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Development and Application of Structural Communication Grid Tests for Diagnosing Students' Misconceptions in the Subject of Biology at Secondary Level

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Abstract

The present study was designed to diagnose student's misconceptions in learning biodiversity in 9th-grade biology. It is a well-known fact that students come to class with misconceptions based on their previous experiences in the subject i.e. biology. Researchers developed Structural Communication Grids (SCGs) on different biodiversity topics to diagnose misconceptions of students, as they may block their learning in a new situation. Five conceptual areas were selected for constructing SCGs like 'Biodiversity', 'Aims and Principles of Classification', 'History of Classification System', 'Two-Three Kingdom Classification System', and 'Five Kingdom Classification System'. The study was descriptive and quantitative and researchers randomly selected two institutions (one for male and one for female) as a sample of the study. Researchers provided SCGs to 58 students (girls=23, boys=35) to diagnose misconceptions in specific areas. The findings of the study made it clear that almost all students had been confronted with huge misunderstandings about the subject of biology in Grade 9. Researchers suggested that structural communication grids should be developed on other topics of biology and for other subjects (chemistry and physics) to promote students' meaningful learning by highlighting their misconceptions.

***Keywords*:** Structural Communication Grids; Misconceptions; Secondary Education; Biodiversity; Classification and Cognitive Structures

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Introduction

The relation of both biology and mankind dates back to the origin of man on this earth. Therefore, this branch of science comes first relative to other divisions of science. With the beginning of life, a man tried to understand the various phenomenons of life processes like health, ailment, birth, development, growth, and death. However, man relies chiefly on plants and animals for fulfilling the needs of foods and accommodations which are no doubt part and parcel of his survival on earth related to biology. Perhaps it was the basic need of man to become aware of living organisms, to maximize benefits from them.

Many factors affect learners' learning and success in a particular educational context. One of the main factors that affect pupils' learning processes is misconceptions of learners in the field i.e. biology. In comprehensible terms, the misconception can be considered as a concept in which the learner's articulations have strange explanations and connotations that do not conform to the scientifically accepted truth. The term "misconception" can be defined as something that people perceive but do not conform to scientifically accurate concepts. According to Bahar (2003), misconceptions correspond to thoughts with imperfect individual perceptions and meanings in students' articulations. To avoid any confusion in the concepts, the term "*Misconception*" rather than "A*lternatives*" was used throughout this study, as it easily conveys the message that a concept might have conflicting meanings with the current scientific ideas of science education.

Background of the Study

The major concern of all National Education Policies (NEPs) in Pakistan, especially the most recent one (Government of Pakistan, 2009b) remained in the provision of quality education in general and science education in particular, necessary for accomplishing radical social development. The Government of Pakistan (2009b) has realized the achievement of comprehensive social development by introducing a strong base of personnel who are equipped with scientific and technological knowledge and skills. The education system in the country has still not been able to provide quality science education to the younger generation. Several factors explain this failure: inadequate science curriculum, school environment, and different classroom practices needed to engage learners and instill a positive attitude toward science. If we analyze critically the state of science education in Pakistan, we

discover a disconcerting situation, illustrated by the low success rate of students in scientific disciplines such as physics, chemistry, biology, and mathematics, especially at the secondary level when students have to decide on their field of study after grade 10.

In Pakistan, biology is taught as an elective subject for students in grades 9 and 10. There is an option available for students in terms of computer science. The prescribed biology curriculum for secondary education includes a broad range of concepts related to biodiversity, cell biology, and life sciences that students need to understand. As per the National Biology Curriculum of 2006 for secondary classes, a well-constructed document, there has been a paradigm shift from teacher centeredness to learner centeredness, from behaviorist approach in learning to constructivist approach in learning and rote memorization to meaningful learning (Government of Pakistan, 2006).

Secondary education is the most important phase of education so that students can decide on their future, both academically and professionally (Alya, 2014). The purpose of the present study was to develop SCGs tests for diagnosing students' misunderstandings in the subject of biology at 9^{th} grade. Biology as a separate subject is taught to the students of lower secondary level. The researcher selected 'Biodiversity' as content for the present study because it comprised of basic information regarding taxonomy and classification.

