisms: Structures and Processes	26	34.67	36	3o.77	50	32.68	75	21.74
2-Ecosystems Interactions, Energy, and Dynamics	26	34.67	37	31.62	39	25.50	117	33.91
3-Heredity: Inheritance and Variation of Traits	2	2.66	9	7.70	20	13.07		
4-Biological Evolution: Unity and Diversity	21	28	35	29.91	44	28.75	153	44.35
Total	75	21.74	117	33.91	153	44.35	345	100

Table (3) has depicted that the total number of redundancies in the first secondary grade was (75) and the percentage was 21.74% for the availability of the four DCI content standards. The total number of redundancies in the second secondary grade was 117 with percentage of 33.91% for the four standards. The total number of redundancies in the third secondary grade was 153 and the percentage was 44.35% for the four standards. The availability of the four standards in the content of third secondary grade achieved the highest percentage, followed by the second, and first grade. The availability of standards in courses ranged from (21.74 – 44.35), which was low representing the proportion of the cut-off limit that is scheduled.

In the first grade, the degree of availability of standards (1), (2) was ranked first, standard (4) was ranked second, and standard (3) was ranked third in the degree of availability (Table 4).

Table (4): The standard grades in high school biology courses content, percentages and rank by availability (First grade)

Standards by DCI	Number of performance indicators	R	%	rank
1-From Molecules to Organisms: Structures and Processes	1-1	1	3.85	6
	1-2	4	15.39	3
	1-3	3	11.53	4
	1-4	5	19.23	2
	1-5	2	7.70	5
	1-6	6	23.07	1
	1-7	5	19.23	2
Total	7	26	34.67	1
2-Ecosystems: Interactions, Energy, and Dynamics	2-1	1	3.85	5
	2-2	2	7.70	4
	2-3	6	23.07	1
	2-4	6	23.07	1
	2-5	2	7.70	4
	2-6	5	19.23	2
	2-7	1	3.85	5
	2-8	3	11.53	3
Total	8	26	34.67	1

3-Heredity: Inheritance and Variation of Traits	3-1	1	50	1
	3-2	1	50	1
	3-4	0	0	2
Total	3	2	2.66	3
4-Biological Evolution: Unity and Diversity	4-1	5	23.81	2
	4-2	6	28.57	1
	4-3	0	0	5
	4-4	4	19.05	3
	4-5	5	23.81	2
	4-6	1	4.76	4
Total	6	21	28	2
Final	24	75	21.74	-

In second grade, the degree of availability of standard (2) was ranked first, standard (1) was ranked second, and standard (4) was ranked third, and standard (3) achieved the fourth rank (Table 5).

Table (5): The standard grades in high school biology courses content, percentages and rank by availability (Second grade)

Standards by DCI	Number of performance indicators	R	%	rank
1-From Molecules to Organisms: Structures and Processes	1-1	1	2.78	5
	1-2	6	16.66	2
	1-3	7	19.45	1
	1-4	7	19.45	1
	1-5	4	11.11	4
	1-6	5	13.88	3
	1-7	6	16.67	2
Total	7	36	30.77	2
2-Ecosystems: Interactions, Energy, and Dynamics	2-1	4	10.81	3
	2-2	4	10.81	3
	2-3	6	16.21	2
	2-4	7	18.93	1
	2-5	4	10.81	3
	2-6	3	8.11	4
	2-7	3	8.11	4
	2-8	6	16.21	2
Total	8	37	31.62	1
3-Heredity: Inheritance and Variation of Traits	3-1	5	55.56	1
	3-2	3	33.33	2
	3-4	1	11.11	3
Total	3	9	7.70	4
4-Biological Evolution: Unity and Diversity	4-1	7	20	2
	4-2	8	22.86	1
	4-3	3	8.57	5
	4-4	6	17.14	3
	4-5	6	17.14	3
	4-6	5	14.29	4
Total	6	35	29.91	3
Final	24	117	33.91	-

In the third grade, the degree of availability of standard (1) was ranked first, standard (4) took second place, standard (2) was ranked third, and standard (3) was at the forth rank (Table 6).