Theoretical Framework

An increasing number of research studies have concluded that students come to class with misconceptions about almost every area of biology. The misconceptions of learners are constant and widespread. It is difficult for educators to change the alternative viewpoints of students on a given subject. These misunderstandings result from the varied personal experiences of students. Students' prior knowledge is related to what they will learn after being taught in class.

The present research is following the psychological theory of learning by Ausubel (1968). In educational psychology, constructivists believe that knowledge is something that needs to be reconstructed as it shifted from one person to another. Learning is not merely considered as an exchange of thoughts from the head of the teacher to the head of the student. The study mainly focused on the issue of meaningful learning and suggested that learners must reconstruct knowledge by relating new information with their terms and understanding because individuals differ on the behalf of prior knowledge, learning style, etc. Learning is

meaningful when there is an appropriate connection between previous knowledge and new learning task. In other words, meaningful learning is the formation of worthwhile associations among ideas, concepts, and information (Otor, 2011).

The main preoccupation of previous research work was to reinforce effective scientific education by diagnosing and diminishing students' misconceptions about teaching biologically stimulating topics such as photosynthesis, respiration, osmosis, evolution, reproduction, genetics, etc. In these studies, the researchers uncovered students' misconceptions using instruments such as essay-type tests, multiple-choice tests, two- or three-level diagnostic tests, interviews, analogy tests, pencil, and paper tests, and free answer tests. The present study aimed to diagnose the misconceptions that students have about biodiversity from Grade 9 biology using structural communication grids.

Objectives of the Study

The main objectives of the present study were:

1. To develop SCG tests on different topics of biodiversity from 9^{th}-grade biology.
2. To diagnose misconceptions held by students in understanding different concepts of biodiversity using SCG tests.
3. To explore the effect of gender in understanding different concepts regarding biodiversity from 9^{th}-grade biology.

Hypothesis of the Study

The objectives of the study were further supported by the following research hypothesis:

H_{01}: There is no significant difference between the students' scores regarding the misunderstanding of different concepts of biodiversity using SCGs.

Significance of the Study

It is imperative to enhance meaningful student learning by shifting the paradigm of behaviorism to constructivism concerning assessment practices. The present study would support subject teachers by familiarizing them with a SCG for assessing learner's concepts in science with an optimal level of accuracy.

The study would be of great interest to policymakers and education planners and would assist curriculum developers in planning curriculum for biology based on learners' level of understanding, that is, where student's linkages about various concepts are strong and where they are weak. The results of the study would identify existing gaps in the student's concepts and prompt the teacher to suggest corrective actions. Students entered science class with misconceptions about science subjects. SCGs have been proved useful in highlighting individuals' misconceptions about biology. This would allow learners to understand the cognitive structures in their minds and to promote meaningful learning.

Delimitations of the Study

The present study was delimited to:

- Only for the students of Model Schools and Colleges under the umbrella of Federal Directorate of Education (FDE), Islamabad.
- Subject matter selected for developing SCG tests includes classification (History, aims, principles, and types) in biodiversity from 9th-grade biology.
- Only 3x3 grids were developed for the present study.
- In the case of SCG tests focused on regular questions only.

Literature Review

Biology as a subject is an integral part of science education. Science is presented to learners first at primary and then at the elementary level. At both levels, students learn subject matter in science which is an amalgamation of physics, chemistry, and biology. At the secondary level, science is divided into separate subjects such as physics, chemistry, and biology. Elementary education is the foundation of science education and builds accurate and meaningful knowledge of biology. This level should play an important role in preventing scientifically inaccurate conceptions (misconceptions). Besides, teachers must acquire sufficient knowledge and skills to overcome students' misconceptions.

Many students encounter misconceptions about what science is and how does it work. Biology is one of the subjects in which learners find it difficult to understand different concepts (Keles & Kefeli, 2010). According to Sesli and Kara (2012), it is known that biology is a difficult

subject to teach and learn because of its content, the difficulty of its biological ideas, and the latent nature of many key processes.

Many words in biology are used in another way in day to day life. The use of such words in everyday life differs in the meaning of these words in a scientific context give rise to misconceptions. According to Gilbert, Osborne, and Fenshman (1982), the word "particle" is technically used to refer to atom, molecule, or ion in science. However, in everyday life, it is considered a tiny but recognizable part of the solid substance.

It has been recognized that teachers might have played a part in the formation of mistakes held by their students (Sanders, 1993& Yip, 1998). These studies highlighted that misconceptions communicated by teachers towards their students as a result of inappropriate instructions. According to Sanders (1993), assessment techniques used by teachers in teaching the subject like biology might be another reason responsible for creating misconceptions in their students.

Textbooks, which contain errors and incorrect study material, can also contribute to the growth of misconceptions conveyed by students (Storey, 1991, 1992). In biology, there are links between different concepts and they allow understanding other concepts. Therefore, the appropriate disposition of subjects and the assimilation of topics ensured a better understanding of the students. For example, before transmitting knowledge about the food chain and food web, it is imperative to teach students about concepts like photosynthesis.

To correct students' misconceptions, it is essential to identify these misconceptions and to further develop different approaches to provide students with the correct conceptual knowledge. It was also detected that the students had misconceptions mainly during the lesson. There should be an immediate procedure for detecting and correcting misconceptions, otherwise, it could affect the subsequent learning of learners. In most countries, including Pakistan, an assessment can be done at the end of the academic session. However, such an evaluation provides little feedback on teaching.

To recognize and analyze misunderstandings at an early stage, it is necessary to use different assessment techniques throughout the course. For example, students should participate in quizzes and discussions during instruction to explore their point of view on a particular concept. A brief test provided to learners at the end of a topic also helps assess their work. SCGs being an alternative assessment technique meant for assessing students' meaningful learning and highlights the insufficiencies

and deficiencies in cognitive structures of knowledge acquired by students (Johnstone, Bahar, & Hansell, 2000).

A growing body of research studies advocated that instructional strategies leading to conceptual change including analogy tests, structural communication grids, concept maps, conceptual change texts, and concept maps could be used to eliminate learners' misconceptions. The purpose of this study was to explore the effect of SCGs in diagnosing students' misconceptions in biology at the secondary level.

In the existing literature, various techniques have been described to identify students' misconceptions about scientific topics. The most widely used method is multiple-choice tests as being scored objectively and conveniently. Oberoi (2017) conducted a research study and mentioned a variety of instruments used by researchers in their studies to elicit misconceptions from science students. These include the following: interview (Fredette & Clement, 1981); multiple-choice test (Haslam &Treagust, 1987); diagnostic test (Treagust, 1988); paper-and-pencil test (Amir & Tamir, 1990); two-tier diagnostic test (Odom & Barrow, 1995); analogies test (Hill, 1997); a ten-question paper-and-pencil test and a two-level diagnostic test (Voska & Heikkinen, 2000); three-level test; structured interview (Mcwilliam, 2002); two-level multiple-choice diagnostic test (Tan, Goh, Chia & Treagust, 2002); two-speed test; a multiple-choice, open-response instrument (Yen, Yao & Chiu, 2004) and a three-level test (Kutluay, 2005).

Research Methodology

The study was descriptive and quantitative in nature. The population of the present study contained 9th-grade biology students studying in institutions working under the FDE. The total number of Model Colleges (Boys & Girls) and Model Schools (Boys & Girls) were 136. However, due to time and convenience constraints, the researcher randomly selected two institutions as a sample of the study. The sample of the study included 58 students (girls = 23, boys = 35). SCG tests were provided to students who had already learned the five conceptual domains, namely biodiversity, classification objectives and principles, classification system history, two-way classification system, and three kingdoms and the five-kingdom classification system. The researcher collected data on student’s misconceptions regarding different areas of biodiversity from grade 9 biology. Initially, results were determined using descriptive statistics and further substantiated these results by making use of independent samples t-test.

The Research Instrument

Keeping in view the above-mentioned methods in obtaining a complete understanding of students' problems related to science learning, the researcher in the present study designated a new instrument that can accurately and objectively detect learner misunderstandings about biodiversity in 9th-grade biology. The SCGs initially goes back to the work of Egan (1972). Since then, it has been developed and used by different researchers in their studies (e.g. Duncan, 1974; Johnstone & Mughol, 1979; Johnstone & Mac Guire, 1987).

Researchers developed 3x3 SCGs on various sub-topics of biodiversity (See figure 1). The instrument developed was validated after discussion with a panel of five judges having a background in teaching biology at the secondary level. They provided valuable insights into the validity of the content, the clarity, and the readability of the SCGs tests. After incorporating suggestions few items were removed and many others were revised.