Table (6): The standard grades in high school biology courses content, percentages and rank by availability (Third grade)

Standards by DCI	Number of performance indicators	R	%	rank
1-From Molecules to Organisms: Structures and Processes	1-1	13	26	1
	1-2	7	14	3
	1-3	6	12	4
	1-4	8	16	2
	1-5	5	10	5
	1-6	7	14	3
	1-7	4	8	6
Total	7	50	32.68	1
2-Ecosystems: Interactions, Energy, and Dynamics	2-1	3	7.69	5
	2-2	4	10.26	4
	2-3	7	17.95	2
	2-4	3	7.69	5
	2-5	2	5.13	6
	2-6	6	15.38	3
	2-7	8	20.52	1
	2-8	6	15.38	3
Total	8	39	25.50	3
3-Heredity: Inheritance and Variation of Traits	3-1	8	40	1
	3-2	7	35	2
	3-4	5	25	3
Total	3	20	13.07	4
4-Biological Evolution: Unity and Diversity	4-1	7	15.91	3
	4-2	8	18.18	2
	4-3	5	11.36	4
	4-4	9	20.45	1
	4-5	8	18.18	2
	4-6	7	15.91	3
Total	6	44	28.75	2
Final	24	153	44.35	-

The content of the courses showed a low degree of availability of NGSS standards; although, these courses were developed by the McGraw Hill Company, based on previous scientific education standards (Series, 2009). The distribution of standards on the content of biology courses for the three grades showed inconsistency, with varying proportions reflecting the imbalance that violates the scientific construction of the student's good content (Figure 1).

See figure (2) to indicate the total percentages of standards on the content of biology courses for three grades.

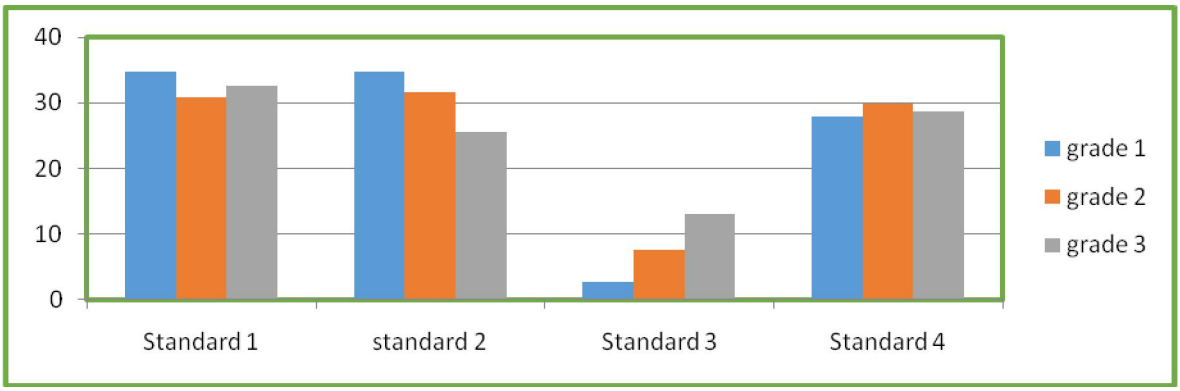

Figure (1) The distribution of standards by DCI on the content of biology courses for the three grades

Figure (2) The Total percentages of standards on the content of biology courses for the grades