Structural Communication Grids (SCGs)

Structural Communication Grid (SCG) is an alternative assessment technique in the form of a numbered grid mainly focused on highlighting the cognitive structures of students. This technique which is quite different from Multiple Choice Tests (MCQs), students is probable to choose those boxes opposite to answer the question and finally to put them in a logical sequence. That is why this technique is known as the "Structural Communication grid" (Johnstone et al., 2000). The most important feature of SCG is to measures meaningful learning and discovering students' misconceptions (Johnstone et al., 2000). Solas (1992) highlighted the usefulness of SCG for assessment purposes. Durmus and Karakirik (2005) considered it a substitute for multiple-choice questions.

Types of SCGs

The Structural Communication Grid (SCG) technique is an alternative evaluation technique used to reveal the cognitive structures of students. The size of the SCG test varies and is determined by the number of cells per grid prepared according to the age level of the students. There is no hard and fast rule for the size of the SCG Test.

Structural communication grids of different sizes, such as 3x3, 3x4, 4x4, are developed in harmony with the age of the learners, and grid cells are numbered (Johnstone et al., 2000).

Construction

The preparation of SCGs requires the teacher to think about a question and suggest the appropriate answer. Then he/she divides the answer into several parts and randomly places them in the grid. In the same way, a teacher asks another question and after suggesting the right answer, fragments it so that one or two components of one question must match another. This process should continue until all cells in the grid are filled. Each grid follows a series of questions to ask the learner. Students respond by putting cell numbers for each question. Sometimes it is essential to put them in a logical order.

Scoring Criteria

In the activities of the structural communication grid, students are asked to choose the number of boxes needed to indicate the answer to the question and the numbers in a logical order. There are two different types of scoring criteria for two different forms of questions, namely regular questions and ordered questions. In the case of regular questions, it is not important to put selected boxes in a logical sequence. Structural communication grid assesses learner's achievement in two different ways: student's raw score includes 50 points out of 100 for choosing correct boxes and remaining 50 points for not choosing the incorrect boxes.

$$\text{Raw Score} = \frac{\text{The number of correct boxes chosen}}{\text{Total number of correct boxes}} - \frac{\text{The number of incorrect boxes chosen}}{\text{Total number of incorrect boxes}}$$

This raw score ranges from -1 to +1. But the student total score can be calculated as follows:

Total Score = (Raw score+1) *50. The final score then ranges from 0 to 10.

In the case of order questions, the order of boxes for each question is important. The structural communication grid assesses the learner's achievements by analyzing the order of the boxes considered. In the process of evaluating a question of order, it is necessary to select the exact sequence of boxes as a response to a given question.

This is done simply by asking two questions:
1. Does the nth correct box come before the n+1 correct box?
2. Is the nth correct box immediately before the n+1 correct box?

For a question that has n number of boxes in the answer, one has to ask these two-question in-1 time. Each correct answer wins one point and each incorrect score zero. Then the raw score for the order question can be calculated as:

$$\text{Raw Score} = \frac{\text{The number of points chosen}}{\text{Maximum points one could get}}$$

The student's gross score can range from 0 to +1. But the total score can be calculated as:

Total Score = (Raw score) *100.

The student's final score for a question comprising both regular and ordered parts was calculated by finding the average of scores from each part. The test score can also be calculated by averaging the scores of each question in the test. The present study was limited to regular questions, which requires candidates to provide only to put box number for each statement rather than classifying them in a particular order.

1	2	3
4	5	6
7	8	9

(Johnstone, Bahar & Hansell, 2000)

Figure 1: The Basic Structure of the SCG

Vertebrates and Invertebrates

1. Gnat	2. Dolphin	3. Butterfly
4. Crab	5. Trout	6. Lizard
7. Goshawk	8. Worm	9. Salamander

Use the above nine-box (es) to answer the questions below.
You can use a box as many times as you wish.
More than one box can be used for each question.
Write the number given on the upper left side of the boxes to show the right answer.

1	Which box (es) show the names of vertebrates' animals?				
2	Which box (es) show the names of invertebrates' animals?				
3	Which box (es) show the names of animals whose appearance and action seem like a fish however it categorized under mammals?				
4	Which box (es) show the names of vertebrates/ invertebrates' animals that live on land?				
5	Which box (es) show the names of vertebrates/ invertebrates' animals that live in water?				
6	Which box (es) show the names of animals that are amphibians?				
7	Which box (es) show the names of animals that are reptiles?				
8	Which box (es) show the names of animals that are insects?				
9	Which box (es) show the names of animals that are mammals?				
10	Which box (es) show the names of animals that are fish?				

Findings

Table 1
The percentage of secondary school students that held the misconceptions diagnosed by using structural communication grids (SCGs) and the percentage of students who answered correctly

Sr. No.	**Conceptual statements on 'Biodiversity'**	% of students that held misconceptions	% of students that answers correctly
1	Biodiversity is the term used to measure a variety of organisms in different species.	31.03	68.96
2	A biodiversity hotspot is a region with a high level of established species.	70.68	29.31
3	Climate, altitude, and soils are the factors that affect the plant & animals' diversity.	39.65	60.34
4	Biodiversity is the result of evolution.	62.06	37.93
5	Food, fiber, and building materials are the advantages of biodiversity.	48.27	51.72
6	Maintaining an ecosystem is an important role of biodiversity.	31.03	68.96
7	Flora and fauna show the basic groups/ oldest groups of organisms.	62.06	37.93
8	Prokaryotes include the organism that has no nuclear & membrane-bounded organelles.	27.58	72.41
	Conceptual statements on 'Aims and Principles of Classification System'	% of students that held misconceptions	% of students that answers correctly
9	Three kingdoms are the work of Carolus Linnaeus.	31.03	68.96
10	Species show the ranks used by Carolus Linnaeus.	67.24	32.75
11	Mineral, vegetables, and animals show the Carolos Linnaeus division of kingdoms.	22.41	77.58
12	Evolutionary relationships show the aim of classification.	60.34	39.65
13	Taxonomic hierarchy means the Taxonomic categories of organisms.	31.03	68.96
14	Taxonomy is the classification of organisms.	58.62	41.37

15	Systematics shows the classification as well as traces of evolutionary histories of organisms.	34.48	66.51
	Conceptual statements on 'History of Classification System'	% of students that held misconceptions	% of students that answers correctly
16	Classification of an organism comes from Greeks.	46.55	53.44
17	First of all, Aristotle discovered the classification.	48.27	51.72
18	Abu-Usman Aljahiz wrote much about the ant's life.	43.10	56.89
19	Similar physical characteristics are the work of Carolus Linnaeus.	58.62	41.37
20	English naturalist John Ray works on plants.	5.17	94.82
21	Work on animals started in the 16^{th} and 17^{th} centuries.	70.68	29.31
22	Augustus Quinines Ravines, the scientist who introduced the naming of plants according to their genera.	62.06	37.93
	Conceptual statements on 'Two, Three Kingdom Classification System'	% of students that held misconceptions	% of students that answers correctly
23	Plantae and Animalia show the component of the oldest classification system.	65.51	34.48
24	Autotrophs and Plantae show the organisms which can prepare their food.	15.51	84.48
25	Plantae is autotrophic organisms.	68.96	31.03
26	Bacteria, algae, and fungi show the composition of the kingdom Plantae.	48.27	51.72
27	Bacteria, algae, fungi, and Animalia are heterotrophic organisms.	39.65	60.34
28	The characteristics of Euglena include both plants and animals.	55.17	44.82
29	Protista shows the position of Euglena as a separate kingdom.	37.93	62.06
30	Plantae shows the Taxonomic position of Fungi.	86.20	13.79
31	Fungi are organisms that are heterotrophic and have chitin in their cell walls.	58.62	41.37

	Conceptual statements on 'Five Kingdom Classification System'	% of students that held misconceptions	% of students that answers correctly
32	Monera stands for the meaning of the term prokaryotes.	91.37	8.62
33	Eukaryotes include Animalia, Plantae, Protista, and fungi.	86.20	13.79
34	Arch bacteria and eubacteria are the organisms that include characteristics of heterotrophic and autotrophic.	79.31	20.68
35	Animalia, Plantae, and fungi are multicellular organisms.	46.55	53.44
36	Plantae is organisms which are multicellular autotrophs.	58.62	41.37
37	Fungi are the multicellular reducers.	79.31	20.68
38	Arch bacteria, eubacteria, and fungi are the organisms that include characteristics of heterotrophic and decomposers.	39.65	60.34
39	Animalia shows the organisms do ingestion and digestion without a cell wall.	65.51	34.48
40	Fungi are the organism with the absorptive mode of nutrition.	65.51	34.48