Discussion

The collaborative process led by the United States of America are rich in content and practice and arranged in a coherent manner in various disciplines and levels to provide world benchmarks for science education among the students. NGSS are based on the framework (K-12) for Science Education placing them National Research Council (NRC). The main features highlighted by these standards include each of the science standards for the next generation. This comprised of three dimensions that include basic ideas, scientific and engineering practices, and crosscutting concepts. The practices and crosscutting concepts are designed to be taught in the context of integration with the core concepts at each stage. These standards focus on basic ideas that include Disciplinary Core Ideas (DCI) with a focus on understanding and application of deeper content. Science and engineering are integrated in science education by raising engineering design for the same level of scientific research in the classroom teaching at all levels that emphasizes on basic ideas for engineering design and technology applications. Scientific practices are those used by scientists in constructing models or theories; while, the engineering practices are used by engineers in building and design systems. Engaging in scientific practice helps students understand how to develop scientific knowledge by engaging in engineering practices that helps in understanding the work of engineers and their methods (Quinn et al., 2012; Rowland, 2014). The cross-cutting concepts interpret scientific topics to appear in all scientific disciplines. It enables the students to develop a cumulative and coherent understanding, which can be used in science and engineering (Quinn; Schweingruber; & Keller, 2012; Keeley, 2014; Potter, 2014). Focusing on a specific core of ideas in science and engineering and includes explanations for various phenomena (Harold, 2012). Similar to the present study, Barber et al. (2015) integrated the three dimensions of the NGSS into Curricula Using Published Biology Data of United States schools. Regarding the performance expectations, it has been stated that students are likely to use mathematical justifications to prove the basic concepts in terms of power and influence, biodiversity, energy flow, and material cycles between living organisms and ecosystem. Understanding systems and developing solutions reduce the impact of human activities on the environment and biodiversity conservation. It is also important to understand crosscutting concepts of systems and models, and realizing scientific and engineering practices and core ideas of ecosystem. Secondary biology teachers negotiated the meaning of the NGSS by redesigning their curriculum, influencing their prioritization of "NGSS" practices focusing on obtaining, evaluating and communicating information, and reasoning with evidence. The teachers' experiences were marked by a central tension between content details and "NGSS" practices. (Friedrichsen & Barnett, 2018). Students become able to ask questions and to define and develop hypotheses and using concepts of probability to explain human genetic diversity. They become capable of understanding and explanation why individuals vary in shape and behavior and function and emotion. The results of present study have shown that students are capable of developing scenarios for processes of natural selection and evolution, communicate, and support multiple points with evidence and proofs. Students apply concepts of probability to explain that certain trends have a specific demographic group, as well as related advantages for certain genetic strain in an environment. But the content of the courses showed a low degree of availability of NGSS standards; although, these courses were developed by the McGraw Hill Company. The distribution of standards on the content of biology courses for the three grades showed inconsistency, with varying proportions reflecting the imbalance that violates the scientific construction of the student's good content.

A suggested framework

The researcher proposed a conceptual framework in the form of Scope and Sequence Matrix according

to Piaget's cognitive growth perspective and Bruner's spiral curriculum for improving biology courses in the light of NGSS. Table (7).

Table (7): Scope and Sequence Matrix for developing biology courses in the light of NGSS

Standards by DCI	Grad 1 Performance Expectations	Grad 2 Performance Expectations	Grad 3 Performance Expectations
1-From Molecules to Organisms: Structures and Processes	**1-1**Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells. **1-2**Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms. **1-3**Plan and conduct an investigation to provide evidence that feedback mechanism maintain homeostasis.	**1-4**Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. **1-5**Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.	**1-6** Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules. **1-7** Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.
2-Ecosystems: Interactions, Energy, and Dynamics	**2-1** Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. **2-2** Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales. **2-3** Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.	**2-4** Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. **2-5** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. **2-6** Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.	**2-7** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity. **2-8** Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.
3-Heredity: Inheritance and Variation of Traits	**3-1** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.	**3-2** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	**3-3** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.
4-Biological Evolution: Unity and Diversity	**4-1** Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence. **4-2** Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.	**4-3** Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait. 4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.	**4-5** Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species. **4-6** Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.