Table 1 clearly shows that almost all students have misconceptions about biodiversity and the classification system. The most difficult statements for students to answer were 2, 21, 30, 32, 33, 34, and 37. Statement 2 on biodiversity, which involved concept such as the hotspot of biodiversity, was the region where the number of established species were high. 29.31% of students answered it correctly. About statement 21, on the "history of classification system", which dealt with the work on animals started in the 16th and 17th centuries. 29.31 % of students answered it correctly. Statement 30, titled "Two-Three-Kingdom Classification System," illustrates the idea that plants represent the taxonomic position of fungi. 14% of students answered it correctly. Statements 32, 33, 34, and 37 belonged to the "Five Kingdoms Classification System", which highlighted concepts such as "Monera means prokaryotic meanings of the term", "Eukaryotes included animals, plants, protists and fungi ", the organism that includes the characteristics of heterotrophs and autotrophs" and "fungi as multicellular reducers". Only 10% of students answered statement 32 correctly. 14% of students answered statement 33 correctly. Statements 34 and 37 were answered accurately by almost 21% each.

The statements most answered by students were questions 1, 3, 6, 8, 11, 13, 20, 24, 27, 29, and 38. In total, 76% of students answered these statements accurately. Statements 1, 3, 6 and 8 related to "biodiversity", referred to concepts such as biodiversity is the term used to measure a

variety of organism in different species, climate, altitude, and soils are the factors affect the plant & animals' diversity, maintaining ecosystem is the important role of biodiversity and prokaryotic included the organism that does not have nuclear organelles and membrane-bound respectively. 68% of students answered these statements accurately. Statements 11, 13, and 15 relating to "aims and principles of classification" described the following concepts: "Minerals, vegetables, and animals show the division of Carola Linnaeus' kingdoms", "systematics shows the classification as well as traces evolutionary histories of organisms" and "mineral, vegetables, and animals show the Carolos Linnaeus division of kingdoms" respectively. 71% of students answered these statements accurately. Statement 20 concerned the work of the English naturalist John Ray on plants related to the History of Classification System. 67% of students answered it correctly. Statements 24, 27, and 29 dealt with "The Two and Three Kingdom Classification System" and dealt with concepts such as "Autotrophs and plants show organisms capable of preparing their food", "Bacteria, algae, fungi, and animals are heterotrophic organisms "Protista shows the position of Euglena as a separate kingdom". 84% of students answered statement 24 correctly and 62% of students answered statement 27 correctly. Similarly, statement 29 was answered correctly by 66% of students. Statement 38 dealt with the "Five Kingdom Classification System" related to concepts such as "Arch bacteria, eubacteria and fungi are organisms that include heterotrophic characteristics and decomposers". 62% of students answered it correctly.

Table 2

The percentage of secondary school students (Male & Female) that held the misconceptions diagnosed by using structural communication grids (SCGs) and the percentage of students who answered correctly.

Sr. No.	**Conceptual statements on 'Biodiversity'**	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
1	Biodiversity is the term used to measure a variety of organisms in different species.	22.85	43.47	77.14	56.52
2	A biodiversity hotspot is a region with a high level of established species.	71.42	69.56	28.57	30.43
3	Climate, altitude, and soils are the factor that affects the plant & animals' diversity.	31.42	52.17	68.57	47.82
4	Biodiversity is the result of evolution.	65.71	56.52	34.28	43.47