Basic ideas in the Matrix and performance expectations where discussed as followed:

1- From Molecules to Organisms: Structures and Processes

This is represented through secondary ideas:

- The structure and functional
- Growth and evolution of living organisms
- Organizing the material and energy flow in these organisms

Performance expectations include:

- Students demonstrate the ability to use checks processes

- Collect evidences about cell function and reproduction
- understand the role of proteins as a key broker in the work cell and living systems
- using models explain photosynthesis, respiration, cycle material, energy flow in the living organisms
- Understanding hierarchy of organisms through cell model processes
- Understand crosscutting concepts of matter and energy, structure and function and systems

2- Ecosystems: Interactions, Energy, and Dynamics

This is represented through secondary ideas:

- Interrelationships in ecosystems.
- Power transmission and material cycles in Ecosystems
- Ecosystem dynamics and function
- Social interactions, dependability and group behavior

Performance expectations include:

- Students will use mathematical justifications to prove what they have gained basic concepts in terms of power and influence, biodiversity and energy flow and material cycles between living organisms and ecosystem.
- Understand systems and developing solutions and systems reduce the impact of human activities on the environment and biodiversity conservation.
- Understand crosscutting concepts of systems and models, and realizing scientific and engineering practices and core ideas of ecosystem.

3- Heredity: Inheritance and Variation of Traits

This is represented through secondary ideas:

- Inheriting genetic factors
- Diversity of genetic factors

Performance expectations include:

- Students become able to ask questions and to define and develop hypotheses and using concepts of probability to explain human genetic diversity.
- Demonstrate understanding and explanation why individuals vary in shape and behavior and function and emotion.
- Explain the mechanisms of genetic inheritance and environmental causes and description of biological and genetic mutations and changing genetic content.
- Understand crosscutting concepts of patterns and causes and effects that can regulate as general concepts.

4- Biological Evolution: Unity and Diversity

This is represented through secondary ideas:

- Evidence about the common origin.
- Diversity and adaptation of natural selection processes.
- Biological diversity and human.

Performance expectations include:

- Students can develop scenarios for processes of natural selection and evolution, communicate and how to support multiple points with evidence and proofs.
- Evaluating evidence about circumstances that could give rise to new species and understand the role of genetic diversity in natural selection.
- Students apply concepts of probability to explain certain trends have a specific demographic group, as well as related advantages for certain genetic strain in an environment.
- Understand crosscutting concepts In terms of cause and effect and the system and their model which are playing an important role in students understanding of the evolution of life on Earth.

Conclusion

The current study conducted in KSA, it revealed the status of the context of biological courses in the term of content and processes. It has prepared a list of standard specifications for the life sciences in high school in light of NGSS and determined the range of availability of standard specifications in high school biology courses content in Saudi Arabia. The next generation standards have been defined using descriptive research approach. Content analysis was performed concerning the biological courses for high school to observe the availability in those courses. The results showed that there was a deficiency in the inclusion of NGSS standards in the field of life sciences with secondary school courses. Future studies need to consider the proposed framework for developing courses that are capable of addressing this deficiency through the content and processes of the biological courses of the secondary level.

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Appendix (1)

Content analysis tool in the field of life sciences for secondary stage in the light of (NGSS)

Standards By DCI	Availability		
	0	1	2
1- From Molecules to Organisms: Structures and Processes			
Performance Expectations Indicators			
1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.			
1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.			
1-3 Plan and conduct an investigation to provide evidence that feedback mechanism maintain homeostasis.			
1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.			
1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.			
1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.			
1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.			

Standards By DCI	Availability		
	0	1	2
2-Ecosystems: Interactions, Energy, and Dynamics			
Performance Expectations Indicators			
2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.			
2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.			
2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.			
2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.			
2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.			
2-6 Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.			
2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.			
2-8 Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.			

Standards By DCI	Availability		
	0	1	2
3-Heredity: Inheritance and Variation of Traits			
Performance Expectations Indicators			
3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.			
3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.			
3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed			

traits in a population.			
4-Biological Evolution: Unity and Diversity			
4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.			
4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.			
4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.			
4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.			
4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.			
4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.			

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