5	Food, fiber, and building materials are the advantages of biodiversity.	51.42	43.47	48.57	56.52
6	Maintaining an ecosystem is an important role of biodiversity.	34.28	26.08	65.71	73.91
7	Flora and fauna show the basic groups/ oldest groups of organisms.	54.28	73.91	45.71	26.08
8	Prokaryotes include the organism that has no nuclear & membrane-bounded organelles.	20.00	39.13	80.00	60.86
	Conceptual statements on 'Aims and Principles of Classification System'	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
9	Three kingdoms are the work of Carolus Linnaeus.	17.14	52.17	82.85	47.82
10	Species show the ranks used by Carolus Linnaeus.	45.71	100	54.28	0.00
11	Mineral, vegetables, and animals show the Carolos Linnaeus division of kingdoms.	28.57	13.04	71.42	86.95
12	Evolutionary relationships show the aim of classification.	51.42	73.91	48.57	26.08
13	Taxonomic hierarchy means the Taxonomic categories of organisms.	20.00	47.82	80.00	52.17
14	Taxonomy is the classification of organisms.	60.00	56.52	40.00	43.47
15	Systematics shows the classification as well as traces of evolutionary histories of organisms.	28.57	43.47	71.42	56.52
	Conceptual statements on 'History of Classification System'	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
16	Classification of an organism comes from Greeks.	40.00	56.52	60.00	43.47
17	First of all, Aristotle discovered the classification.	40.00	60.86	60.00	39.13
18	Abu-Usman Aljahiz wrote much about the ant's life.	45.71	39.13	54.28	60.86
19	Similar physical characteristics are the work of Carolus Linnaeus.	51.42	69.56	48.57	30.43
20	English naturalist John Ray works on plants.	5.71	4.34	94.28	95.65
21	Work on animals started in the 16th and 17th centuries.	68.57	73.91	31.42	26.08
22	Augustus Quinines Ravines, the scientist who introduced the naming of plants according to their genera.	57.14	69.56	42.85	30.43

	Conceptual statements on 'Two, Three Kingdom Classification System'	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
23	Plantae and Animalia show the component of the oldest classification system.	62.85	69.56	37.14	30.43
24	Autotrophs and Plantae show the organisms which can prepare their food.	17.14	13.04	82.85	86.95
25	Plantae is autotrophic organisms.	68.57	69.56	31.42	30.43
26	Bacteria, algae, and fungi show the composition of the kingdom Plantae.	45.71	52.17	54.28	47.82
27	Bacteria, algae, fungi, and Animalia are heterotrophic organisms.	42.85	34.78	57.14	65.21
28	The characteristics of Euglena include both plants and animals.	68.57	34.78	31.42	65.21
29	Protista shows the position of Euglena as a separate kingdom.	48.57	21.73	51.42	78.26
30	Plantae shows the Taxonomic position of Fungi.	80.00	95.65	20.00	4.34
31	Fungi are organisms that are heterotrophic and have chitin in their cell walls.	48.57	73.91	51.42	26.08
	Conceptual statements on 'Five Kingdom Classification System'	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
32	Monera stands for the meaning of the term prokaryotes.	91.42	91.30	8.57	8.69
33	Eukaryotes include Animalia, Plantae, Protista, and fungi.	88.57	82.60	11.42	17.39
34	Arch bacteria and eubacteria are the organisms that include characteristics of heterotrophic and autotrophic.	77.14	82.60	22.85	17.39
35	Animalia, Plantae, and fungi are multicellular organisms.	40.00	56.52	60.00	43.47
36	Plantae is organisms which are multicellular autotrophs.	57.14	60.86	42.85	39.13
37	Fungi are the multicellular reducers.	71.42	91.30	28.57	8.69
38	Arch bacteria, eubacteria, and fungi are the organisms that include characteristics of heterotrophic and decomposers.	25.71	60.86	74.28	39.13
39	Animalia shows the organisms do ingestion and digestion without a cell wall.	60.00	73.91	40.00	26.08
40	Fungi are the organism with an absorptive mode of nutrition.	57.14	78.26	42.85	21.73

Table 2 presented data on misconceptions of boys and girls separately on the notions of "biodiversity" and "classification system". The overall percentage of misconceptions among boys remained at 49% and girls at 57%, which indicates that girls are more misinterpreted than boys in reading biology in Grade 9.

Table 3
Comparative Analysis of Male and Female Students that held the Misconceptions diagnosed by using Structural Communication Grids (SCGs) and the Percentage of Students who answered correctly.

Sr. No.	Different Conceptual areas from 9th Grade Biology	% of students that held misconceptions		% of students that answers correctly	
		Male	Female	Male	Female
1	Biodiversity	44	51	56	49
2	Aims and Principles of Classification System	36	55	64	45
3	History of Classification System	44	53	56	47
4	Two, Three Kingdom Classification System	54	52	46	48
5	Five Kingdom Classification System	63	75	37	25
6	Total	48	57	51	43

In table 3, misconceptions held by female students were more than male students in almost all conceptual areas, except for the two, three kingdom classification system. On the other hand, the percentage of students who answered correctly was identical for both sexes.

Null Hypothesis No: 1

H_{01}: There is no significant difference between the student's scores regarding misunderstanding of different concepts of biodiversity using structural communication grids.

Table 4
Summary of the Statistics on Scores of Post-tests of Overall Students

Group	N	Mean	S.D.	df	t	Sig. (2-tailed)
Male	35	17.17	7.24	78	2.744	.008
Female	23	13.27	5.32			

Level of significance $= \boldsymbol{\alpha} = 0.05$

Summary of the results in table 4 comprising t= 2.744 and ρ = .008indicated that there existed a statistically significant variation in mean scores regarding misconception of male students (M = 17.17, SD = 7.24) and female students (M = 13.27, SD = 5.32). Hence the null hypothesis, $H_{01,}$ was rejected.

It was decided that female students are more misinterpreted than male students in reading biology in Grade 9.

Discussion

The findings of this study clearly show that students have difficulty understanding five conceptual areas of biodiversity. This study complements previous studies in which science misconceptions were maintained by students (Odom, & Barrow, 1995, Kose, 2008 and Subayani, 2016). To confirm the exact understanding of scientific knowledge, it is essential to highlight science-related misunderstandings by identifying misconceptions about science in general and biology in particular (Bell, 2001; Hodgson & Pyle, 2010; Mayer, 2002; Ross, Tronson, & Raymond, 2006). Now, the question arises that how to identify these difficulties in student's learning in biology. In previous studies, researchers utilized numerous instruments for diagnosing student's misconceptions about topics such as photosynthesis, respiration, osmosis, genetics, evolution, and so on. These practices include essay type tests, multiple-choice tests, two or three-tier diagnostic tests, interviews, analogies tests, paper, and pencil tests, and free-response tests which are considered as traditional assessment techniques. The major drawback associated with such methods is their guessing factor. These techniques depend only on the end product and tell nothing about the process through which an individual gained certain information. On the other hand, alternative assessment techniques are following the constructivism theory of learning and involve student's partial knowledge judgment. Structural Communication Grids (SCGs) is an alternative assessment technique. The most important feature of SCG is to measure meaningful learning and discover students' misconceptions (Johnstone et al., 2000). Bahar (2003) used structural communication grids as conceptual change strategies for identifying student's misconceptions in biology. Solas (1992) highlighted the usefulness of SCG for assessment purposes. Durmus and Karakirik (2005) considered it as a substitute to MCQs.

Conclusions

In Pakistan, Science is taught to the students up to grade 8^{th} which includes topics on biology, chemistry, and physics. But science itself is not considered a homogeneous subject and when students start learning biology at the secondary level, they have numerous misconceptions

related to their previous experiences and normal classroom practices failed to reduce these difficulties. In other words, students misunderstand new concepts in a particular subject and finally get rid of that subject, because, the issue is with the assessment procedure followed in assessing student's performance. Traditional assessment practices are only known for knowledge identifiers and tell nothing about misconceptions held by students. Based on the data obtained in the present study, it was observed that SCG tests are useful in evaluating student's cognitive structures and determining their misconceptions in biology at the secondary level.

The present study was conducted to find out student's misconceptions in five areas from 9th-grade biology like 'Biodiversity', 'Aims and Principles of Classification System', 'History of Classification', 'Two, Three Kingdom Classification' and 'Five Kingdom Classification'. The findings of the study highlight that misconceptions are held by almost all students. The percentage of misconceptions held by students in 'Five Kingdom Classification' was comparatively more than in other areas. Similarly, female students showed more difficulties than male students in learning biology. The research studies already examined student's concepts include photosynthesis, evolution, genetics, respiration, osmosis, reproduction, ecology, and cells (Driver, Guesnee & Tiberghein, 1985). The present study was unique in the sense that it involved student's misconceptions concerning biodiversity and classification.

Recommendations

The study recommends incorporating structural communication grids side by side with traditional assessment techniques to enable learners to self-assess. Teachers may be trained in preparing SCGs on different topics and used to discover misconceptions held by students. It may be taught to prospective teachers during pre-service and in-service teachers' training programs. Finally, it is suggested that more and more research studies may be conducted on different topics in biology and on topics in other subjects like chemistry and physics to promote students' meaningful learning by highlighting their misconceptions.

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